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How to collaborate in a mega metro project using BIM 360 and OpenBIM approach

Cecilie Irgens
COWI

Magne Ganz
Multiconsult

Learning Objectives

- Collaboration between 52 disciplines (30 Companies and 460 Members) using BIM 360
- CDE and Data Workflows between softwares
- The greater purpose of metadata
- Automation of tasks in every step
- Modelbased cost estimation and scheduling
- Modelbased bidding and execution

Description

Increasing demand in the building and construction industry, for digitally integrated design and execution, places great demands on the establishment of data environments. Processes and organisational measures must be established that support project execution, where data loss is avoided, where the entire project life cycle is considered and where it can be monitored and analyzed directly from models. At the same time, customers and partners want to follow the project development to a greater extent on a transparent data platform in new forms of collaboration such as Joint Venture and Client Involvement. Added to this is the fact that automation is to a greater extent a crucial competitive parameter and an important factor in reaching project deadlines.

This presentation describes how a project can be established organisationally and digitally to achieve a high degree of seamless collaboration across disciplines, companies and software. It also describes some of the digital solutions that have been established as well as some ambitions for where the project is going, for the next 7 years. The article is based on the Fornebubanen, which is a multidisciplinary project with 52 disciplines and a construction budget of just over 1,6 billion Euro.

The goal is to have most information such as BoQ, Commercial requirements, CO_2 imprints, classification, Operation and Maintenance information linked directly to the models. These models are combined into several coordination models for holistic and multidisciplinary representation of the total digital project. Processes, quality assurance, Intergrated Concurrent Engineering (ICE) or simultaneous design, design reviews, tender documentation and construction documentation are all based on the project's digital 3D information models. These collaboration models are produced as GIS models for overall understanding and as technical collaboration models for issue handling and technical assessments and communication. Gamification and Digital Asset model will be presented to the stage it has been developed.

Speaker(s)

Cecilie Irgens is an electrical engineer with a master degree in organization and management. First encounter with BIM in 2007. Project experience with technical know-how after 14 years in construction as an advisor in the field of electrical engineering, BIM management and software development. Loves to explore new tools and learn how to work smarter with the right methodology. Cecilie is specially focused on collaboration and what really works out there. Since January 2020 she has led the Digital Collaboration team.

Magne Ganz has a Masters degree in Structural Engineering from 2002 and has since 2006 had a strong focus on BIM and connected technologies. Revit, Dynamo, data flow and task automation is the passion. Being in the industry for 18 years and working with VDC and BIM the last 9 years, gives Magne the perfect background for contribution to Digital Collaboration and BIM-approach at this mega metro project.

Contents

Project introduction

Oslo municipality agency Fornebubanen (FOB), is about to add an extension to the metro system, creating a new tram line from Majorstuen to Fornebu.
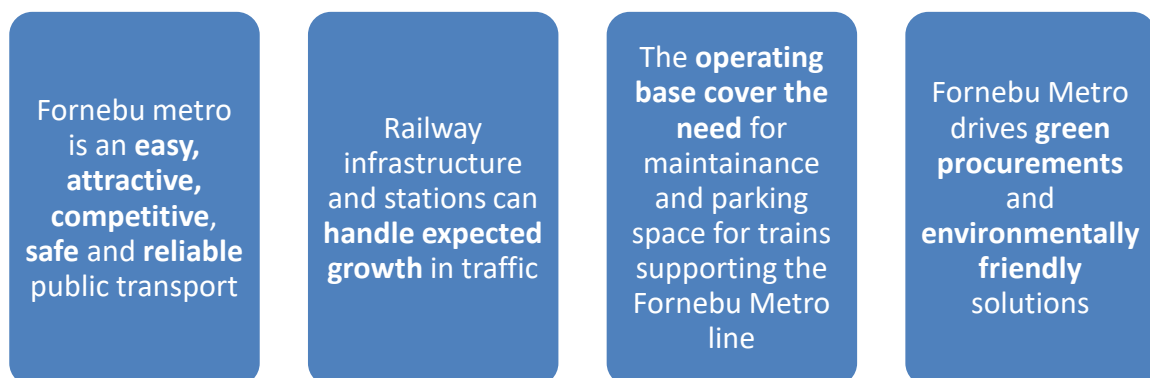
Characteristics of this project are demanding ground conditions, construction completion with large construction pits in narrow urban areas, interface with existing metro / railway / tram, a complicated stakeholder picture and a formidable scope. This makes Fornebubanen one of the most challenging transport projects in Norway in modern times.

The new metro line will provide effective public transportation for inhabitants of the entire Oslo region.

About Fornebubanen Metro

- Largest metro project in Oslo in 20 years
- From city center to outersuburb in 12 minutes
- First suggested 100 years ago
- 8.2 km tunnel
- 6 stations
- 8 departures per hour
- 8000 passengers per hour vs 3000 today (bus)
- Total cost 16.2 billion NOK / 1.8 billion USD / 1.6 billion Euro
- To be completed in 2027

The desired effect

Fornebu metro is an **easy, attractive, competitive**, **safe** and **reliable** public transport	Railway infrastructure and stations can **handle expected growth** in traffic	The **operating base cover the need** for maintainance and parking space for trains supporting the Fornebu Metro line	Fornebu Metro drives **green procurements** and **environmentally friendly** solutions

About the builder: "Etat Fornebubanen"
 The project Fornebubanen is owned by a collaboration between Oslo and Viken county municipality; Oslo municipality agency Fornebubanen (FOB)

Project Scope

Although Fornebubanen is a large infrastructure project, we say in short that it is "*A building project with tunnels in between*". And really, our client is to build 6 stations with an 8.2 km tunnel, with and technical infrastructure along its path.

This is a design to cost project, with a total frame of 16.2 billion NOK (1.8 billion USD).

Currently the path of the tunnel is underground and not straight in any direction, and is difficult to set due to demanding ground conditions and interface with existing trains, trams and traffic. As long as the path is not completely set, the exact placement of several stations are still uncertain.

The six stations have different architects, and thereby unique expressions. They vary in size, shape and function. The final station also functions as a maintainance base. The deepest station is Lysaker, 45 meters under ground.

The new metro line has complex technical interfaces both internally and externally.

Key challenges

- Demanding ground conditions
- The Fornebubanen project is just one of the larger infrastructure projects to be completed over the next few years in the same area.
- Approx 2 million m³ of rock, soil and sludge is to be removed
- Complex stakeholder structure
- The scope is gigantic – its a mega metro project!

Size
To illustrate just how large this project is – here are some statistics from BIM360

- 29 companies
- 540 members
- 4208 files
- 26 Official Coordination models SMC+NWD
- 2075 Discipline models

Distribution of file types
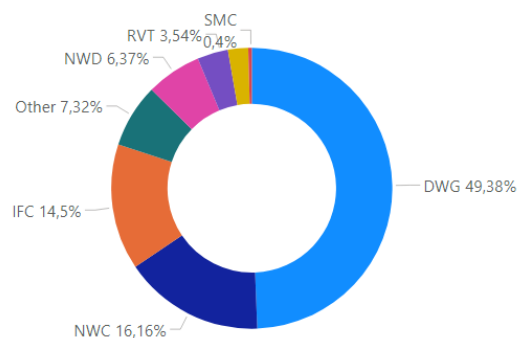
It would be really interesting to compare the chart above against file size, but unfortunaly the document log function doesn't export file size.
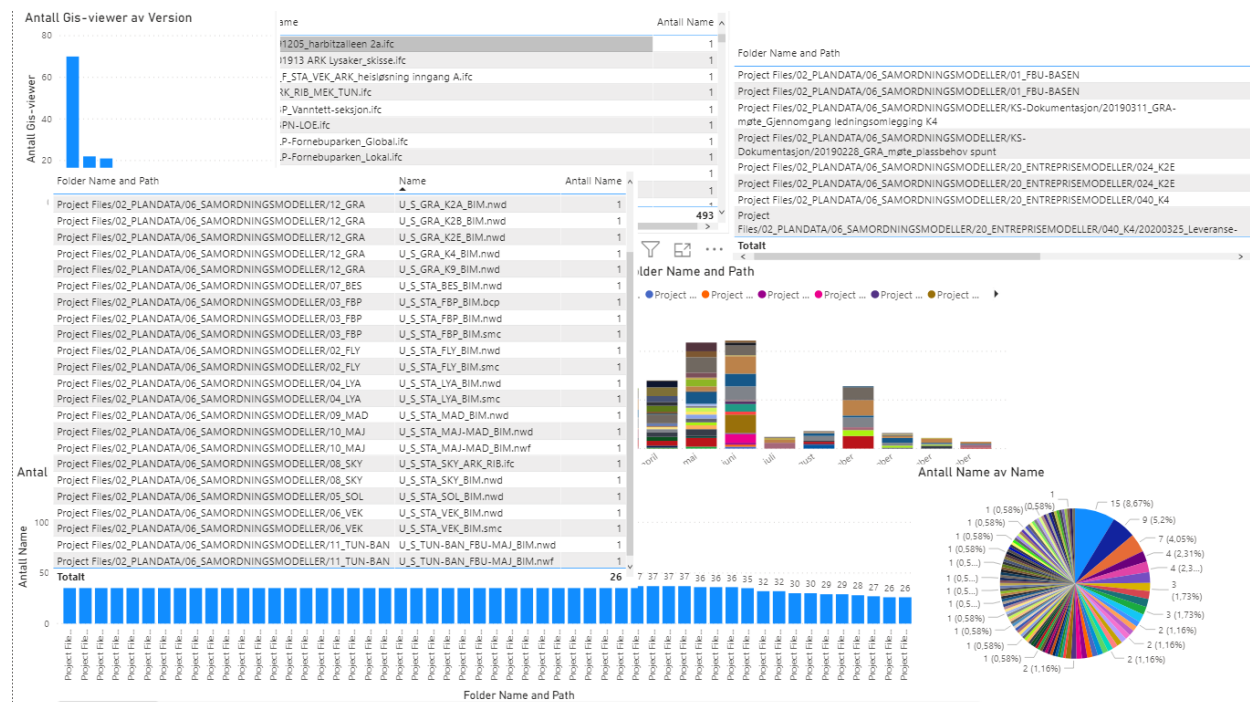
Tip: For a quick overview on file statistics, use the "document log" functionality in BIM360 and use it as dataset in Power BI.
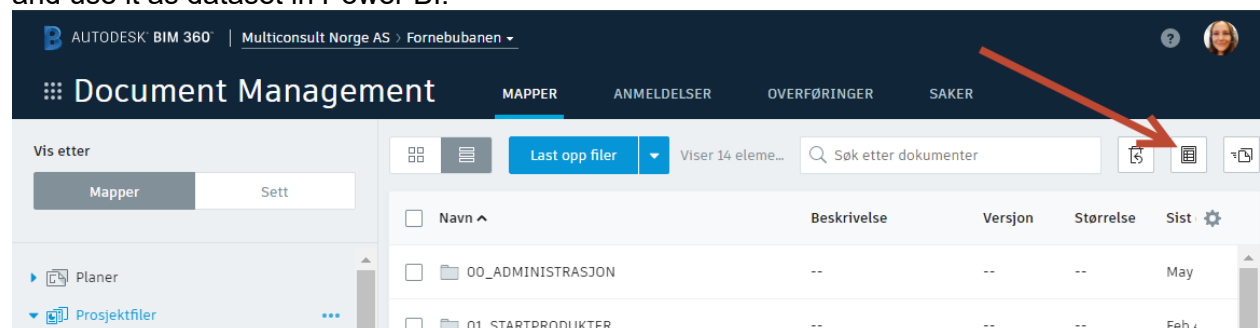
For our data we've used filters to sort out the desired data, i.e. the number of IFC files.

Included in scope - innovation and technology!

The client wants to contribute to the industry developing in a digital perspective, including developing new products and improving processes using BIM and other technological tools.

The design team

As explained earlier, the Fornebubanen project is managed by"Etat Fornebubanen (FOB); an agency collaboration between the Oslo and Viken county municipality. The agency is responsible for the construction of the Fornebubanen metro line, which will stretch between Oslo and Fornebu.

Collaboration

PGF
The joint venture engineering group called PG Fornebubanen (PGF) consisting of Multiconsult and COWI, was established in 2017. This team will provide engineering services from concept design til construction documentation and implementation of the infrastructure as well as any subsequent work. In addition to the design of the entire metro line with infrastructure, the contract includes; design of workshops – and deposit-base infrastructure; all subway stations, and the track-connection to Majorstuen hub. As of today there are about 400 engineers, controllers and project managers involved in PGF.

- Breaking through barriers

- Designing the future since 1930

Multiconsult is one of the leading firms of consulting engineers and designers in Norway. With roots going back to 1908, the company has played an important role in Norway's development and economic growth. Thanks to its 2850 highly skilled members of staff, the company is able to provide a range of services including multidisciplinary consulting and design, project engineering and management, verification, inspection, supervision and architecture – both in Norway and overseas.

COWI is a leading consulting group that creates value for customers, people and society through our unique 360 approach. Based on world-class competencies within engineering, economics and environmental science, COWI tackle challenges from many vantage points to create coherent solutions for our customers. COWI has more than 85 years of experience in the business, and COWI is a leader within its field because of more than 7300 employees who are leaders within theirs.

Organization and why

Being a large project organisation,is just as large as a middle sized company. The full organisation is hard to understand at a glance. The chart below shows the main structure, with the core design team in the middle. The core design team is organised into "objects"; i.e. stations; tunnel; groundwork and super- and substructure which are separate sub-teams within PGF.
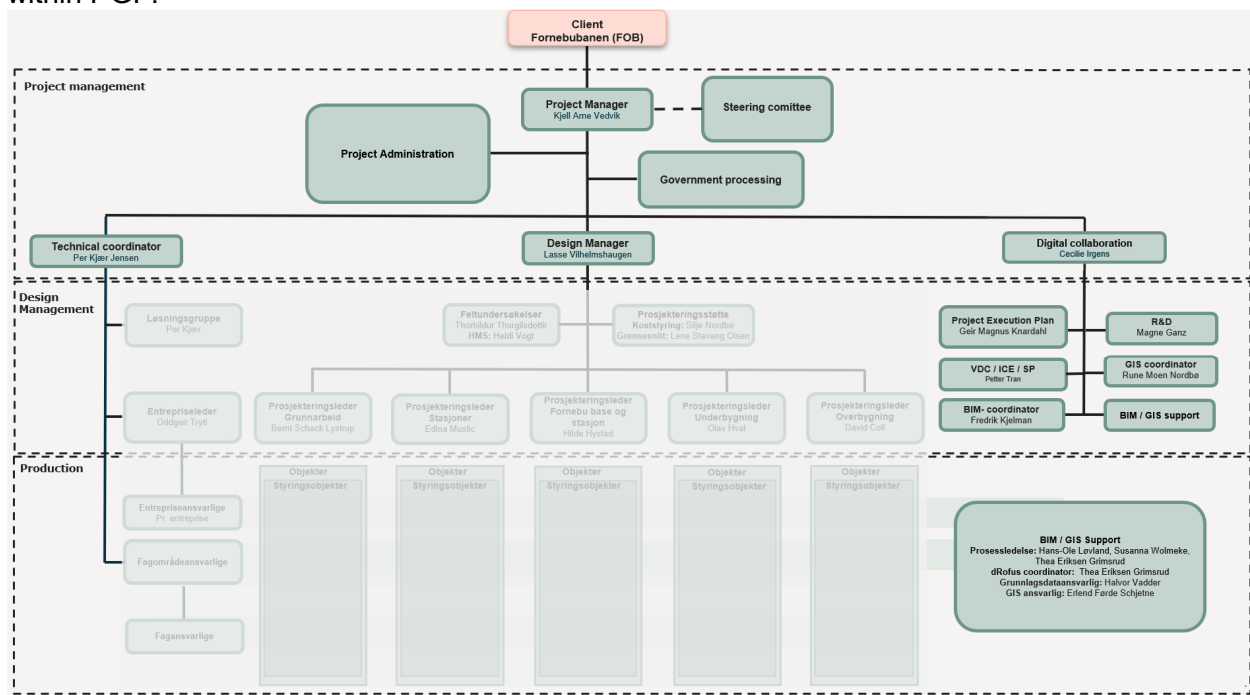
Interdisciplinary functions are embracing the core design team, technical to the left and digital collaboraiont on the right. The purpose of this organisation is to coordinate disciplines across the different "objects" and ensure uniform methodology in the assignment.
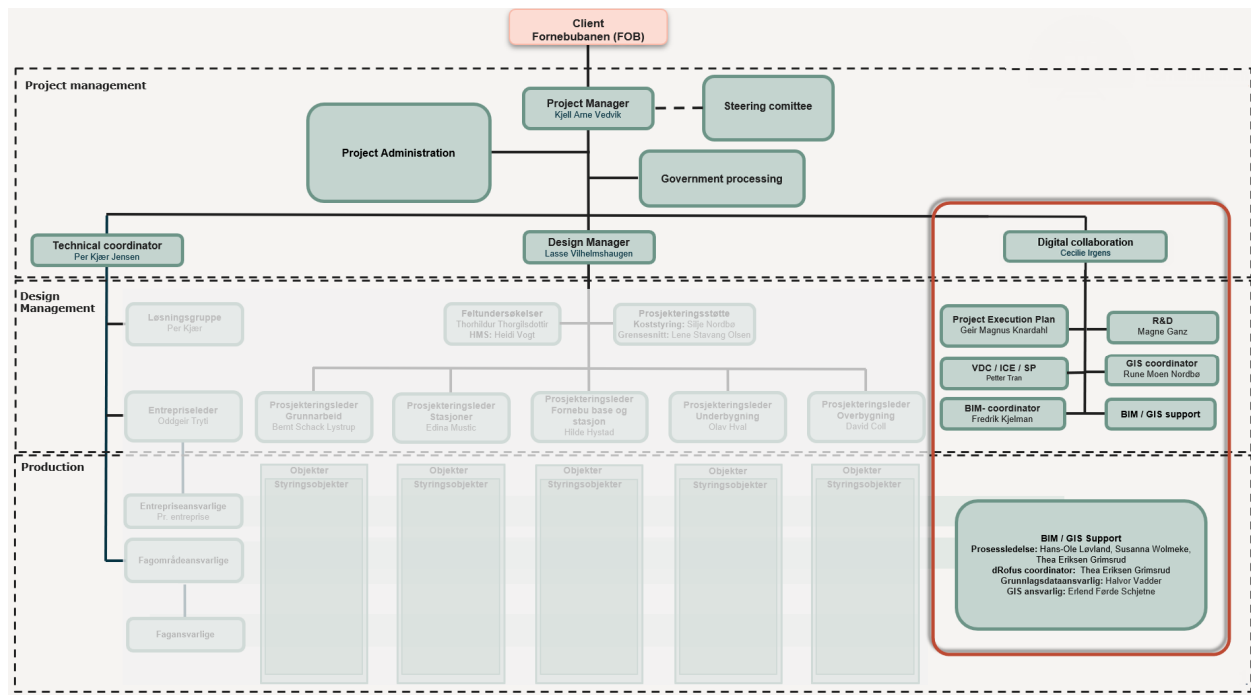
The function of the digital collaboration team is to standardise work tasks and processes, automate time thieves and streamline processes and technology.

The work of the digital collaboration team involve:

- Develop and maintain:
    - Project Execution Model (PEM)
    - BIM Framework
    - Script, addins and apps

- Support and processes work:
    - BIM
    - GIS
    - Basemaps
    - ICE
    - Lean
    - Cloud solutions / databases

- Identify and manage digital innovation opportunities

- Communicate and implement processes and technology for all the above

The team consists of experts in BIM, GIS, VDC/Lean, R&D, methodology and technology.

In short, we're working for seamless collaboration across disciplines, companies and software.

Common data environment

The adventure of finding the right platform

Asking the right questions

Being an atypical infrastructure project with high ambitions in BIM-deliveries, it was from early on decided to "BIM-ify" as much as possible. That ment in practical terms to use traditional infrastructure software like NovaPoint and Civil 3D as little as possible, as we do not see such tools as "full blood" BIM tools. They lack the possibilities to customise the output the way we wanted to. So instead of seeing the project as a typical rail project we viewed it as a series of buildings connected with tunnel segments. For building design we mainly use Revit. So the initial idea was to do as much as possible in Revit. We quickly got some resistance due to available resources for the design group. When most discussions had landed, this was the result:

- **Novapoint / Civil 3D** for:
  - Rail technicalities
  - Water and sewer
  - Power supply along rail
  - Landscaping and terrain
  - Geology
- **Tekla Structures** for:
  - Tunnel structures (blasting, concret linning etc)
- **Revit** for stations:
  - Arcitecture
  - Structure
  - Geotechnical structures
  - HVAC
  - EL
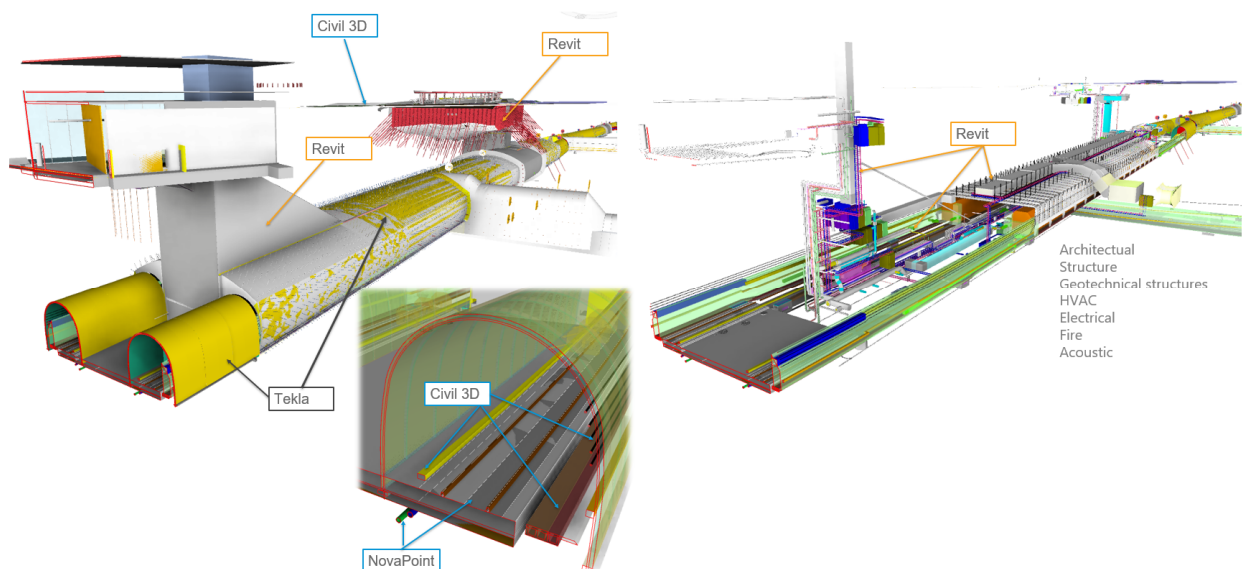 - Fire and Acoustics

Figure 1: Model software in use

So, why all this focus on software early on? It is simply because the use of software is the key driver for how the digital collaboration can be executed. When choosing a platform for

exchanging files, collaboraton and coordination, **file types** has to be taken into consideration.

And along with that:
- What is the best collaboration method for each software?
- Where is the designers located? Split-location or co-location?
- Is there one cloud solution that can handle it all?
- Do we need multiple cloud solutions?
- Do we also need a traditional file server?
- What about office documents?
- What about issue communication?

History, experience and rules

The more comprehencive work for common data environment started in the beginning of detail design in Desember 2018 / January 2019. Previously we had completed tender design using BIM 360 Team (the version before 360 Docs + Design) for Revit models, Bentley Projectwise for all common CAD-files, Sharepoint for all common documents and a mix of company specific fileservers, c-drives and personal OneDrives. We had to do something.

Being a joint venture of two companies and constant having the need for working both co-located and split-located, BIM 360 Teams made us able to do just that. However 360 Teams did not have sufficient permission and version management. Due to the vast amount of Revit and Civil 3D, going further with Autodesk Cloud was the obvious choice. That being said, we had a significant job in front of us.

The new solution BIM 360 Docs + Design was brand new. We had to move all our early design models from 360 Teams to 360 Design, make up a reasonable folder structure and a thoughtful permission system on a system we didn't have knowledge in or, at the point, didn't know if we could fully trust. Nevertheless, we felt that we needed to do a big change, so we started to draft the ideal dataflow bringing all the softwares and file formats together.
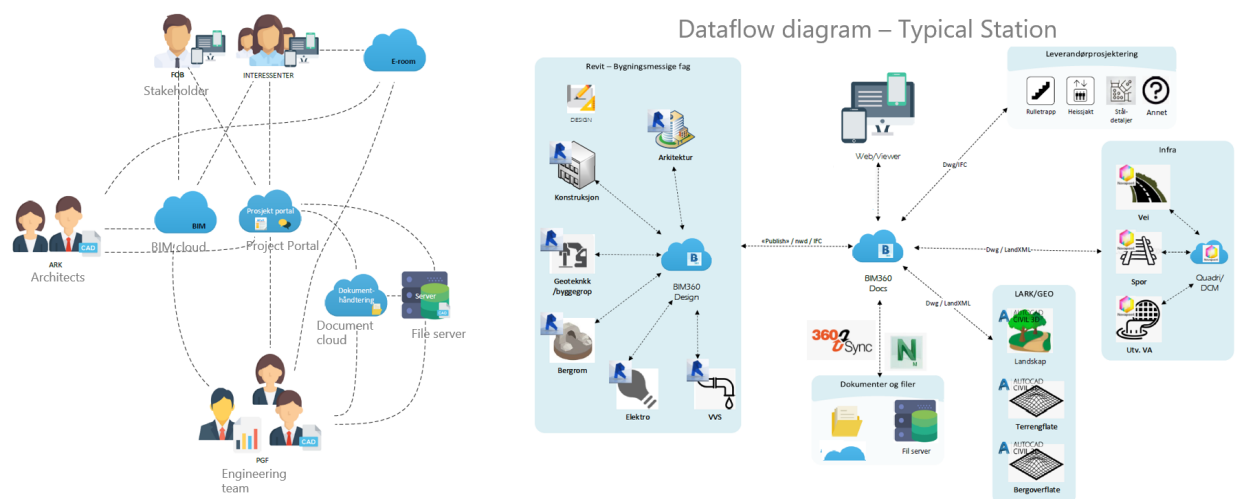

Figure 2: Dataflow diagrams

This work resulted in the following rules:
- No one is allowed to store anything locally (C-drive, OneDrive etc) or on a local company file server
- Email should not include attachments, only link to source.
- We must be true to the projects' defined dataflow.

Creation of common data environment

Based on the rules above, we took action. We decided to:
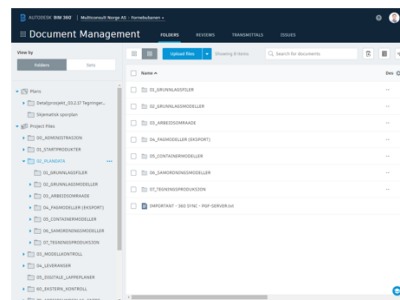
Discontinue:
- Emails with attachements
- Local file servers on separate companies LAN
- Bentley ProjectWise for CAD-files
- BIM 360 Teams

Add:
- BIM 360 Docs
- BIM 360 Design
- BIM 360 Sync
- Common fileserver
- Sharepoint website (Project Information Portal)

Continue to use:
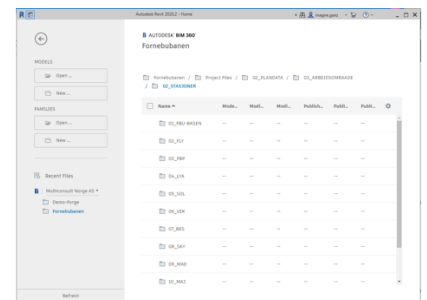- Sharepoint as document portal (later transferred to Office 365 / Teams).
- Trimble NovaPoint Quadri as cloud service for Rail, Road and Sewer.

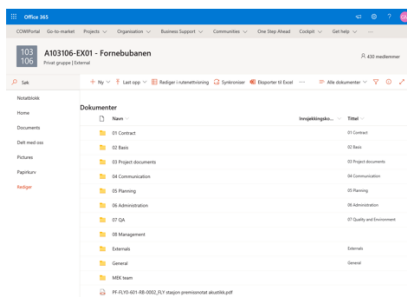Those changes were in fact the creation of our common data environment.

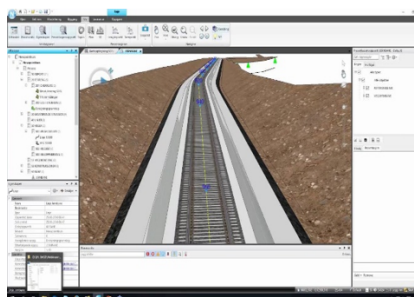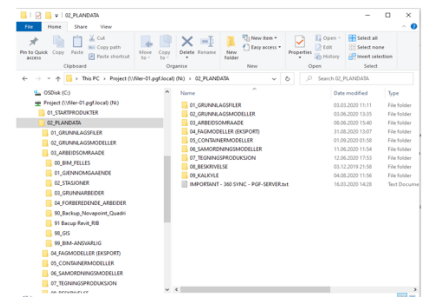| Sharepoint Information Site | BIM 360 Docs | BIM 360 Design |
| MS Office 365 | Trimble NovaPoint Quadri | Common File Server |

Figure 3: Common Data Environment - CDE

BIM 360 folders and permissons

Folders

In January 2019, the BIM Team or "Digital Collaboration Team" as we call it, gathered in a meeting room with these two major tasks to solve. We had limited time as the rest of the design team was eager to get started, but they had no formal guidelines regarding:
- Where to save what?
- Who should be able to change what? (view, upload, edit, delete).

.. and the team with the responsible to carry out those tasks had never before:
- Used the chosen cloud service
- Been in a project so large and complex

The pressure was on…

Luckily our most strategic member (Magnus Christensen) quickly was able to present the main flow as a mindmap, which in turn would set the guide lines for how the folder structure would look like.
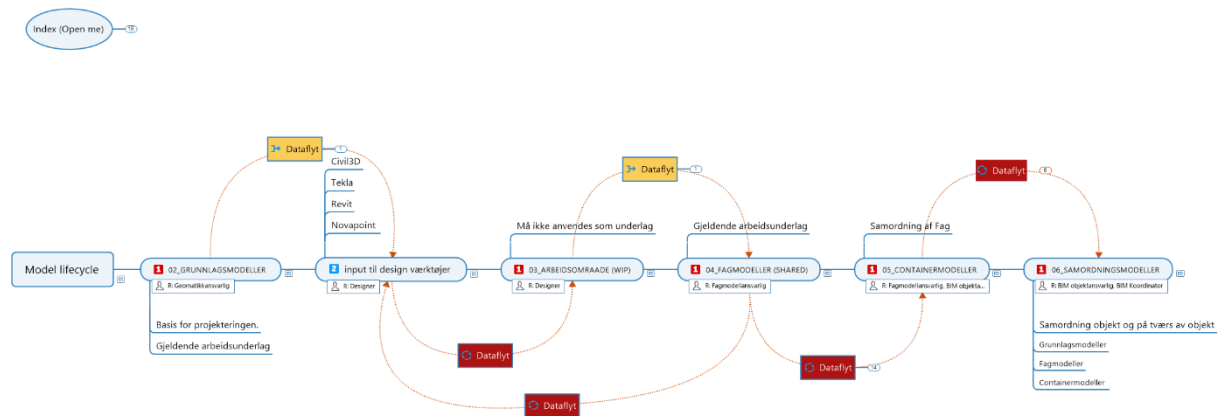
Figure 4: Workflow Mindmap

Based on the map above the main pieces of the folder structure was formed.

Figure 5: main folder structure

But given that there in reality were 7 projects in one project the arrangement of the sub-folders was a more thorough discussion. Questions that were raised were:

- Order subfolders by disciplines?
- .. by type of construction?
- .. by area?

In this process we tried to predict the most efficient way to work and for the designers in each stations to find the available files easy.

And there it was! We had to treat the project as 7 separateprojects and reflect that in the sub folders. Our conclusion was that this breakdown would benefit the project most.

So the hierarchy below each main folder became:

```
01. THROUGHOUT
        01. RAIL
                    01.        TRACK
                    02.        HVAC
                    03.        ELECTRICAL
        02. TUNNEL
                    01.        STRUCTURE
                    02.        GEOLOGY
                    03.        WATER AND SEWER
                    04.        ROADS
                    05.        FIRE
                    06.        GUIDEWAYS
        03. AUTHORITIES
        04. GIS
02. STATIONS
        01. FORNEBU
                    01.        ARCHITECTURE
                    02.        STRUCTURE
                    03.        ELECTRICAL
                    04.        HVAC
                    05.        ROAD
                    06.        LANDSCAPE
                    07.        WATER AND SEWER
                    08.        ACOUSTIC
                    09.        FIRE
                    10.        GEOTECHNIC
        02. FLYTÅRNET
        03. FORNEBUPORTEN
        04. LYSAKER
        05. VEKERØ
        06. SKØYEN
03. GROUNDWORK
        01. FORNEBU
        02. FLYTÅRNET
        03. FORNEBUPORTEN
        04. LYSAKER
        05. VEKERØ
        06. SKØYEN
        07. MADSERUD
```

Once the folders where in place, there where time to make it work, hence setting permissions.

Permissions

We knew that there was a need for strict permission control in the project. PGF. the engineering team itself, is a collaboration between 8 companies:
COWI, Multiconsult, Future technology, Johs Holt, Scan Survey, Nordic Infra, Jotne and LINK Architecture.

Our client is FOB – "Etat Fornebubanen" and the metro infrastructure owner is Sporveien.

Add to that, 5 different Architect groups (9 companies) and 10 different external stakeholders.

The first thing we had to figure out was how to collaborate internally in PGF and which permissions that are needed to make it work. The engaging of model resources using Revit was important to get started. Then look into the "Design Model – delivery" folder, hosting all the exported files from all softwares. As the scope of permission settings expanded, we saw that we needed an ovewiew. An Excel sheet was created to keep track.
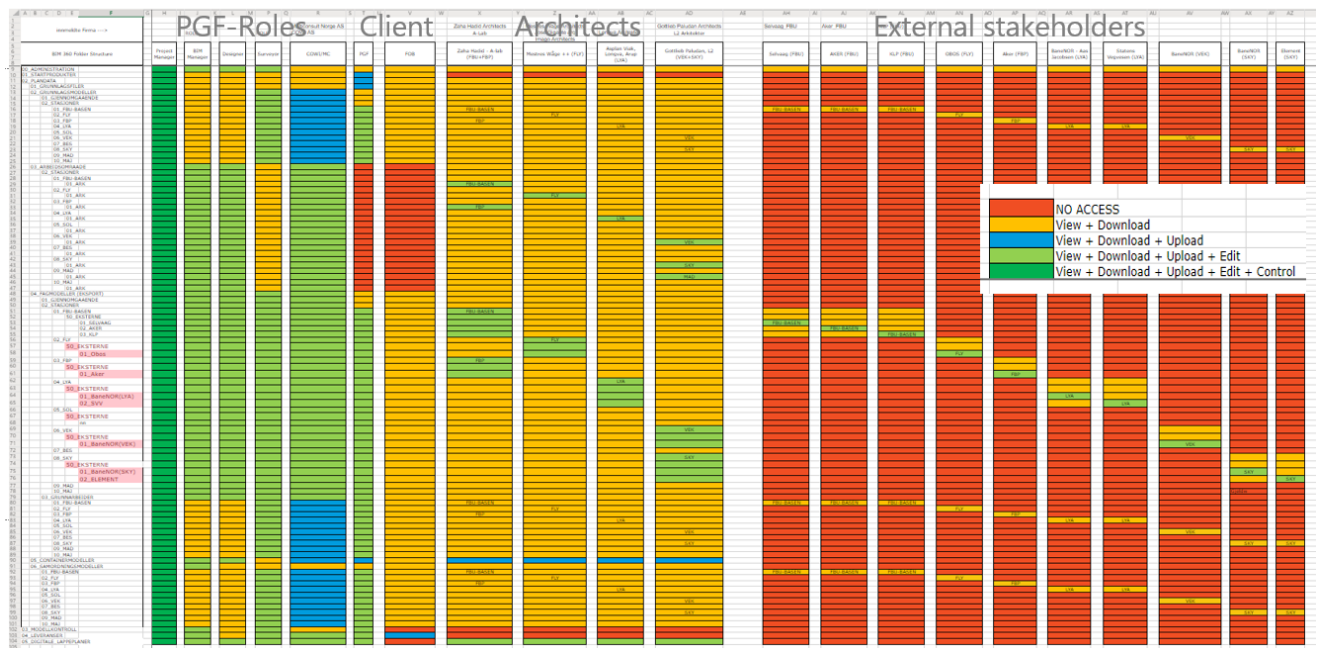

Figure 6: Overview of permission settings

After some "trial and error" and we found out that the best way to control permission settings were:

1. Add permissions per company.
2. Start with as limited permissions as possible on top folder, then expand further down on sub-folders, as needed for that company (or Role).
3. Limit the use of Roles
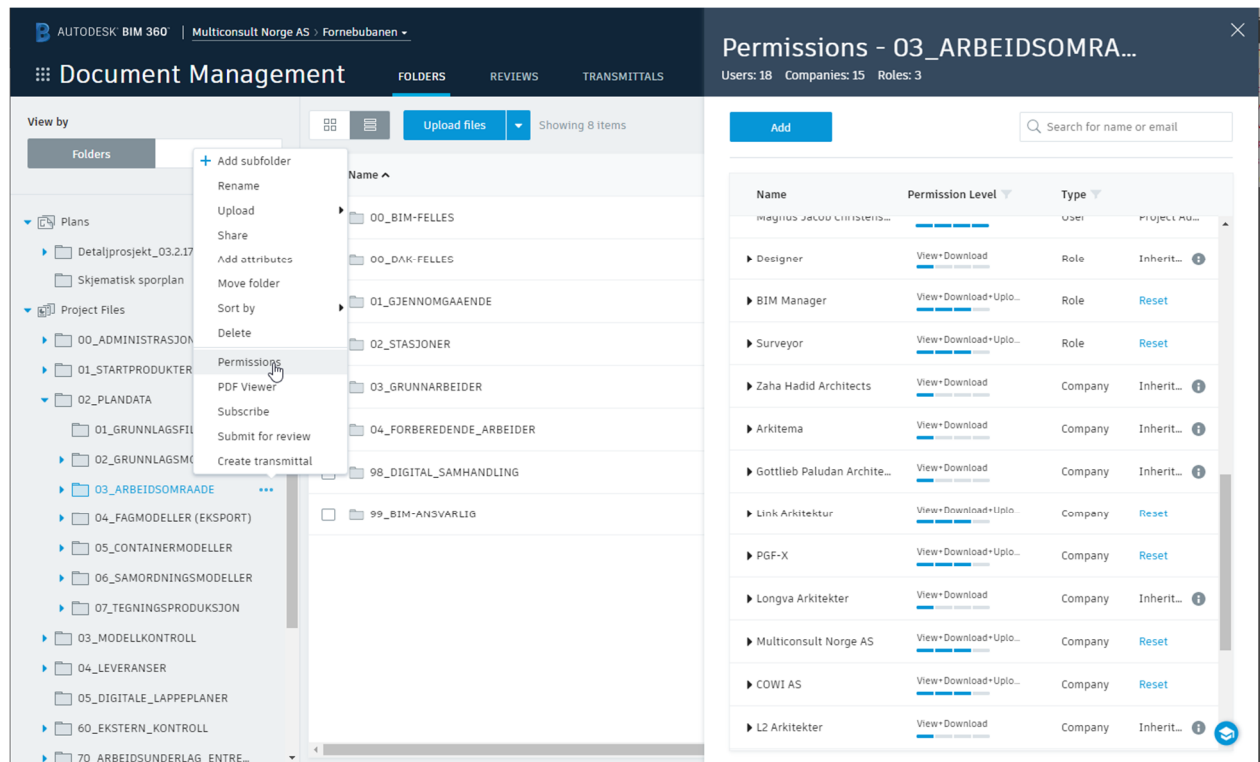4. Limit the numbers of Admins.

Figure 7: Permission settings in BIM 360 Docs

It is important to know that permission settings in 360 Docs is applicable for 360 Design (aka access and permission when using Revit Cloud Models). A Revit user need "View+Download+Upload+Edit" as permission for the folder where the Revit-file is, in order to make design changes.

PS! New users often get confused by the version and "Last Updated" of the Revit-file when viewing in 360 Docs. This is simply because 360 Design is in another cloud, only accessible through Revit. The Last Updated in 360 Docs reflect the last time the Revit-model was "Published" from Revit to 360 Docs.

Since the BIM 360 Docs + Design was so new to us and the organisation so complex we didn't dare to use the "Design Collaboration" module in BIM 360. Hence we don't have the "shared" and "consumed" folders. We "live link" Revit to Revit and the other we just link form the delivery-folder. It might be a bit "dirty" but it works. To our excuse, we do have a system for element status in model. This clarify the model maturity so each discipline can see the model maturity of the linked models. This system reduce the need for "shared" and "consumed" packages.

BIM strategies and processes

BIM Framework

Having an organisation of over 400 people and about 80 designers (those who model) is clearly not enough just have a common data environment. Every client demand, internal and external processes and dataflow has to be written down in a series of documents that belong to a certain hierarchy.

Not only does it have to be written down, it also needs to be validated and approved both internally and externally and then repeated again and again in order to make everyone in the project aware that these are important documents. Why? Because they ultimately describe our final product, the BIM. The BIM that is the subject for design optimalisation, analysis, 4D, 5D, construction and facility management. Despite all of this you will likely find the challenge to get everyone onboard and take it seriously.
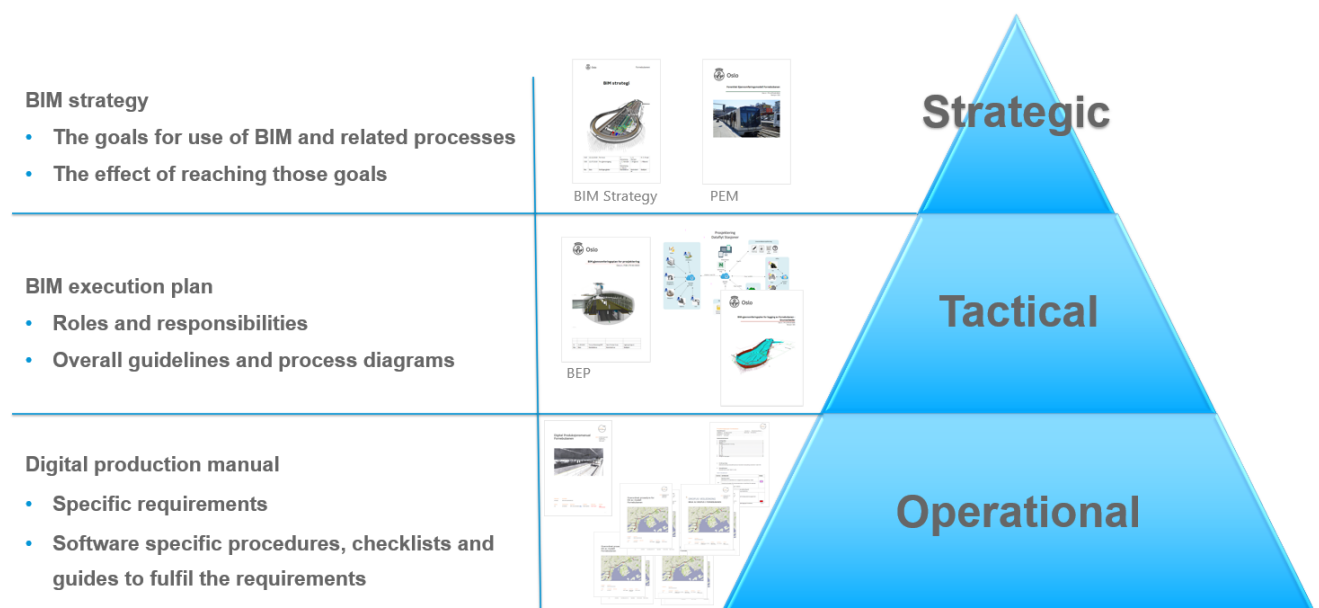

Figure 8: The BIM framework

Client demands – BIM strategy

The ambitious goals and requirements for this model centric approach is written by our client in the document "BIM strategy". Let's look at som "highlights" from that document.

"BIM is the key information element in our collaboration"

"In this project, the client wants to contribute to the industry development in a digital perspective, including developing new products and improving processes using BIM and other technological tools."

"The BIM model shall be adapted for ongoing updates of data to calculations for construction costs.

"A link between the construction schedule and the model shall be used to perform buildability analyses of the construction phase and for visual communication with stakeholders."

"The source of information must be gathered in one central database."

"The use of drawings must be reduced to an absolute minimum for all phases of the project and also towards approval authorities."

"Information from the construction site to the BIM model must be continuously returned."

"The public must be informed about relevant project information in the project's GIS portal."

"The experience of the digital project can easily be conveyed through different types of visualizations, such as. Virtual Reality (VR), Augmented Reality (AR) and gaming technology."

BIM Execution Plan (BEP)

BIM execution plans describe on an general level how the demands in the BIM Strategy is planned to be carried out. Ther are one BEP for the Design and several BEP's for each Construction contract, and a third BEP for the operational phase.

BIM Execution Plan for Design

The purpose of this document is to specify at a general level (not software-specific) what is stipulated in the BIM Strategy. In addition, a separate "BIM implementation plan for construction" and "BIM implementation plan for handover to operation" have been prepared (being prepared jointly with Sporveien).
Further on the document describes the BIM Organization and connected support functions. It briefly describes all the BIM-related Roles in the project and points to all relevant documents in the "Operational" segment of the BIM Framework.
The document points out the need for a "last planner"-approach, ICE sessions and thus the need for a work breakdown structure. All of this is covered in the the Design team document "Project Execution Model". BEP for Design also gives an introduction to the Common Data Environment, softwares in use and other services connected to BIM.

Important parts of the document is the definition of:
Project Status System for model elements
Properties and property sets on model elements
Classifications of BIM elements
These are topics that are covered in more detail in the "Digital Production Manual"

BIM Execution Plan for Construction

This document describes for the Contractor (in each contract) how BIM is utilised during construction, instead of traditional drawings. It also set demands and requirements for the Contractor regarding BIM knowledge, survey data and how to collect and deliver "as-built" data back to design team.

BIM Execution Plan for Handover and Operation

This document is created, but we are expecting adjustments in the coming years. We would like to prepare our BIM as early as possible for demands and requirements regarding this phase.

Digital production manual (DPM)

The digital production manual (or digital design manual) is a thorough and specific document that goes into detail in all BIM requirements, yet it is not software specific. Software specific procedures are created as separate documents for each topic.

The digital production manual goes in depth on the following topics:
- BIM organization
- BIM roles
- BIM responsibles for each coordination model and each discipline model
- Basis data and basis data responsible (surveys and basis models)
- Softwares and software responsibles
- Common data environment
- Collaboration plattforms
- Folder structure
- Model naming syntax
- Model standards and common demands
- Project base points and georeferenced coordinate system for each station
- Leves and grids for each station
- Project break down structure
- Model communication – element status (model maturity index) and quality level
- Properties and property sets for exported models
- Drawing specific details, naming, layers, title blocks
- Dataflow for each sub-project
- Common routines

Software specific procedures, guides and checklists

Due to the project size, extensive BIM requirements, different softwares used,the variaety of skills amongst the model resources, software specific procedures - guides and checklists were unavoidable. New procedures and updates procedures is a constant work in progress along the evolvment of the project.

List of procedures:
- Common use of shortnaming and expressions
- Procedure for using model element status for model maturity communication
- Revit procedures:
    - Procedure for using the common decisions
    - Procedure for copying from common template
    - Procedure for exporting to IFC, NWC and DWG
    - Procedure for modelbased cost calculation and construction description
- Common Novapoint and Civil 3D routines
- How to use BIMCollab for issue handling

List of guides:
- How to use NavisWorks in model review and coordination
- Revit guides:
o How to start a new cloud workshared model
o How to use the BIM 360 "Link Topography"
o Common guidelines for Worksets and Links
o How to link DWG with Global Coordinates
- How to use dRofus room data base

List of checklists:
- Checklist for weekly model export
- Checlist for discipline model QA
- Checklist for IFC delivery
- Checklist for DWG delivery
- Checklist for drawing QA

The greater purpose of metadata

Besides the actual model geometry, the importance of the I in the BIM cannot be emphasised enough. The information in the BIM is used in different purposes in all phases of the project.

Model maturity communication through element status

Communication of model maturity is key to inform all others how far each model element has come in the design process. In this project we use element status. The definition (and color coding) of element status is described in the project execution model (PEM). Color coding is visualised in specific views by filter in model software and in coordination software.

| Status Code	Color	Definition
S0		**Identified** The model element is identified as a needed and roughly placed in the model.
S1		**Preliminary** **Geometry**: The model element is defined with preliminary position and outer geometry. **Information**: Element has correct Type Name, classification code and WBS-code. **QA**: Verified inside own discipline.
S2		**Ready for coordination** **Geometry**: The model element is defined with correct geometry and positioning for coordination purposes. **Information**: Element has correct Type Name, classification code, WBS-code and other information required for S2 as described in Digital Production Manual **QA**: Verified inside own discipline.
S3		**Freeze** **Geometry**: Issues found in coordination are corrected. Model element has final geometry and positioning. Futher detailing must be carried out without affecting other disciplines. **Information**: Element has correct Type Name, classification code, WBS-code and other information required for S3 as described in Digital Production Manual **QA**: Verified by BIM-coordinator and discipline
S4		**Ready for tender** **Geometry**: Model element is detailed as needed for calculation by contractor. **Information**: Element has correct Type Name, classification code, WBS-code and other information required for S4 as described in Digital Production Manual. Information required for correct calculation by contractor **QA**: QA as described by procedure for BIM delivery
S5		**Ready for production/construction** **Geometry**: Model element is detailed as needed for production by contractor. **Information**: Element has correct Type Name, classification code, WBS-code and other information required for S5 as described in Digital Production Manual. Information required for production by contractor. **QA**: QA as described by procedure for BIM delivery
S6		**As built** **Geometry**: Model element is represented as built. Verified by survey or 3D scan. **Information**: Element has information as required for operation and maintenance. **QA**: QA as described by procedure for BIM delivery
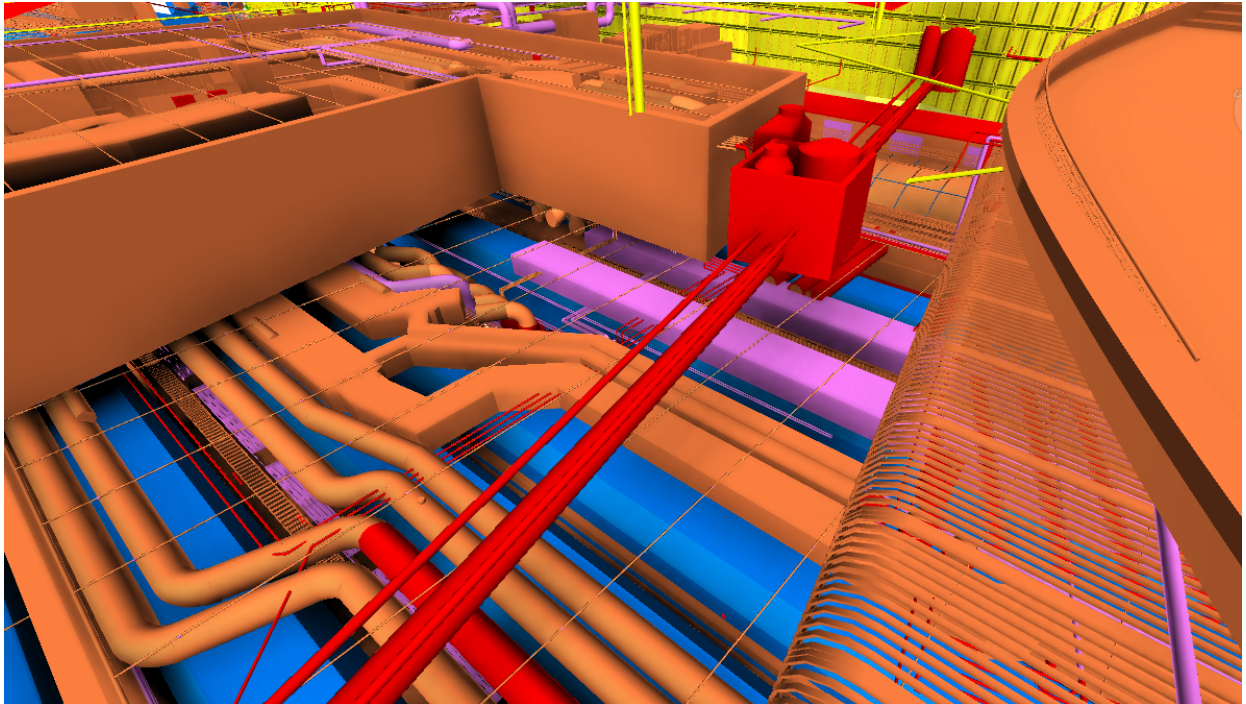
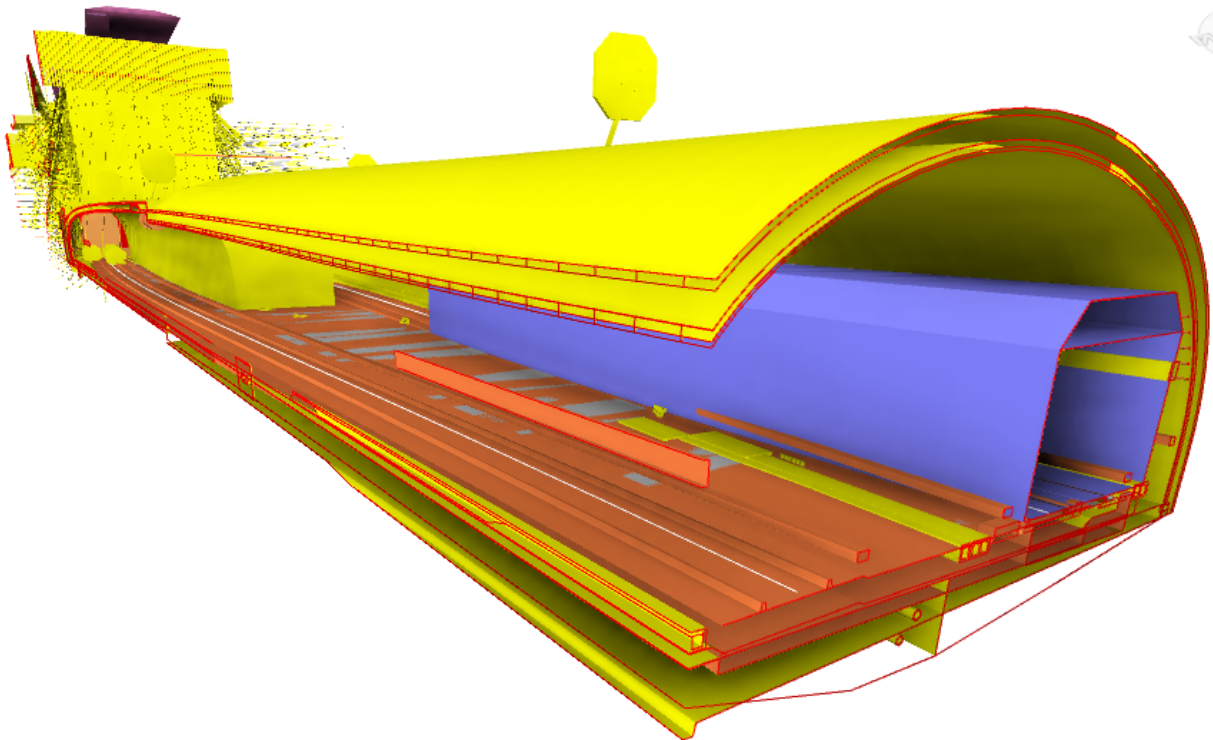Figure 9: A section of the Base colored by Design Status

Figure 10: Tunnel section colored by design Status

WBS and classification – the backbone

Work breakdown structure

The purpose and use of a work breakdown structure (WBS) are multiple. The two main reasons are to answer the following questions:

- How do you eat an elephant?
- Where are the model elements located?

The obvious answer to the first question is: bit by bit, because you cannot eat it all in the one meal. You would have to divide the task into several tasks that are manageable. When the breakdown into smaller tasks are "physically" related, as by location, the same WBS can be the answer to both questions. This is what was done in this project, the WBS on level 3 describes location down to ech tunnel segment (between two stations) and each station. Example: 1.3.04 = Fornebuporten station. Level 4, 5 and 6 are sub-divisions of each station and tunnel segment.
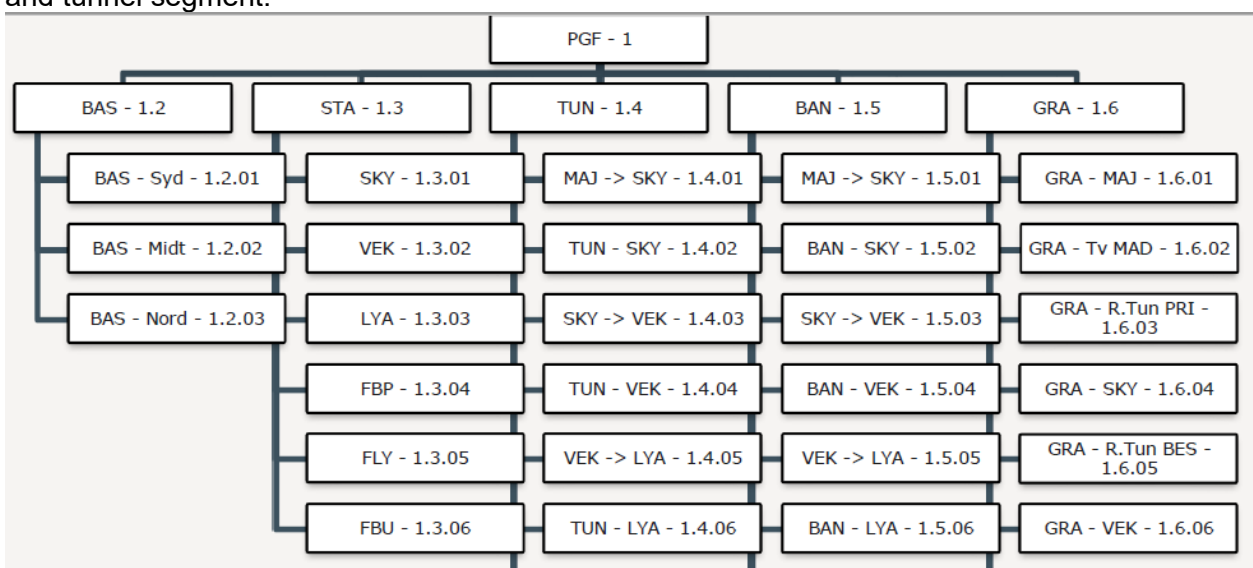
Figure 11: WBS hiearchy down to level 3 for parts of the project
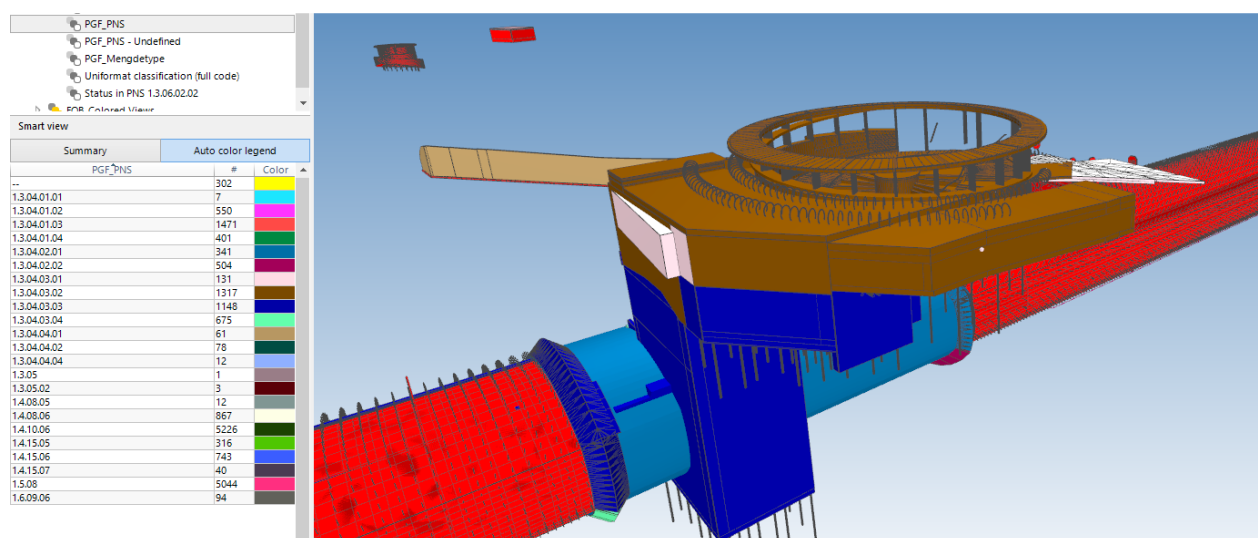
Figure 12: Fornebuporten Station colored by Work Breakdown Structure Level 5

25

Classification codes

The purpose of classification codes is to group model elements of same kind. This is so the softwares used downstream for quantity estimation, cost calculation and 4D simulation easly can sort the elements based on what it represents. The Classification Code will also be a part of the total Element Code for Facility Management. In this metro project with all kinds of disciplines involved, we were not able to find only one classification system that could be applied. The typical infrastructure disciplines like road, water and sewer, tunnel construction and geotechnics are classified according to the **Road Administration Handbook V770**. The disciplines related to building design (stations) classify by national code **NS 3451 Building Element Table**. Elements that will be directly used in the operation of the metro system must also be classified by **Oslo Metro Administration Coding Manual**.
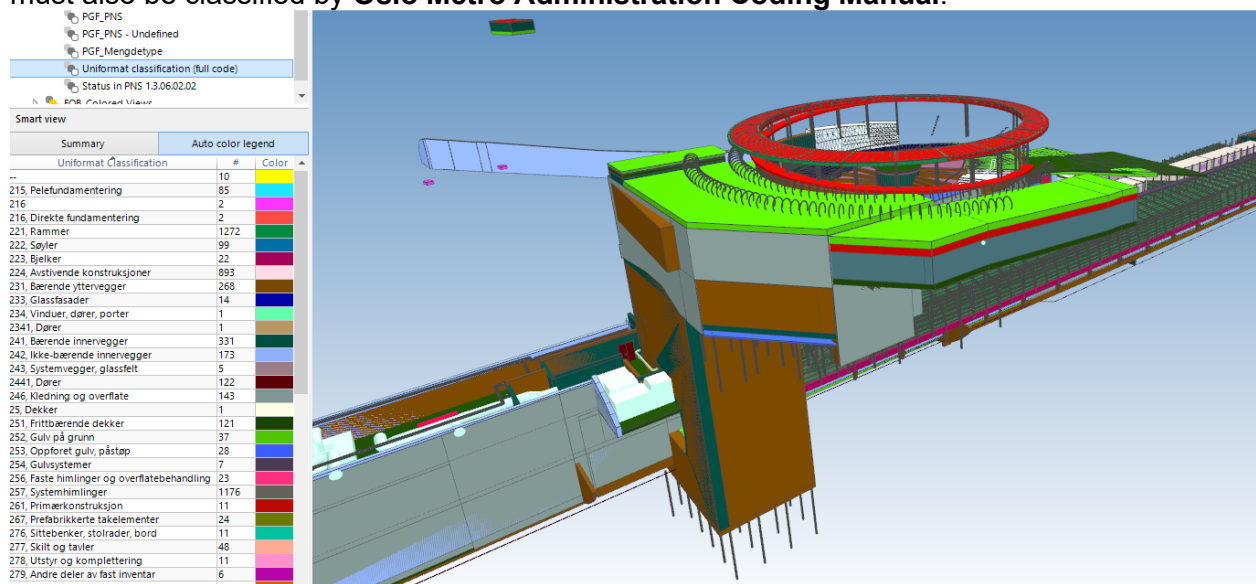
Figure 13: Fornebuporten station colored by Classification Codes

Construction phase

As stated in the BIM Strategy the aim is to execute construction with the minimal use of drawings. Since there are no national or international standards that describe BIM for construction, the project needs to define this internally. Therefore, all disciplines have to review their "normal" deliveries like drawings, schemes, lists and models and transfer the information normally delivered into only model based delivery. What this really means, is:

- The geometry must "accurately enough" represent the actual product (but not necesserely in detail, as this will slow down model performance). So the aim for "good enough" or "fit for purpose" is important regarding geometric detailing.
- The placing and positioning must be in correct "real world" coordinate system within constructuction tolerances.
- The information on each model element must be accurate and sufficient for calculation, fabrication and installation. This is partly done by referring to the building and construction description codes. But also with specific requirements for material, covering, anchoring, treatment etc.

The result of this transition is solved somewhat different for each discipline.

One principle which is used is that only the general arrangement model is in full extent.instead of fully detail the whole model. Parts of the model are then detailed down to the last bolt, nut and weld and the detailed parts of the model are the replacement of 2D detail drawings.
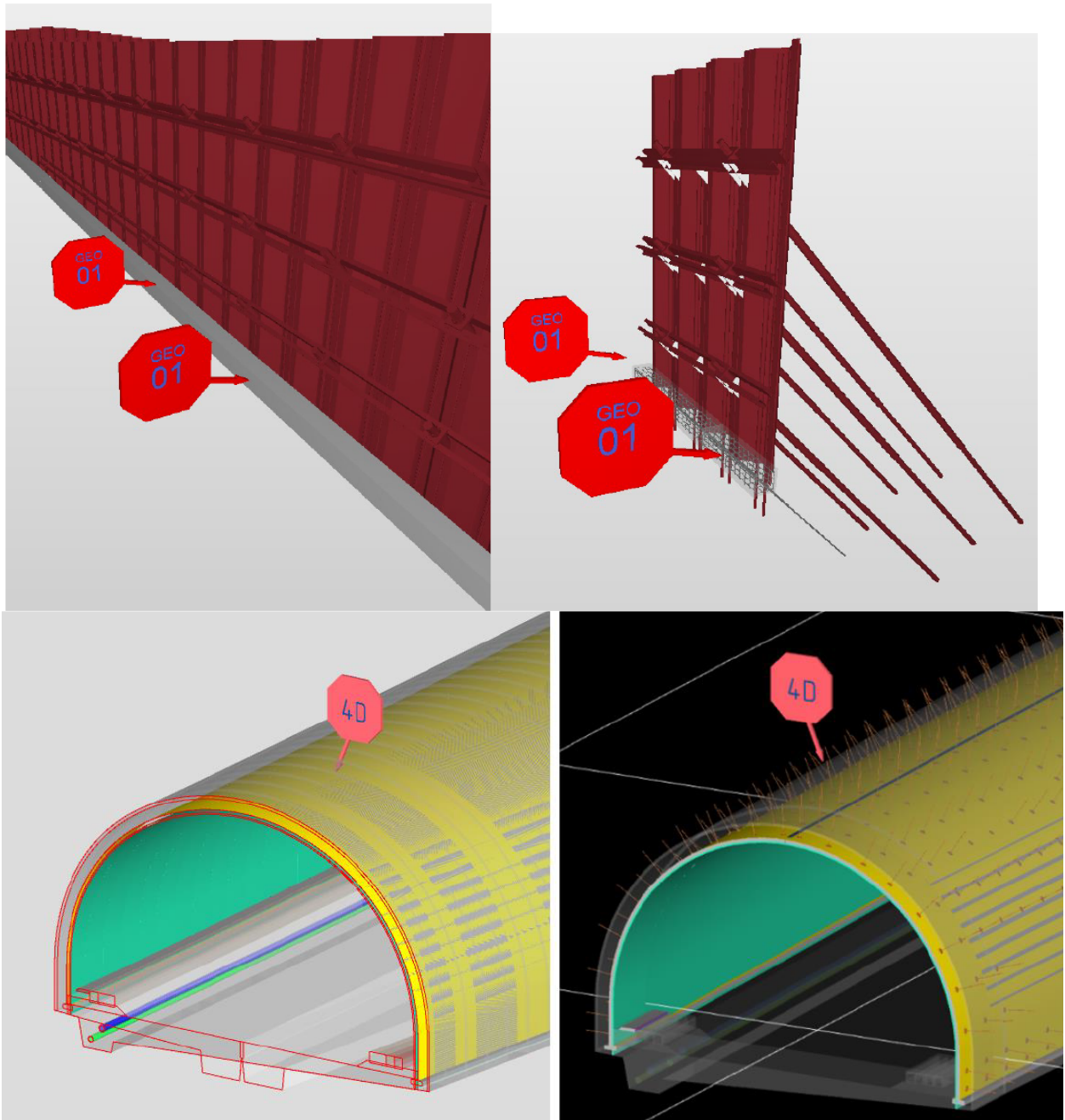Example:

Figure 14: GA-model on the left - Detailed modelsection on the right

Discipline Model Example

Geotechnical structures for the construction pit is the discipline that is first out creating model for construction and hence have the most detailed information as of today.

In the following example the necessary information is sorted into separate Property Sets in the exported model.

**FOB_Info** = information to the contractor regarding Status, ID, execution codes etc.

Property	Value
FOB_Eksistensstatus	Ny
FOB_Entreprise	K4
FOB_Fase	--
FOB_ID	--
FOB_Link	--
FOB_Mengde 1 (m2)	8.30 m2
FOB_Mengde 2 (m2)	7.60 m2
FOB_Mengde 3 (m)	0 mm
FOB_Mengde 4 (m)	11.85 m
FOB_Mengdelistepost 1	83.61312 Levering av stålspunt (m2)
FOB_Mengdelistepost 2	83.6134 Ramming av stålspunt (m2)
FOB_Mengdelistepost 3	83.6151 Sveising av stålspunt (m)
FOB_Mengdelistepost 4	83.6132 Påsveising av rør på stålspunt (m)
FOB_Merknad	--
FOB_Revisjonsdato	--
FOB_Status	S4
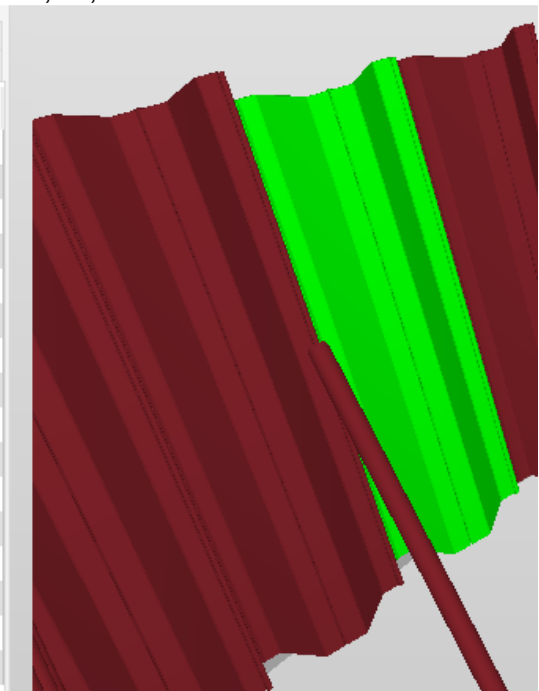
FOB_Merke = The coding system for operation and maintenance.
Area, SystemCode, FunctionCode, SequenceNumber

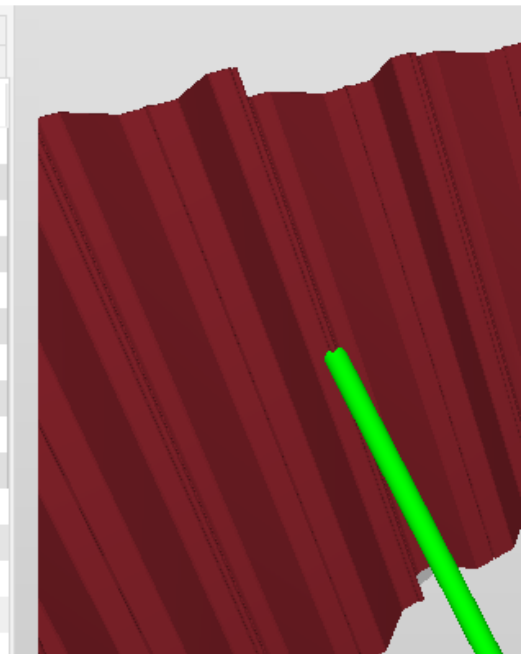| Property	Value
FOB_Funksjonskode	SPU
FOB_Merkeeier	SPV
FOB_Merkesystem	SPV
FOB_Omraade	P
FOB_Sekvensnummer	13
FOB_System	670
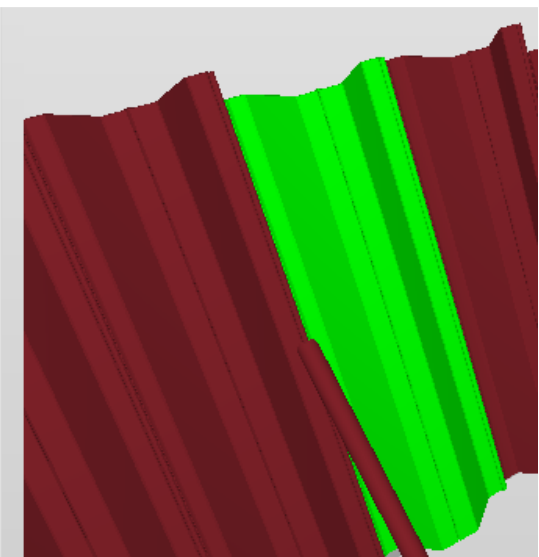
PGF_Info = information for internal processes within the design team. WBS, Classification, Product Type etc..

Identification	Location	Quantities	Material	Relations	Classification
Hyperlinks	BaseQuantities	FOB_Info	FOB_Merke	PGF_GEO_Info	PGF_Info

Property	Value
PGF_Byggeplasstilbakemelding	True
PGF_Fagkapittel	83
PGF_Klassebeskrivelse	Stålspunt
PGF_Klassifisering	83610000
PGF_Leveransepakke	--
PGF_Mengdetype	Spunt AZ 28 700
PGF_PNS	1.6.12.03.03
PGF_Revisjonsign	--
PGF_Revisjonsindeks	--
PGF_Statussign	MHBX 17.06.2020
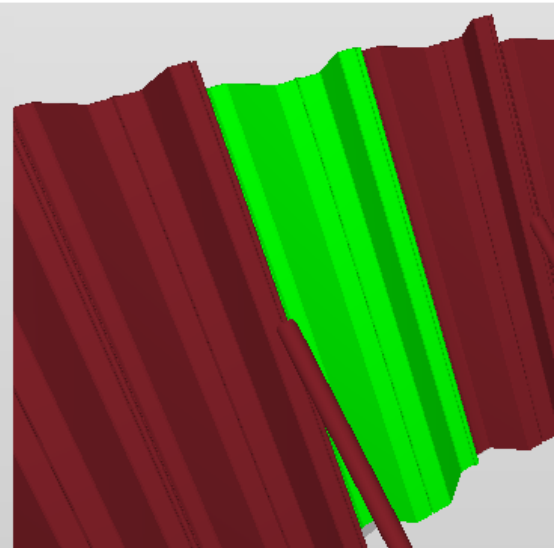
PGF_GEO_Info = Specific info provided by the discipline. Drilling Angle, Drilling depth, Locking Forces, Testing Forces etc.

Identification	Location	Quantities	Material	Relations	Classification
Hyperlinks	BaseQuantities	FOB_Info	FOB_Merke	PGF_GEO_Info	PGF_Info

Property	Value
Boring i berg	7.64 m
Boring i loesmasse	3.36 m
Forankringslengde i berg	6.00 m
GEO Detaljnummer	Ukjent
Helningsvinkel	45 °
Laaselast	910 kN
Merknad	
Min. frilengde	5.00 m
Proevelast	1950 kN
Total lengde stag	11.00 m

Applied BIM and OpenBIM

Fileformats

Due to the amount of different design software involved we have obviously a lot of Native Formats that can't be transferred directly between softwares nor used directly in coordination. Wwhen using NavisWorks, you can append most file formats, however that doesn't give you the need for control over information (Properties and Property Sets). As explained in the previous chapter the information in the model is extremely important in this project, since the model is the "one and only" source throughout the project phases.

We have for this reason based all of our deliverys regarding design models on OpenBIM (IFC) for all softwares that support OpenBIM. For more infrastructure oriented softwares, that either doesn't support OpenBIM or poorly support OpenBIM we use dwg (with extended properties). The aim is that the Properties and Property Sets will look the same regardless of Design Software used and regardless of delivery format: dwg or IFC.

The delivery formats are combined into container models, coordination models and work packages. Special formats needed for specific use cases is also a possibility, but has to be requested by the contractor in each case.

To vizualise this we have created this scheme:
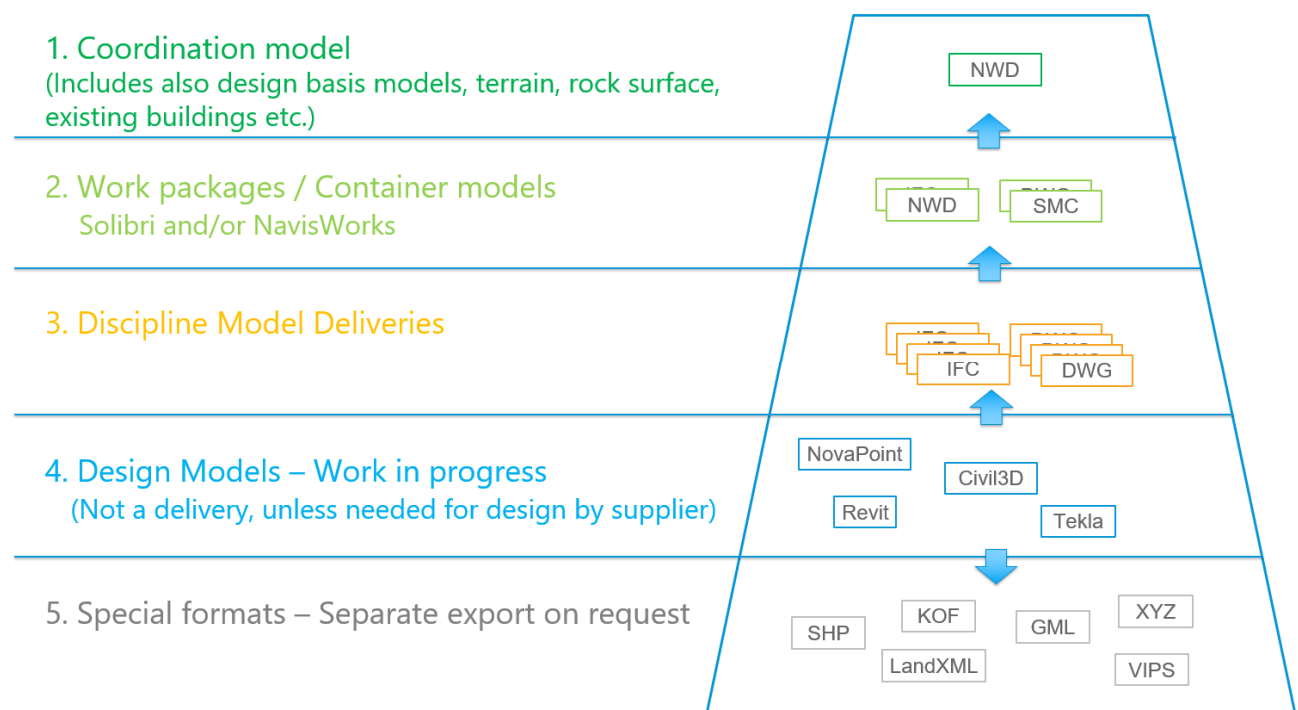
Figure 15: Software, formats and coordination

The use of OpenBIM is important standardisation that open up possibilities for use in other softwares downstream, like 4D (time) and 5D (cost). This will be covered in a later section of this report.

Coordination

As shown in the figure above, the discipline model deliveries are DWG, IFC and FBX. They are exported to the folder "04_FAGMODELLER (EKSPORT)" every Friday. Due to the project extent and amount of files. We have separate Coordination models per station and one for the whole tunnel.
There are 6 stations (called FBU, FLY, FBP, LYA, VEK and SKY) and one 8 km tunnel that connects the stations. Her is an overview:
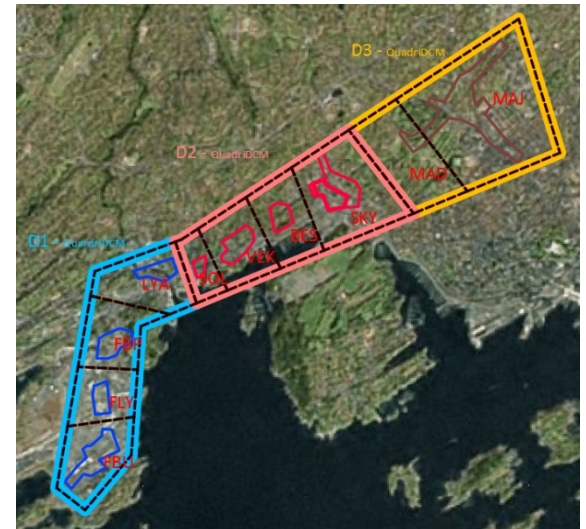

Figure 16:The project divided into sub-areas per station

We use mainly two softwares for coordination:
NavisWorks: is used to combine all disciplines, regardless of OpenBIM or not. NavisWorks has a robust 3D-viewer and tackle large files and a large amount of discipline models. NavisWorks also have the capability of showing textures which is commonly used to visualise terrain with orthographic photo.
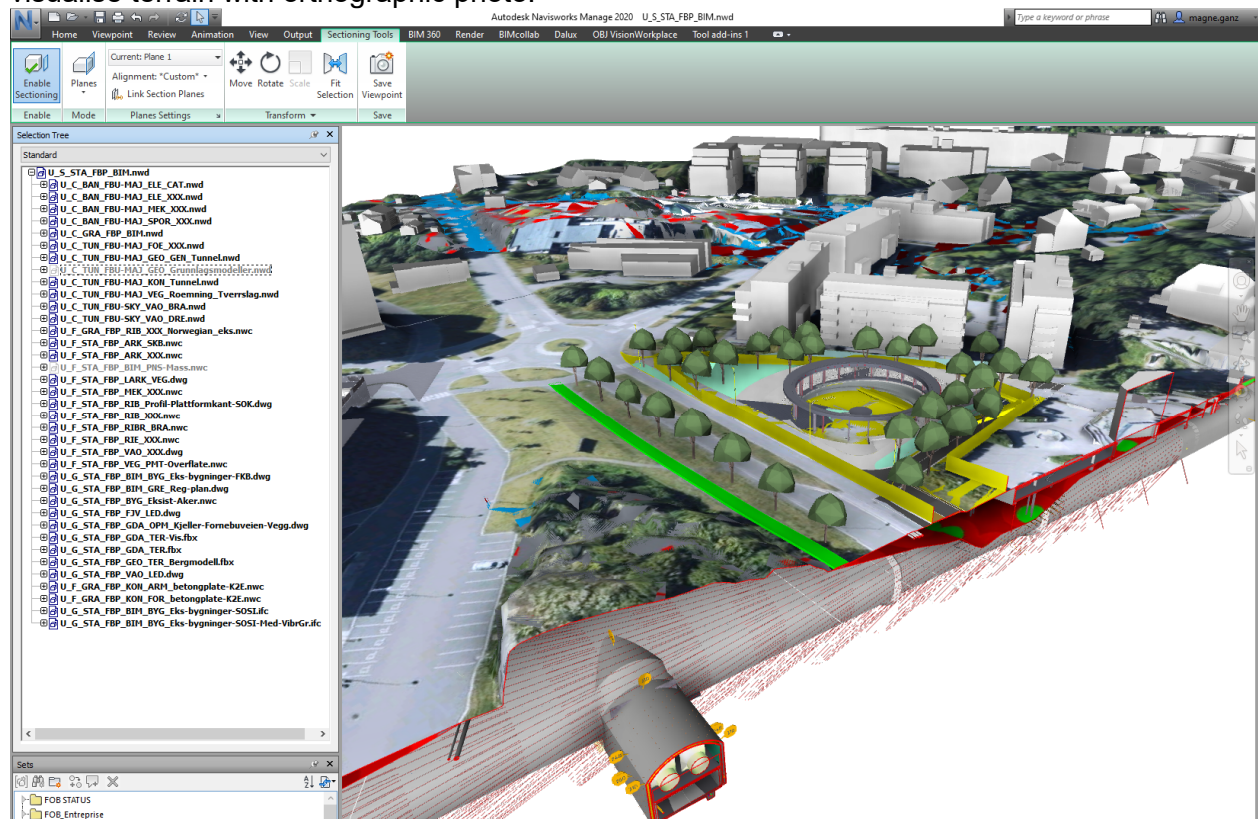
Figure 17: Snapshot of NavisWorks - FBP

Solibri: is used to coordinate the building related disciplines per station. Solibri is the best Model Checking software. It has a great classification system, information takeoff possibilities and a rule set manager where you can customise everything you want to check. Visualising model information is easier and quicker in Solibri than in NavisWorks.
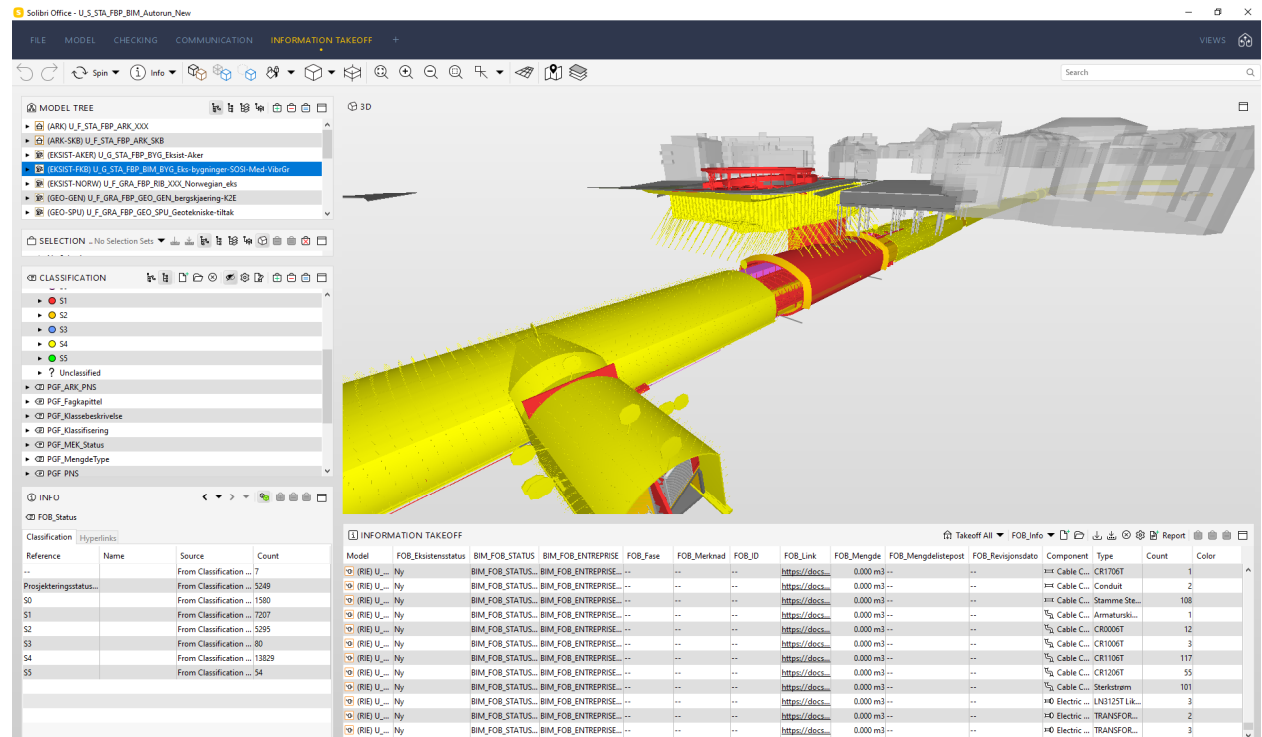
Figure 18: Solibri - Color by Design Status

The coordination models are updated every Monday morning and saved to the folder
"06_SAMORDNINGSMODELLER" (Coordination models) so everyone in the project can
access and view them as much as they need.

The coordination models are widely used in all kinds of meetings. There are also specific
model coordination routines between milestones in the project. These consist of a series of
coordination meetings, rule based checking, issue handling and lead up to next milestone
where there is a gate review to assure the model quality is as expected for that particular
milestone.
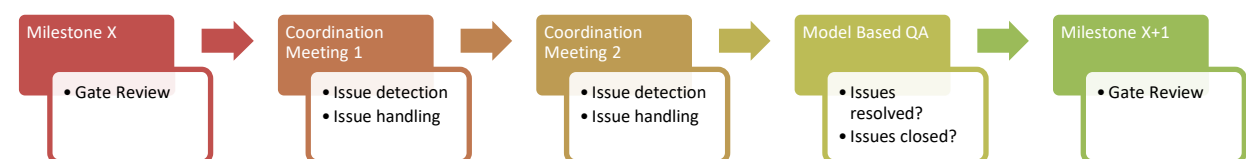
Rulechecking

The models delivered in OpenBIM (IFC) Solibri is mainly used for checking. This is because Solibri has a bigger variety of rules to be applied and also has more custisation. The rules in Solibri are customized so only elements above Status S1 are considered. The checking process is also grouped per discipline and per WBS-location.
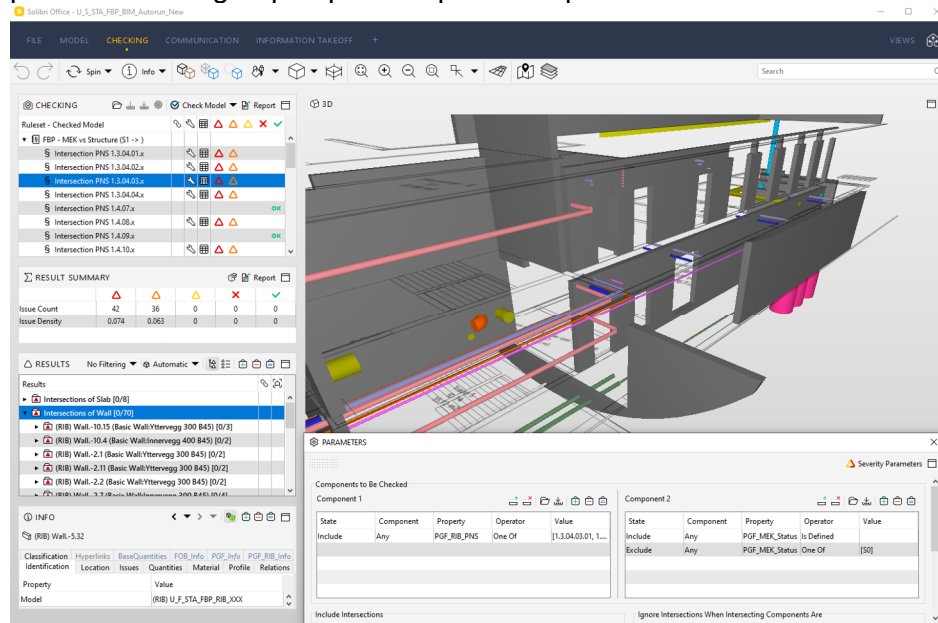
Figure 19: Rule checking i Solibri – HVAC vs Structure in WBS-location 1.3.04.03

Navisworks is used for general coordination, visual control of all files and clash detection control of dwg-files.,
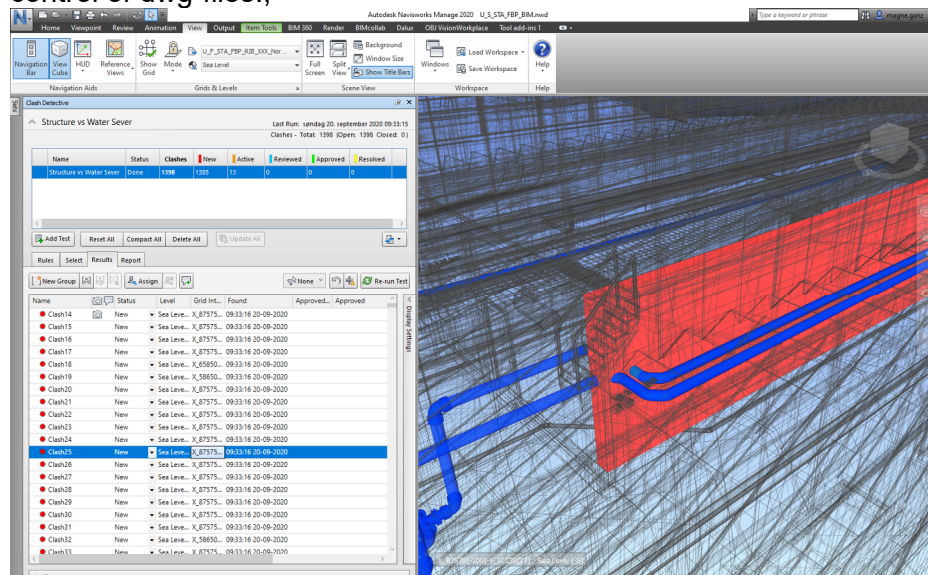
Figure 20: Clash detection in Navisworks – Water and Sewer vs Structure

Issue management

After issues are detected using Solibri and/or NavisWorks in 7 different Coordination models, the next step is to communicate the issues to the persons needed to resolve and close the issue. In Northern Europe we like open formats and BCF is the open standardised formatfor BIM-related issues, BCF is short for BIM Collaboration Format.

BCF carries the necessesary information per issue:

- Title
- Description
- Assigned to
- Snapshot of issue
- View Point Coordinates and directions
- Model Element ID's
- Date to solve
- Milestones
- Area

This information is of course important to have, but is not enough by itself - you also need a system to mange this. The system should have connection to all softwares involved and also an interface for those not using the models. We found that the issue management in BIM 360 was too limited for our use so BIM Collab became our go-to solution.   BIM Collab is based on BCF and have e Cloud Solution with interface (add-in) for all design and coordination softwares used in this project. Every issue is now synchronised up to BIMCollab and down to the specific person in a specific design model. It is easy to identify what to fix, where the issue is and what the deadline is for resolving it.
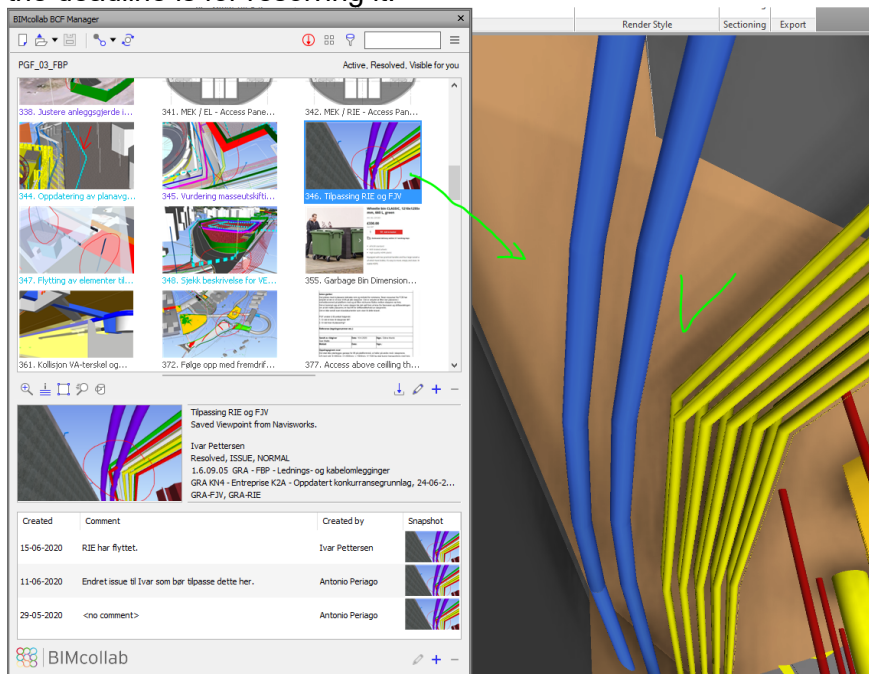
Figure 21: BIMCollab BCF Manager in NavisWorks

Figure 22: BIMCollab web viewer

Figure 23: Softwares supported by BIMCollab

Room and asset management

In the early phase of the project the Room Data Base (RDS) and requirement lists were managed in Excel. We quickly discovered that Excel is not suitable for this kind of

information handling as it's lacking the possibility to add user rights, user tracking, user interface for large data sets and connection to BIM in a safe manner.
 The client agreed to our suggestion that this kind of information is best to keep in a database with proper user administration and the possibility to synchronise withBIM. After a couple of months with research and demos we landed on dRofus.

A quote from dRofus web-site:
"dRofus is a unique planning, data management and BIM collaboration tool that provides all stakeholders with extensive workflow support and access to building information throughout the building lifecycle.
Unlike any other planning tool in the market, dRofus was developed directly on behalf of public building owners. Capturing client requirements (EIR), validating design solutions (BIM) against client requirements, management of public standards and equipment planning are core features in the software. dRofus has strong ArchiCAD, Revit and IFC integration with bi-directional data sync capabilities."
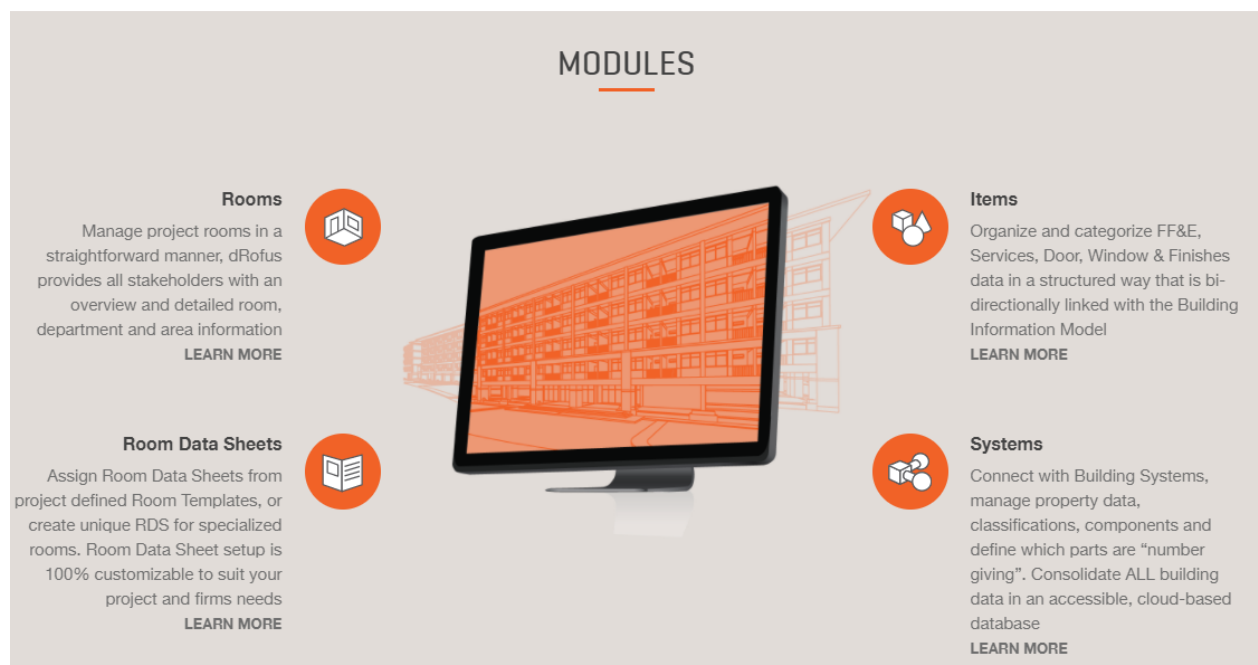

Figure 24: dRfous Modules

Room list and Room requirements

We decided to utilise the room module first. We started to define important datafields for room requirements and then created template rooms. Similar room occurences in each station would then inherit all or parts from the template rooms.
When room instances was modelled in Revit, they where linked with the room occurrence in dRofus. All data and requirements is further managed in dRofus. Only some data like room ID, number, name and Are is synchronised with Revit. Linked room can then be vizualised in the web-viewer when IFC-files are uploaded.
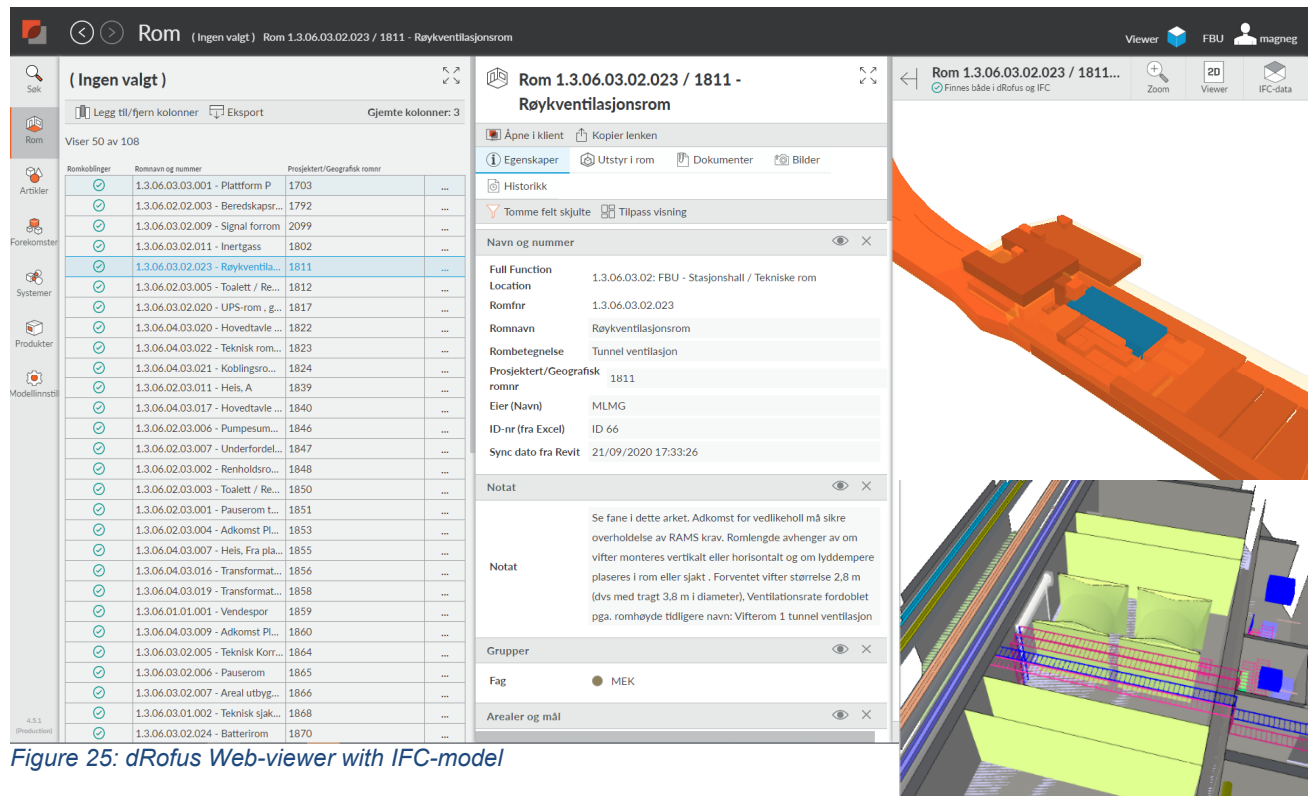
Figure 25: dRofus Web-viewer with IFC-model

Doors and other Items

As for rooms, there are more information connected to model elements than what is manageable within Revit. There are also a number of non-modelling resources that needs to view and edit information without access to the Revit-model.

The Item types, their properties, requirements and occurrences are manged in dRofus, but linked and synchronised to and from Revit. The information can continue to be added throughout the project life cycle, so in the end every Item and Occurrence can have the complete data for Operation and Maintenance added by the Design Team, Client, Stakeholders, Owner and Contractor.
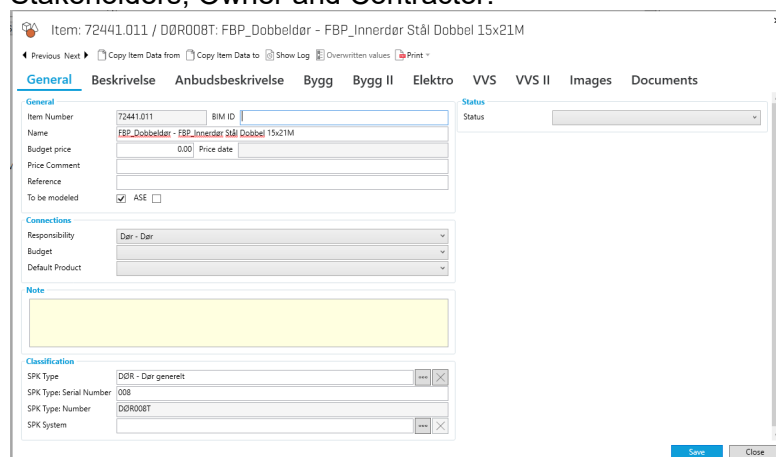
Model based cost estimation and scheduling (4D / 5D)

5D Cost and building description

The overall process of cost estimation and construction description is:
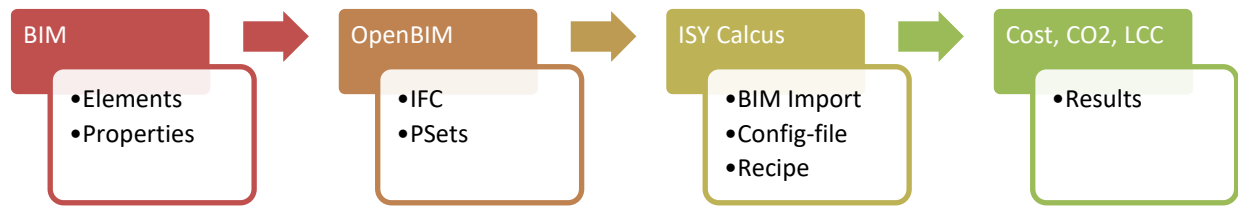
For the disciplines using Revit, this process have been more streamlined than for the disciplines using Tekla or Civil 3D. The reason isn't the software itself, but the coding requirements, the typical infrastructure disciplines codes according to The National Road Administration. This coding doesn't work very well with the software and "sorting system" used in building description or cost calculation.

For more building oriented disciplines using Revit the workflow for cost estimation is like this:
The Revit model is coded with:

| Revit Property	IFC Property	Description
Type Name	PGF_MengdeType	If some model elements have unequal unit costs, a new Type should be created. All similar elements of same Type should have same unit cost.
Keynote	PGF_FagKapittel	Coded with the "Material Work", i.e. "05 Concrete Works", "07 Steel Structure", "21 Painting".. etc..
Assembly Code	PGF_Klassifisering	Coded with 3-digit code according to National Standard 3451. Example: "231 – Structural Wall", "222 – Structural Column", etc..
Assembly Description	PGF_KlasseBeskrivelse	Description corresponding to the code above
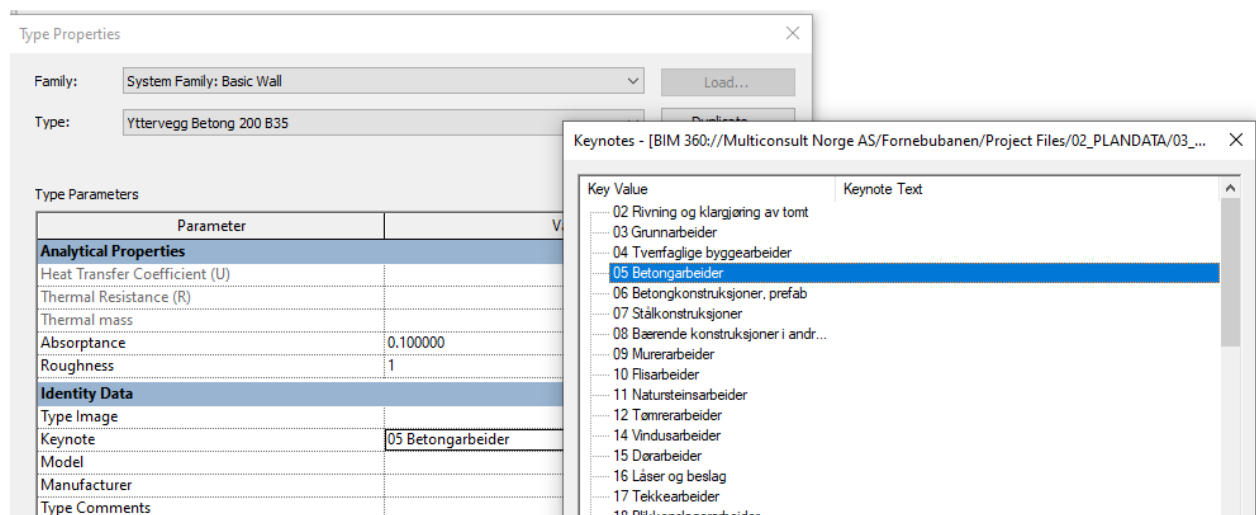
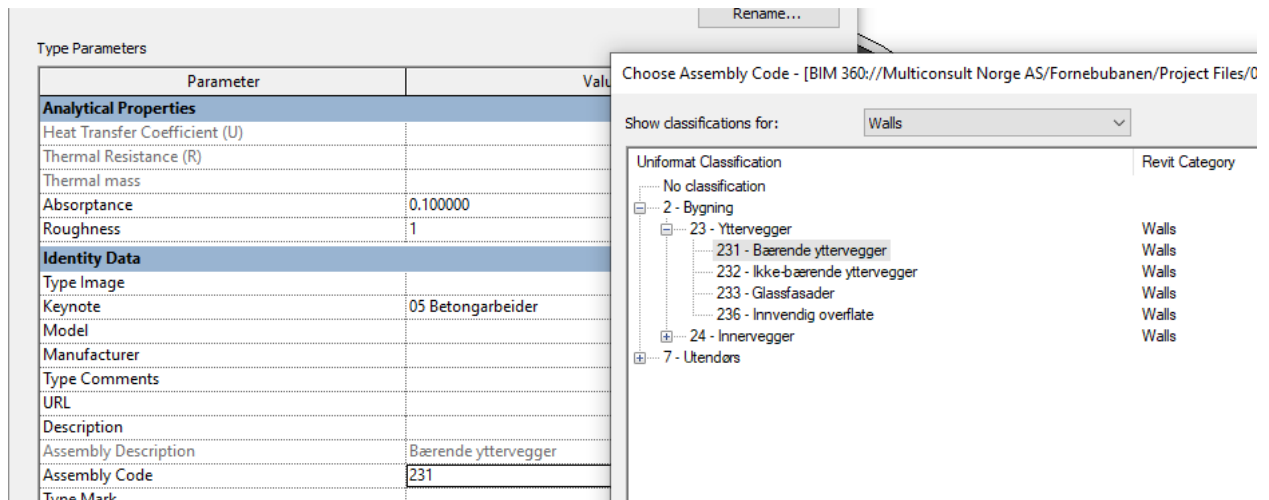*Figure 26: Look up table for "Keynote" in Revit Type Properties*

Figure 27: Look up table for Assembly Code in Revit Type Properties

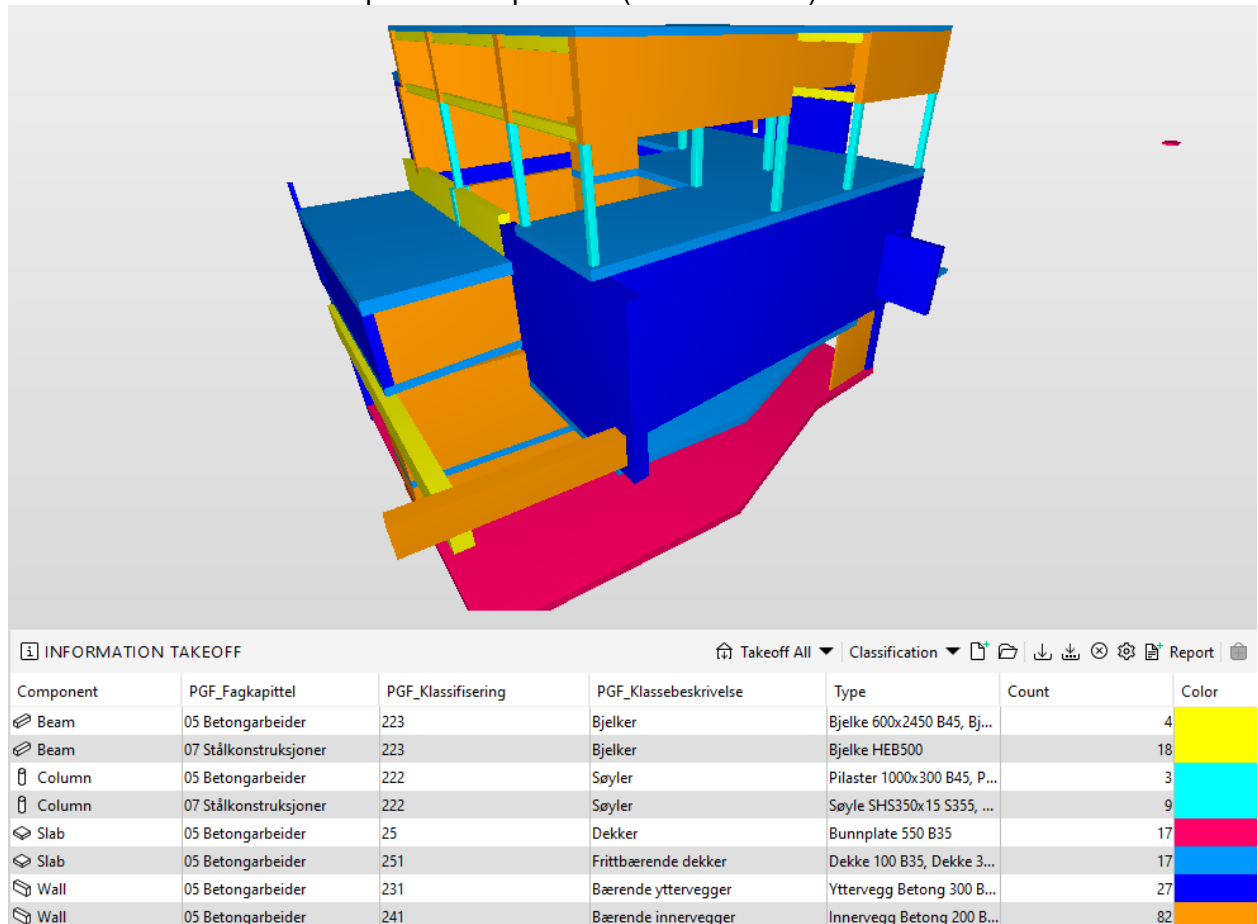When the Revit model is exported to OpenBIM (IFC fileformat) it looks like this.

Figure 28: Snapshot of Solibri and Information TakeOff – Color by Classification (PGF_Klassifisering)

When the IFC is imported into ISY Calcus, the root structure and the quiantities are in place. The next step is to customise recipes and apply those on different Types.
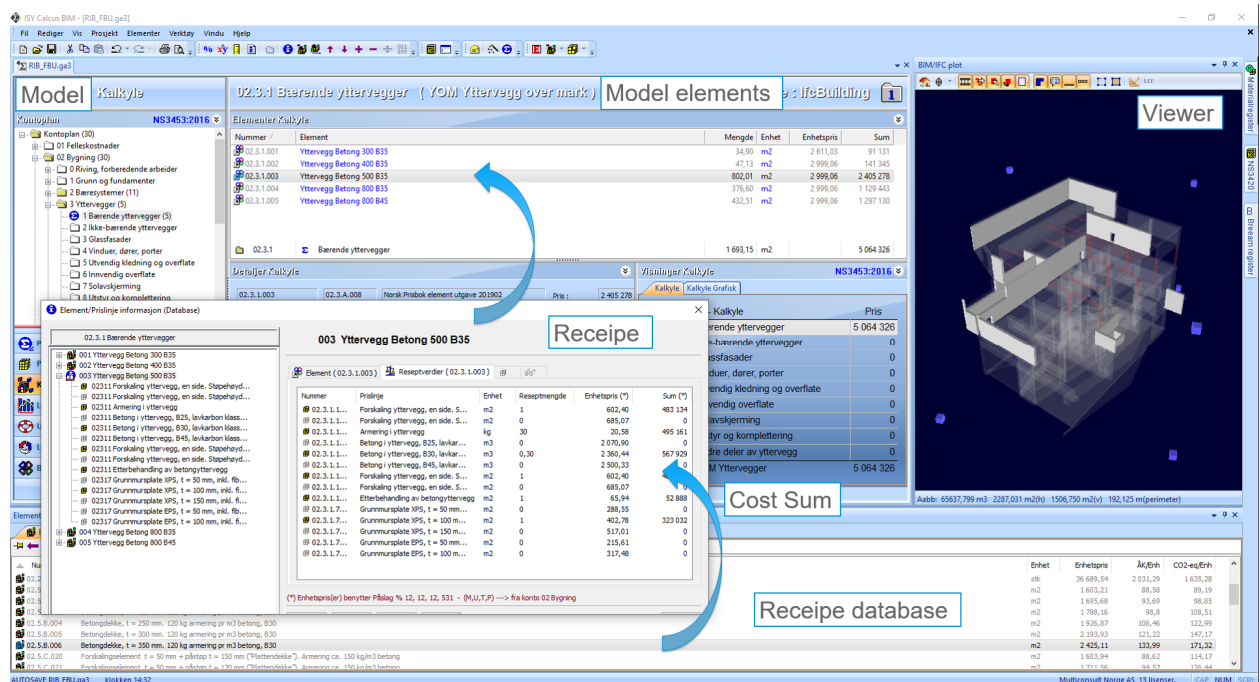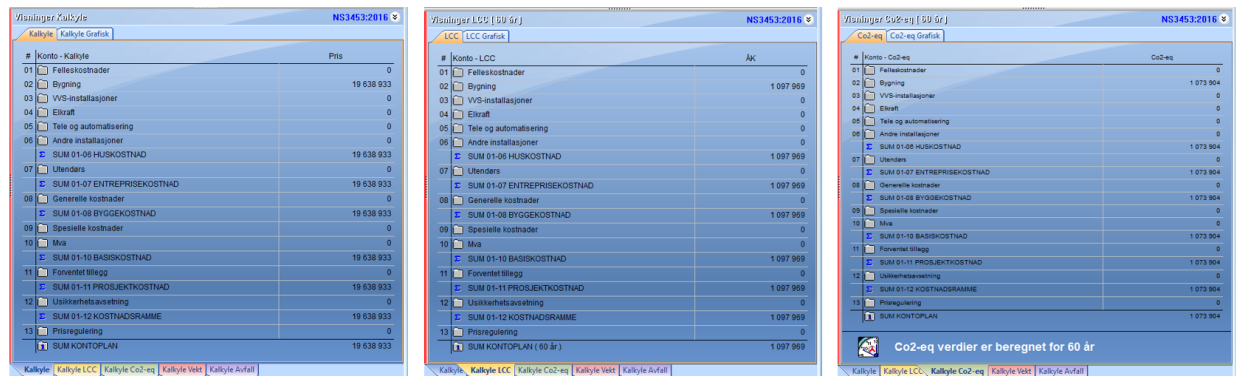
Figure 29: Applying receipes (unit cost) and cost calculation

Example of results based on applied receipes on model Types with quantities.

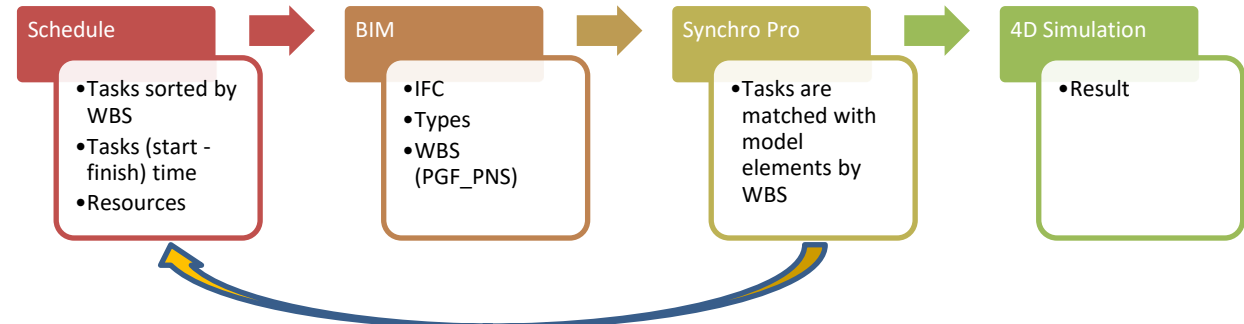Cost Calculation   LCC Calculation   Co2-eq Calculation

Figure 30: Cost, LCC, Co2 Results from OpenBIM and ISY Calcus

The same workflow applies on construction Description used for tender. But then the result is a detailed work description with quantities. The tenderer (contractor) inserts unit prices for the actual construction cost.

4D Scheduling

Within the design team, there is a discipline working specifically with construction scheduling and simulation. The workflow is:

Schedule
- Tasks sorted by WBS
- Tasks (start - finish) time
- Resources

BIM
- IFC
- Types
- WBS (PGF_PNS)

Synchro Pro
- Tasks are matched with model elements by WBS

4D Simulation
- Result

As mentioned, all model elements already have the necessary information (Properties), i.e. both models and schedules are based on the same WBS (PGF_PNS). The automatic matching (assigning) of smodel elements to tasks is easy. The manual labor is to review the simulation, optimise the solution and specify animation direction for demolition and construction.
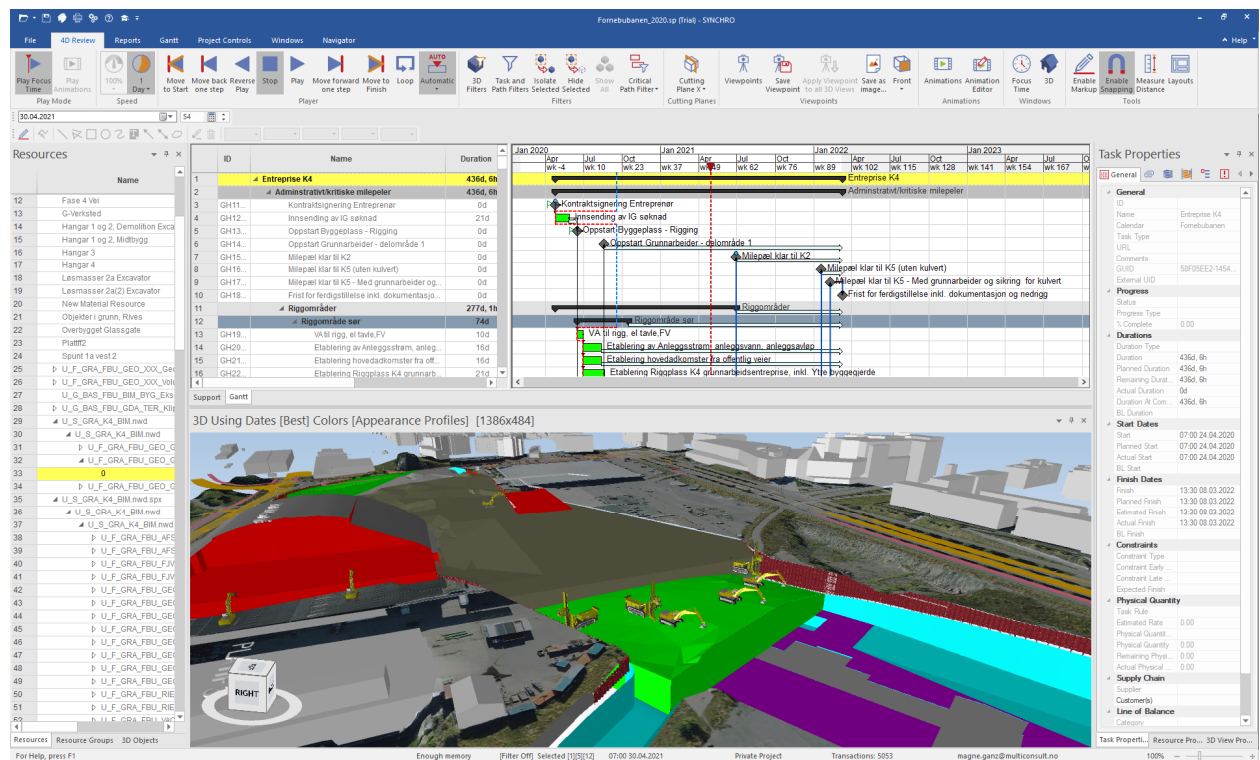

Figure 311: Synchro Pro 4D simulation of Contract K4 – ground works at Fornebu Base.

Construction Visualisation

For certain specific communication purposes it is beneficial to visualise a specific phase in more detail than playing a 4D animation and in those cases InfraWorks is used. Creating stills and slideshows are often great in meetings and towards authorities.
It is also possible to use the concept "Proposal" in InfraWorks as Phases, to visualise different points of time - a kind of semi-4D.
Below is an example of Skøyen station in early design phase, visualising a large construction pit with interface to existing train station, a small river and several office buildings.
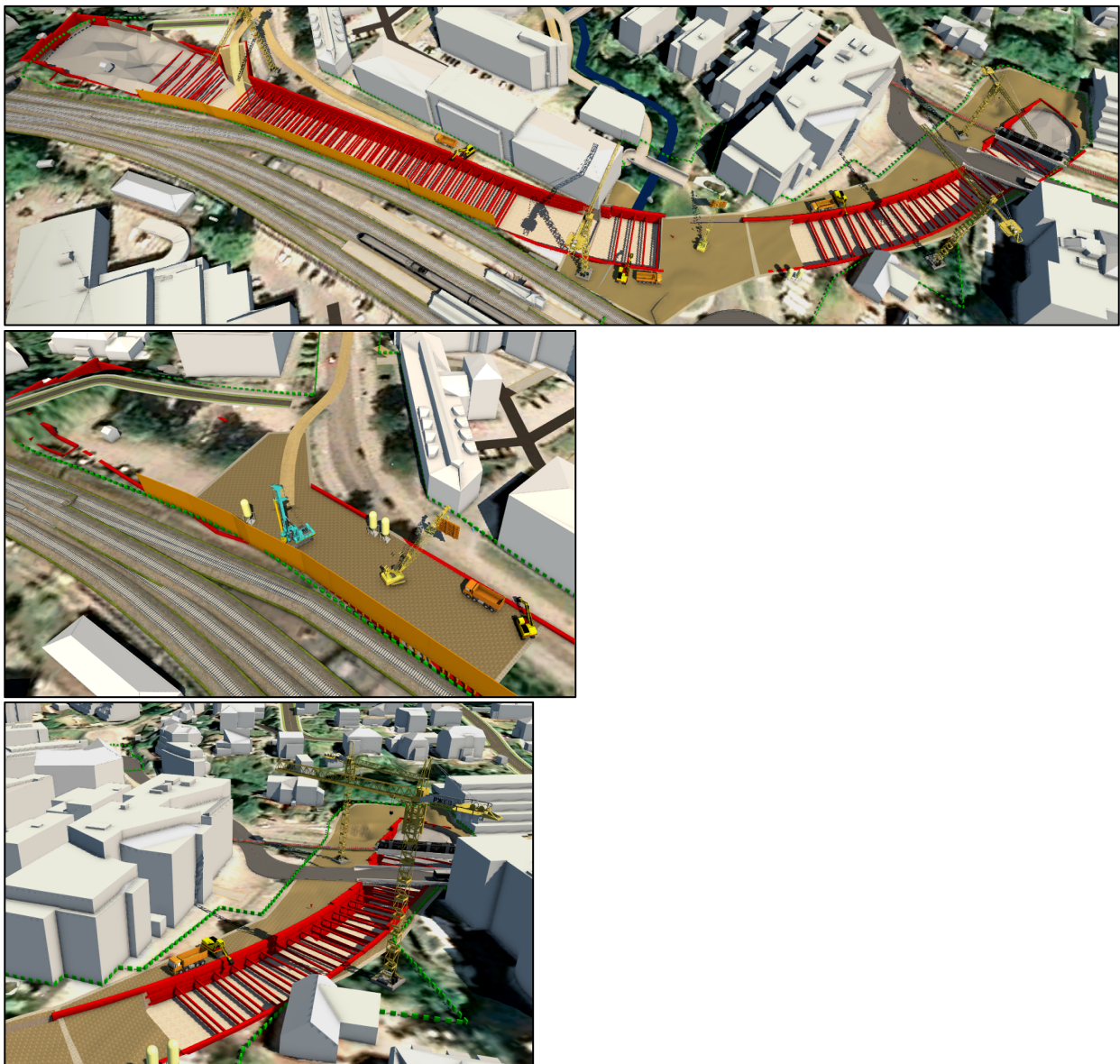
Figure 32: Snapshots from InfraWorks – Skøyen station, early concept design alternative.

Model based execution

To meet the requirements regarding model based execution and to clarify for the Contractor what the design group deliver and what is expected of the contractor, a "Model Execution Plan for Construction" is created for each build contract. The document describes, in short, how the model delivery is structured and what information that can be found and also, how that information is intended to being use.
The document also have requirements regarding the Contactor's BIM skills and how "as-built" data is supposed to be delivered back in the form of survey, 3D scans etcetera.

It is entirely up to the contractor to make the most out of the model based design delivery. For instance, making use of:

- Machine guided prosesses like excavation, piling and drilling.
- New technology lik AR and/or VR
- Utilizing the use of tablets like Microsoft Surface, iPad or Android devices

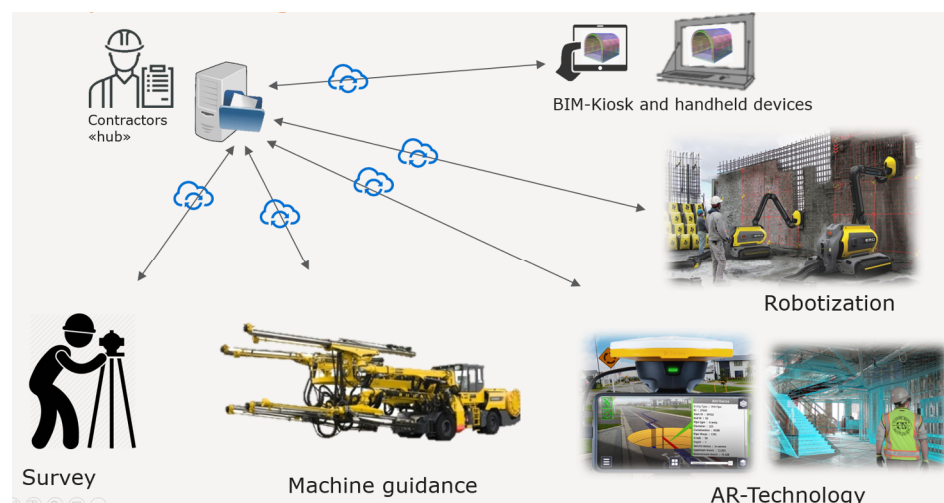*Figure 33: Examples on using BIM-data in construction*

Figure 34: Possible technologies to use

Automation of tasks

In order to execute such a large and ambisious project you both have to invent better ways to work and be more efficient. Discovering and implementering automation of tasks is an ongoing process. During the last two years we have made some progress that includes the use of web-plattforms, batch routines, scripting and visual programming.

Order design basis – GIS Viewer

When you start a project like this, gathering data about the existing situation such as terrain, rock surface, existing buildings and infrastructure (both above and under ground) is kind of a "project" of its own. After collecting and preparing existing data for use there are always a need ofr more fresh data from the field. It could be need for drilling, laser scanning, drone scanning and other surveys.

To keep track of new needs and already ordered data, we have an ordering system in our GIS-Web-Portal. From that portal you can see all activity,their status and create a new order. While ordering you can accurately specify geographical boundary and what kind of boundary needed. This makes the process more effective and accurate.
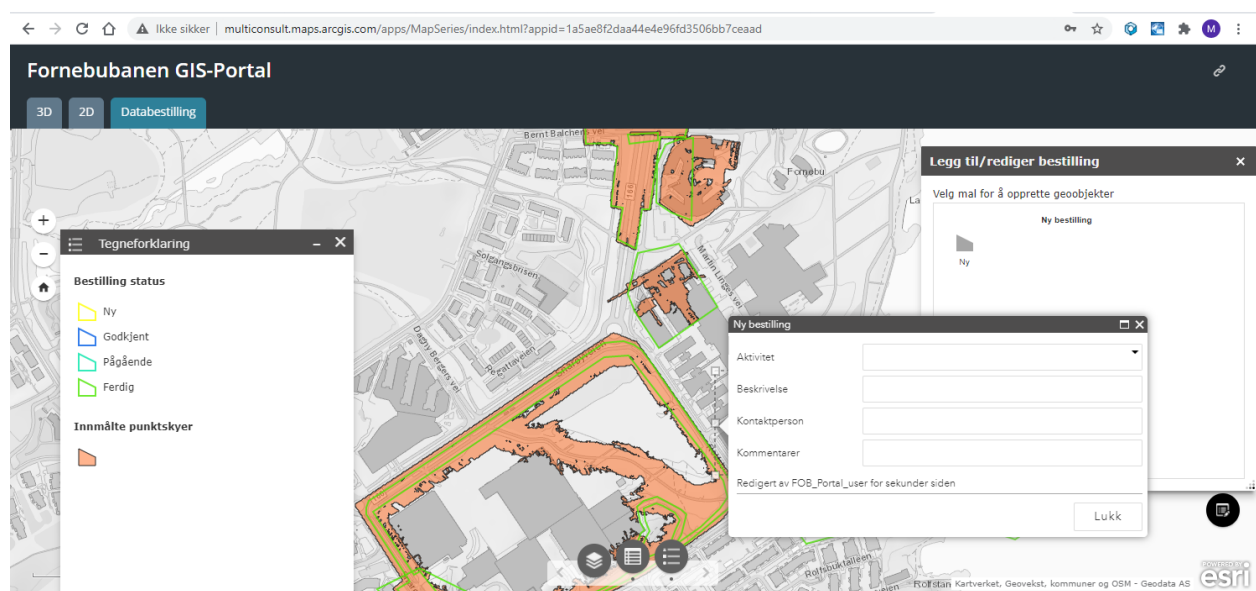

Figure 35: GIS-Portal - order design basis reality capture

Grasshopper and Tekla

Tekla is the software used for structures in tunnels. The tunnel centerline comes form the rail discipline using Trimble NovaPoint. The different crossections used in the tunnel are rulebased and controlled by parameters. Geological observations and assessments are also inputs to the tunnel structure. The rail center line for the south bounding and north bounding routes have both vertical and horizontal curves.

Creating this kind of tunnel geometry manually in Tekla is time consuming and nearly impossible to maintain accuracy. The benefit of using visual programming is enormous.

The discipline for tunnel structures have generated all possible tunnel profiles in a database.
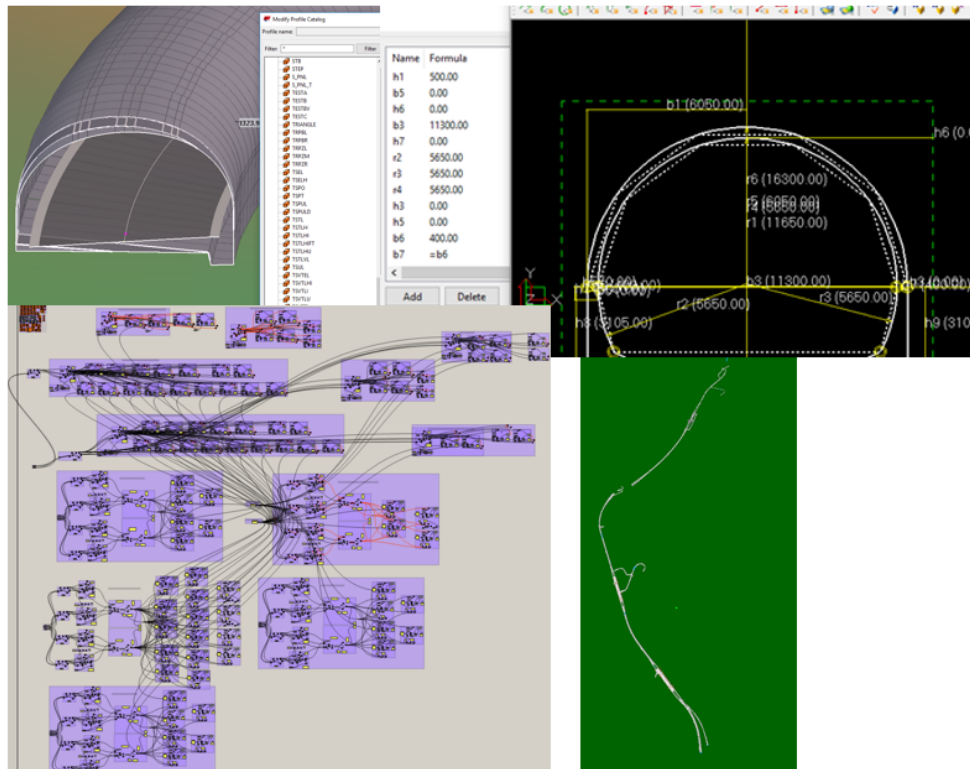
Figure 36: Grasshopper and Tekla for tunnel structures

Dynamo for Civil 3D

Civil 3D is used modelling of geological situations and visualisation of drill samples. The geological models are important design basis for other disciplines and will directly influence the placing of rail center line and stations. Having control over and able to visualise rock quality is import for cost control in the entire project. The geological modeles are an important part of the coordination models. This kind of information is complex and difficult to model with the standard tools available in Civil 3D. However with the 2020-version you can use Dynamo to read information from sources like Excel or csv to generate the models needed.
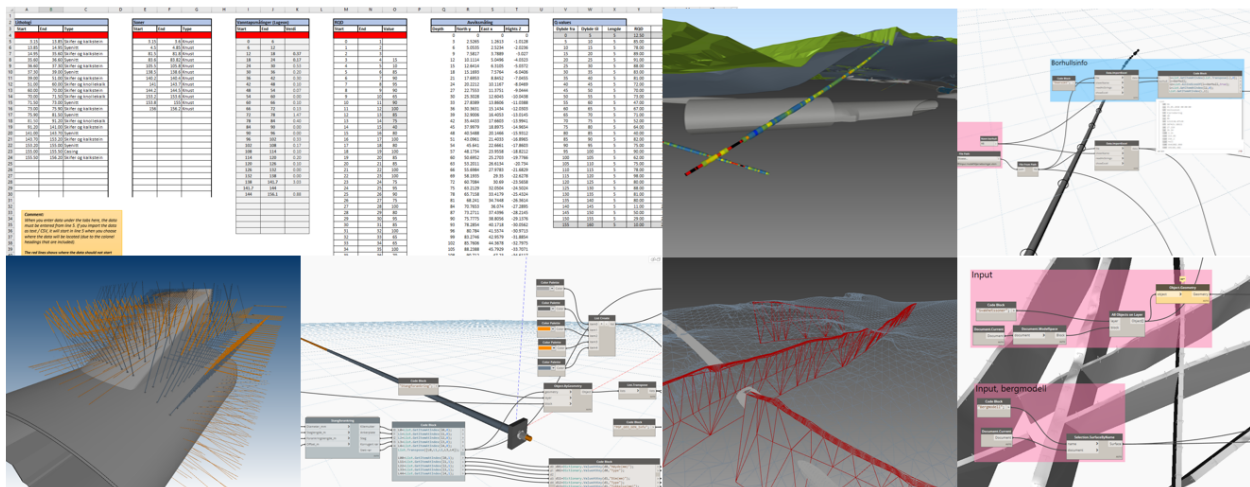
Figure 37: Geology with Dynamo and Civil 3D – drill holes, weakness zones and anchoring

Dynamo for Revit

Given that the disciplines connected to the stations use mainly Revit, there are always complex or repetitive tasks that can be executed faster or more accurate using visual programming. Dynamo for Revit has been around for a while and for some Dynamo is just "the way of work" and for others it is a bit "scary" and they need some help.

There are several modelling operations and tasks that have been scripted with Dynamo in the project. We have a common folder for Dynamo scripts in BIM 360 with over 30 dyn-files in use.

Here are som examples:

Automating the relation between Work Breakdown Structure and model elements

Each "physical" zone in the WBS are represented with volumes modelled as Mass in Revit. The masses is in a common "Levels and Grids" model for each station and for the tunnel. The "Levels and Grids" model are linked into the discipline model. Levels and Grids are managed by the "Copy/Monitor" tool in Revit. Dynamo is used for transferring the Location Code from Mass elements in linked file to the model elements in the discipline model within the separate masses.
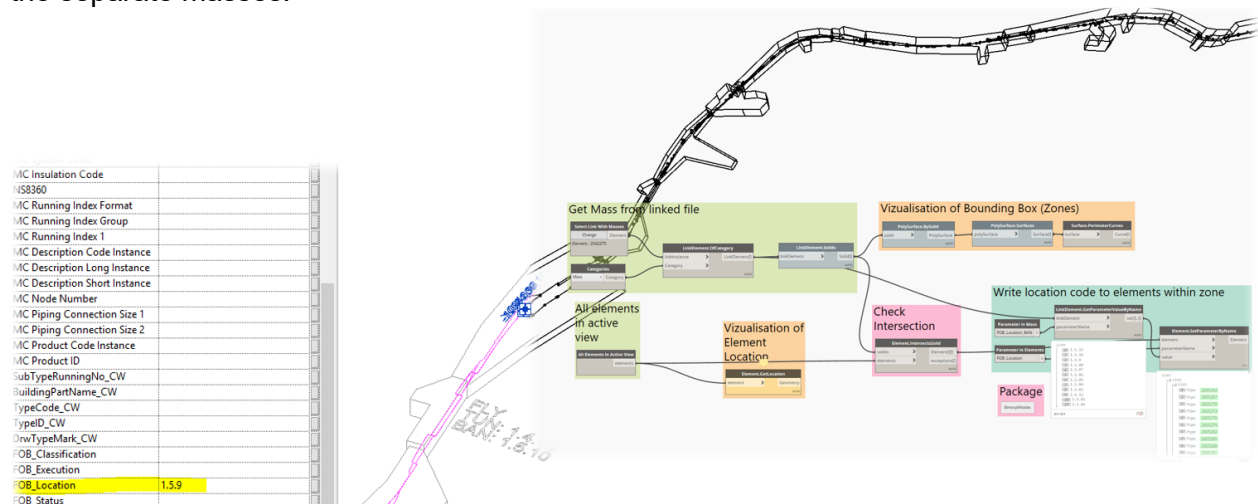

Figure 38: Dynamo script for WBS element relation

Automating modelling of Geotechnical structures

Geotechnical structures for the construction pit are modelled as SheetPiles, Anchors and jet piles. All of those elements have a lot in common: they have a lot of instances per model and they are related to rock surface and/or terrain surface. When you have to individually place and adjust the length to fit these surfaces Dynamo is the obvious tool. In stead of using a full workweek with manual labor. Creating a script will take 1-2 hours and running the script will take 2-5 minutes. Using the node "Point.Project" with related Vector is the key. Here are some examples:
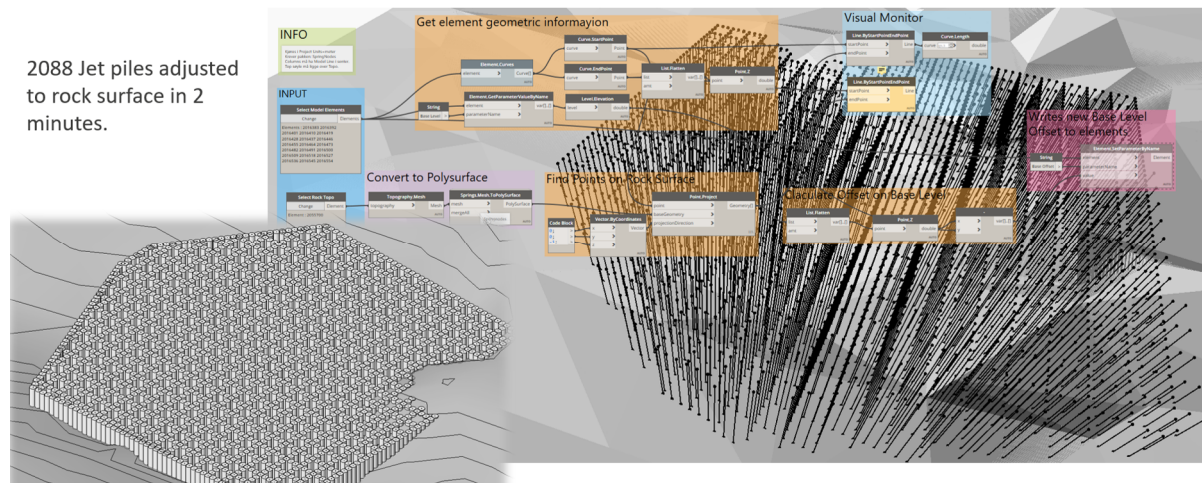
2088 Jet piles adjusted to rock surface in 2 minutes.

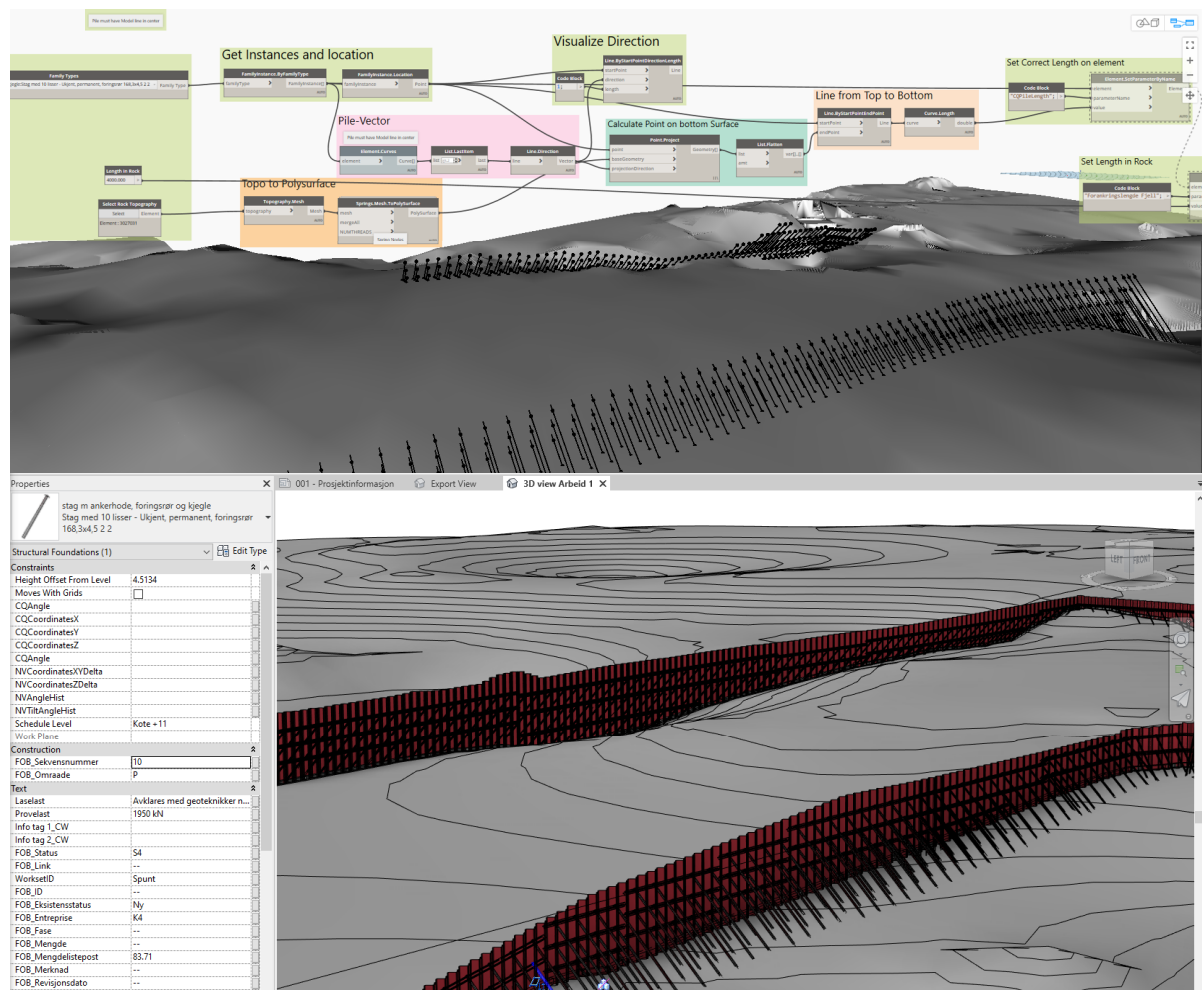*Figure 39: Dynamo automation for jet piles*

Figure 40: Adjust Anchor length for sheet pile wall with Dynamo

One of the headaches with Revit is when working with structures related to terrain and rock surface - the standard cut command in Revit does not work with Toposurface. Simply, you can not select a concrete element and cut it with a Toposurface. As a workaround Dynamo

is used to create Void-elements that follow the Toposurface. Once the void-elements are created, you can use the normal cut command.
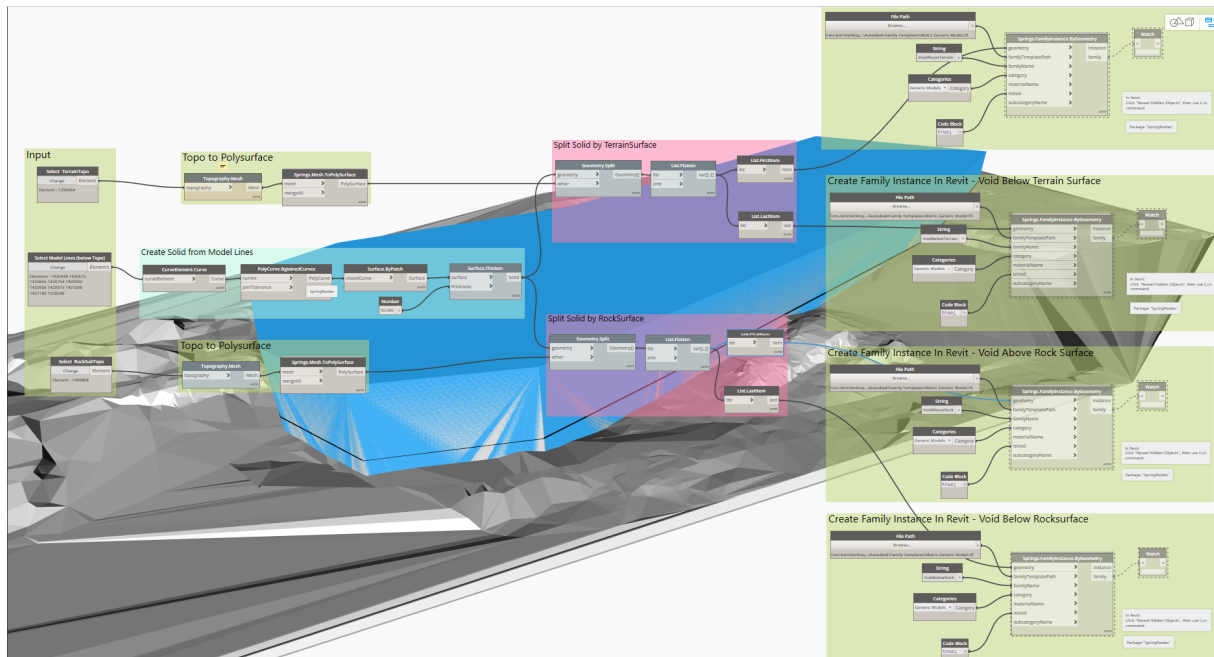
Figure 41: Creating Void-elements that follow Toposurface

The discipline Fire and Safety is quite new in BIM. When modelling the escape route following rail center line in Revit, Dynamo is a useful tool and this 3D escape zone is used in clash detection with other disciplines. The volume should not have intersecting elements in it. The passengers needs a clear passage if they have to evacuate the train.
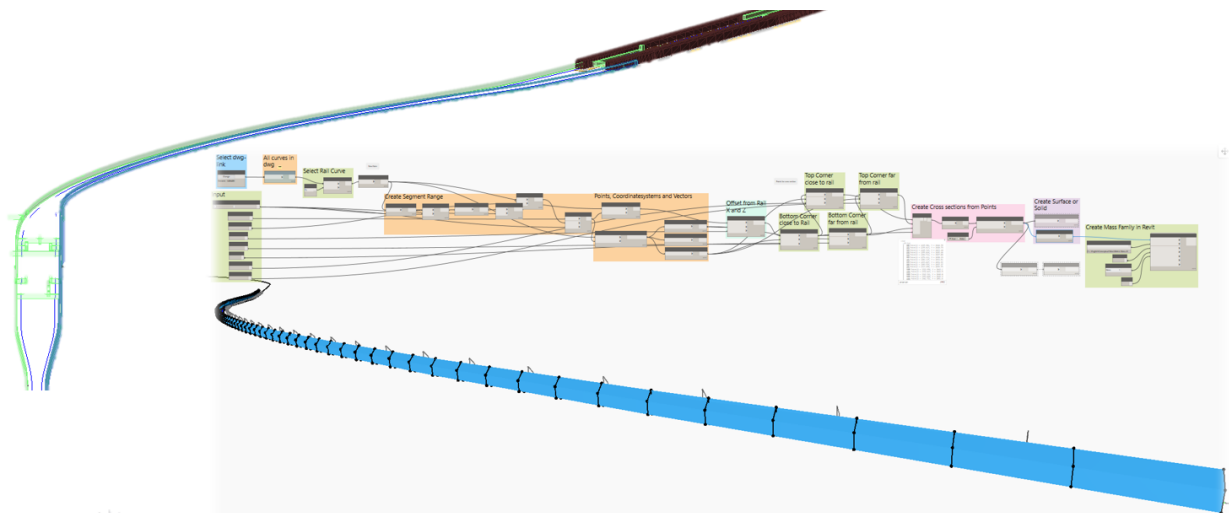
Figure 42: Model escape route in BIM with Dynamo

Trimble Novapoint used for Rail design is not a full BIM software. The design is mainly represented by surfaces and lines. BIM'ification of rail components, for instance sleepers, can be done with Dynamo and Revit or Dynamo and Civil 3D.
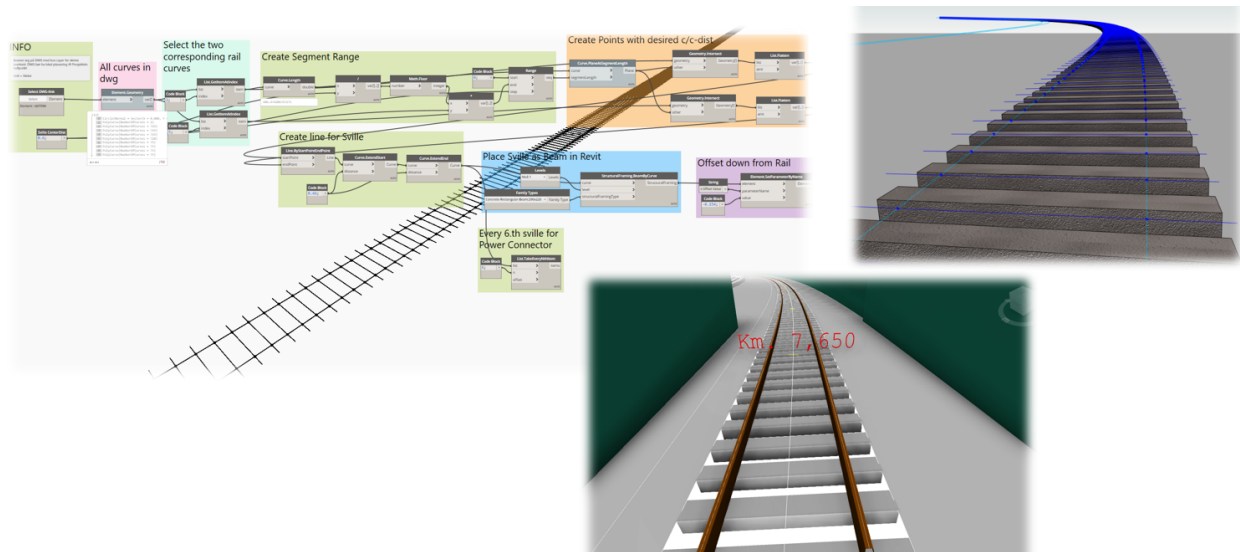
Figure 43: BIM'ification of rail sleepers with Dynamo and Revit

Model Delivery List

A model list is required for every delivery, and also useful to have. From the start of the project the model list was manually maintained in Excel. Since we have over 500 discipline models a manually updated list is in practice impossible to maintain.

All weekly exports and deliveries are always uploaded to BIM 360 folder "04 Discipline Models (Export)". With that as our only true source, we generated an Model List web app using Autodesk Forge. Combining the App with Custom Attributes makes it possible to have a "live up-to-date" model list on demand through the app.

Figure 44: BIM 360 Exported models with Attributes

The Forge app can extract all files and attributes from a BIM 360 folder (with sub-folders). The app can filter, sort and Export to Excel.

Files in 03_FBP

Nr of files: 117

Name	File type	Folder	Created	Created by	Last modified	Last modified	Entreprise	Kvalitetsnivå	Leveranse
U_F_STA_FBP_ARK_SKB.dwg	.DWG	03_FBP	2020-04-22 - 20:32	Pablo Vivas	2020-08-27 - 17:23	Pablo Agustin Vivas	K6	KN1	Nei
U_F_STA_FBP_ARK_SKB.ifc	.IFC	03_FBP	2020-04-22 - 20:40	Pablo Vivas	2020-08-27 - 17:23	Pablo Agustin Vivas	K6	KN1	Nei
U_F_STA_FBP_ARK_XXX.dwg	.DWG	03_FBP	2019-05-24 - 18:57	Mauro Sabiu	2020-09-18 - 18:27	Pablo Agustin Vivas	K6	KN1	Nei
U_F_STA_FBP_ARK_XXX.ifc	.IFC	03_FBP	2019-05-17 - 16:57	Mauro Sabiu	2020-09-21 - 19:15	Pablo Agustin Vivas	K6	KN1	Nei
U_F_STA_FBP_MEK_XXX.dwg	.DWG	03_FBP	2019-03-01 - 11:24	Anders Honoré Pedersen	2020-09-18 - 17:13	Michelle Kühl	K6	KN1	Nei
U_F_STA_FBP_MEK_XXX.ifc	.IFC	03_FBP	2019-03-01 - 11:24	Anders Honoré Pedersen	2020-09-18 - 17:13	Michelle Kühl	K6	KN1	Nei
U_F_STA_FBP_RIB_XXX.dwg	.DWG	03_FBP	2019-03-01 - 15:55	Christopher StorrusteEidsvaag	2020-09-20 - 16:34	Michele Depaoli	K6	KN1	Nei
U_F_STA_FBP_RIB_XXX.ifc	.IFC	03_FBP	2019-03-18 - 16:04	Christopher StorrusteEidsvaag	2020-09-20 - 16:35	Michele Depaoli	K6	KN1	Nei
U_F_STA_FBP_RIE_XXX.dwg	.DWG	03_FBP	2019-05-06 - 08:59	Marta Naasen Hellesnes	2020-09-18 - 16:22	Cindie Odette Colletta	K6	KN1	Nei
U_F_STA_FBP_RIE_XXX.ifc	.IFC	03_FBP	2019-05-06 - 08:59	Marta Naasen Hellesnes	2020-09-18 - 16:22	Cindie Odette Colletta	K6	KN1	Nei

Figure 45: Forge App User interface for Model List

Name	File type	Folder	Created	Created by	Last modified	Last modified by	GIS-Viewer	NavisWorks	Solibri
U_F_STA_FBP_ARK_SKB.dwg	.DWG	03_FBP	2020-04-22 - 20:32	Pablo Vivas	2020-08-27 - 17:23	Pablo Agustin Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_SKB.ifc	.IFC	03_FBP	2020-04-22 - 20:40	Pablo Vivas	2020-08-27 - 17:23	Pablo Agustin Vivas	Nei	Ja	Ja
U_F_STA_FBP_ARK_XXX.dwg	.DWG	03_FBP	2019-05-24 - 18:57	Mauro Sabiu	2020-09-18 - 18:27	Pablo Agustin Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_XXX.ifc	.IFC	03_FBP	2019-05-17 - 16:57	Mauro Sabiu	2020-09-21 - 19:15	Pablo Agustin Vivas	Nei	Ja	Ja
U_F_STA_FBP_MEK_XXX.dwg	.DWG	03_FBP	2019-03-01 - 11:24	Anders Honoré Pedersen	2020-09-18 - 17:13	Michelle Kühl	Nei	Nei	Nei
U_F_STA_FBP_MEK_XXX.ifc	.IFC	03_FBP	2019-03-01 - 11:24	Anders Honoré Pedersen	2020-09-18 - 17:13	Michelle Kühl	Nei	Ja	Ja
U_F_STA_FBP_RIB_XXX.dwg	.DWG	03_FBP	2019-03-01 - 15:55	Christopher StorrusteEidsvaag	2020-09-20 - 16:34	Michele Depaoli	Ja	Ja	Ja
U_F_STA_FBP_RIB_XXX.ifc	.IFC	03_FBP	2019-03-18 - 16:04	Christopher StorrusteEidsvaag	2020-09-20 - 16:35	Michele Depaoli	Ja	Ja	Ja
U_F_STA_FBP_RIE_XXX.dwg	.DWG	03_FBP	2019-05-06 - 08:59	Marta Naasen Hellesnes	2020-09-18 - 16:22	Cindie Odette Colletta	Nei	Nei	Nei
U_F_STA_FBP_RIE_XXX.ifc	.IFC	03_FBP	2019-05-06 - 08:59	Marta Naasen Hellesnes	2020-09-18 - 16:22	Cindie Odette Colletta	Nei	Nei	Ja
U_F_STA_FBP_VEG_PMT-Overflate.dwg	.DWG	03_FBP	2019-02-27 - 14:46	Antonio Periago	2020-04-17 - 17:09	Lene Anita Nordsve	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX_Option A.nwc	.NWC	OLD	2020-05-22 - 15:31	Pablo Vivas	2020-06-15 - 10:22	Pablo Agustin Vivas	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX_Option A_Alt.nwc	.NWC	OLD	2020-05-28 - 17:15	Pablo Agustin Vivas	2020-06-15 - 10:22	Pablo Agustin Vivas	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX_Option A_Parasol.nwc	.NWC	OLD	2020-04-29 - 10:03	Pablo Vivas	2020-05-22 - 15:31	Pablo Vivas	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX_Option A_Sunken Garden.nwc	.NWC	OLD	2020-04-29 - 10:03	Pablo Vivas	2020-05-22 - 15:31	Pablo Vivas	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX_Option B_3 Heis.nwc	.NWC	OLD	2020-05-14 - 15:59	Pablo Vivas	2020-06-15 - 10:22	Pablo Agustin Vivas	Nei	Ja	Nei
U_F_STA_FBP_ARK_SKB.nwc	.NWC	01_NWC-EKSPORT	2020-04-22 - 20:32	Pablo Vivas	2020-08-27 - 17:00	Pablo Agustin Vivas	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX.nwc	.NWC	01_NWC-EKSPORT	2019-05-17 - 16:42	Mauro Sabiu	2020-09-18 - 18:13	Pablo Agustin Vivas	Nei	Ja	Nei
U_F_STA_FBP_MEK_XXX.nwc	.NWC	01_NWC-EKSPORT	2019-03-01 - 11:23	Anders Honoré Pedersen	2020-09-18 - 17:13	Michelle Kühl	Nei	Ja	Nei
U_F_STA_FBP_RIB_XXX.nwc	.NWC	01_NWC-EKSPORT	2019-04-09 - 09:33	Christopher StorrusteEidsvaag	2020-09-24 - 10:04	Michele Depaoli	Ja	Ja	Ja
U_F_STA_FBP_RIE_XXX.nwc	.NWC	01_NWC-EKSPORT	2019-05-06 - 08:59	Marta Naasen Hellesnes	2020-09-18 - 16:22	Cindie Odette Colletta	Nei	Ja	Nei
U_F_STA_FBP_ARK_XXX_Option A.dwg	.DWG	03_OLD	2020-05-22 - 15:38	Pablo Vivas	2020-06-15 - 10:21	Pablo Agustin Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_XXX_Option A.ifc	.IFC	03_OLD	2020-05-22 - 15:38	Pablo Vivas	2020-06-15 - 10:21	Pablo Agustin Vivas	Nei	Ja	Ja
U_F_STA_FBP_ARK_XXX_Option A_Alt.dwg	.DWG	03_OLD	2020-05-28 - 17:15	Pablo Agustin Vivas	2020-06-15 - 10:21	Pablo Agustin Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_XXX_Option A_Alt.ifc	.IFC	03_OLD	2020-05-28 - 17:15	Pablo Agustin Vivas	2020-06-15 - 10:21	Pablo Agustin Vivas	Nei	Ja	Ja
U_F_STA_FBP_ARK_XXX_Option A_Parasol.dwg	.DWG	03_OLD	2020-04-29 - 10:03	Pablo Vivas	2020-05-22 - 15:36	Pablo Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_XXX_Option A_Parasol.ifc	.IFC	03_OLD	2020-04-29 - 10:01	Pablo Vivas	2020-05-22 - 15:36	Pablo Vivas	Nei	Ja	Ja
U_F_STA_FBP_ARK_XXX_Option A_Sunken Garden.dwg	.DWG	03_OLD	2020-04-29 - 10:03	Pablo Vivas	2020-05-22 - 15:36	Pablo Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_XXX_Option A_Sunken Garden.ifc	.IFC	03_OLD	2020-04-29 - 10:01	Pablo Vivas	2020-05-22 - 15:36	Pablo Vivas	Nei	Ja	Ja
U_F_STA_FBP_ARK_XXX_Option B_3 Heis.dwg	.DWG	03_OLD	2020-05-14 - 15:56	Pablo Vivas	2020-06-15 - 10:21	Pablo Agustin Vivas	Nei	Nei	Nei
U_F_STA_FBP_ARK_XXX_Option B_3 Heis.ifc	.IFC	03_OLD	2020-05-14 - 15:56	Pablo Vivas	2020-06-15 - 10:21	Pablo Agustin Vivas	Nei	Ja	Ja

Figure 46: Exported Excel Sheet – Model List

360 Sync (N'Sync)

As described in the chapter "Common Data Environment" we have several softwares that are not able to sync directly with BIM 360 Docs/Design. We have Tekla, Navisworks, Solibri, Novapoint and loads of discipline specific softwares that works best with a local file server. Since we have manifested BIM 360 as the one true source, all disciplines are committed to upload weekly exports an deliveries to BIM 360. Every night a copy of those files are downloaded (synchronised) to the common PGF fileserver. The fileserver is mapped to the drive N:, hence the PC running the sync is called *N'Sync* (like the former Boyband). N'Sync is running the software "360 Sync" form Applied Software® on specific folders every night.
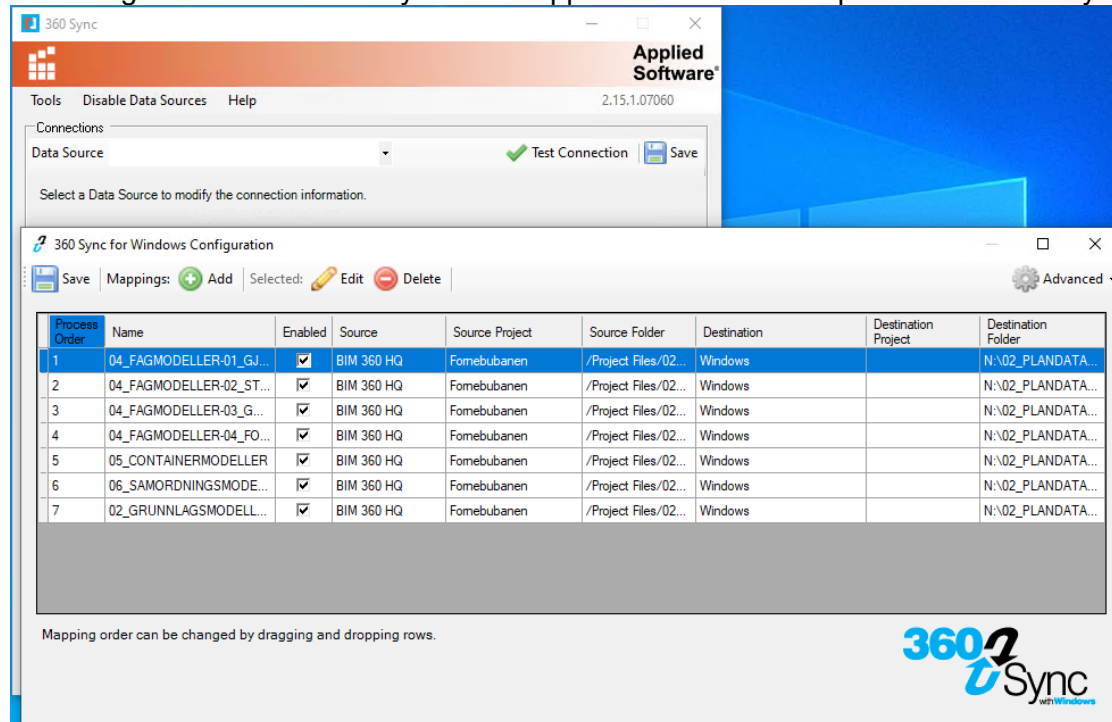
Figure 47: N'Sync and 360 Sync from Applied Software.

Navisworks Batch Utility

Maintaining seven coordination models (one for each station and one for the whole tunnel) with about 40 discipline models in each, can be a quite time consuming task. Whenever you one to automate a workflow, you first have to standardize. In order to persue the aim of automate Navisworks coordination models, you first have to standardise the following: folder structure, file naming, export routines, upload routines, 360 sync routines, container models, search sets, appearance override and saved views.

Container models is the step between exported dwg's and IFC's and the nwf-model. Container model is a collection of discipline models to nwd-files. We discovered that if we also standardise our container models (nwd) to cover the needs for every coordination model, this is where we can save time.

The nwf and nwd for the coordination model is still maintained by a BIM Coordinator, but the prosess of opening the nwf is "super fast" due to the automated nwd's and all the BIM coordinator needs to do is to apply search sets, appearance override, run clash detection and create saved views. Some of this can by automated with "DynaWorks" Package in Dynamo.

Navisworks Batch Utility was then used to automate the creation of container models (nwd's).

All discipline models was grouped into containers following the same system as folder. Every station coordination model will have 6 containers appended:

- G-models (Design Basis models)
- EXT (External models in relation to that station)
- TUN (Tunnel models with interface to that station)
- BAN (Rail models with interface to that station
- GRA (Ground works in that station)
- STA (Station disciplines)

Batch Utility runs with a Bat-file pointing to Navisworks FiletoolsTaskRunner.exe and a FileList.txt. Filelist is a list of discipline models per container. As an example, here are the BatchUtilty folder for Lysaker Station (LYA).
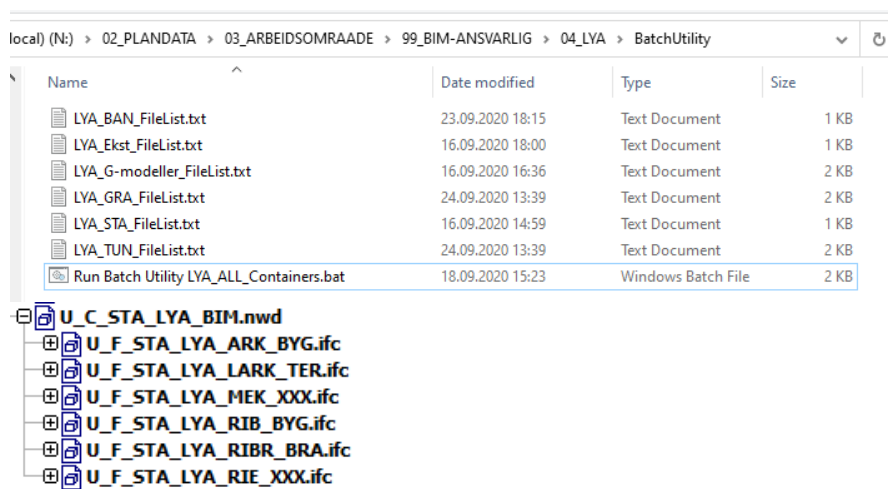
Figure 48: Batch Utility FileLists, Bat-file and Container file (nwd) example.

To run the The Windows Batch File you can double click it or add it to Windows Task Schduler. When running the bat-file, all the nwd's needed for Lysaker Station will be created. The first lines of the bat-files looks like this. The last four lines are repeated, but with different file names.

```
@ECHO off

ECHO NavisWorks Batch Utility is running.
ECHO The script is busy creating new nwd-containers for STA LYA
ECHO Please wait ..

ECHO Creating U_C_G_LYA_BIM.nwd
"C:\Program Files\Autodesk\Navisworks Manage 2020\FiletoolsTaskRunner.exe" /i
"N:\02_PLANDATA\03_ARBEIDSOMRAADE\99_BIM-ANSVARLIG\04_LYA\BatchUtility\LYA_G-modeller_FileList.txt" /of
"N:\02_PLANDATA\03_ARBEIDSOMRAADE\99_BIM-ANSVARLIG\04_LYA\Container\U_C_G_LYA_BIM.nwd" /version 2019
```

Figure 49: Bat file content
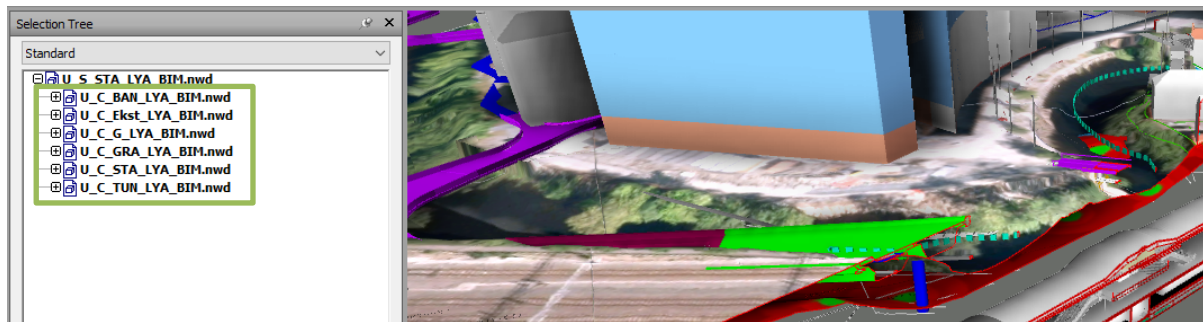
Figure 50: Coordination model with containers

Solibri Autorun

Solibri Office (former Solibri Model Checker) is possibly the OpenBIM software that has the most developed rule checking that can be applied. Whilst Navisworks offer clash detection Solibri offers a lot more possible rules to apply when quality checking both discipline models and also coordination models. From Solibri Office v.9.10 Solibri Autorun is included in the subscription. In a large project like this it would be madness not to take advantage of that. Navisworks Batch Utility is able to combine models into nwd's or nwf's. Solibri Autorun is capable of more than just combining files. Heres is a list of what you can automate with Autorun:

- Combine or update IFC'files
- Specify discipline and shortnames for the files
- Load Classifications
- Load Rule sets
- Run the checker
- Autocomment the checking result
- Create presentations containing the checking results
- Save presentations as BCF (or PDF or Xls)
- Save the smc-file

What Autorun cannot do:
- Load Information TakeOff definitions (ITO's)
- Run "Take off all" or "Take off selected"
- Export ITO's to Excel.

How it works:
Solibri Autorun is set up using two files:
1. XML file with all instructions
2. BAT file that starts Solibri with the XML instructions

A simple XML-file that open one discipline model, classifications and rules, looks like this:

```xml
<?xml version="1.0" encoding="ISO-8859-1"?>
<batch name="Simple Batch" default="root">
<!-- This is the starting task -->
<target name="root">

<!--- Open Model(s) -->
<openmodel file="N:\02_PLANDATA\04_FAGMODELLER (EKSPORT)\03_GRUNNARBEIDER\02_FLY\U_F_GRA_FLY_GEO_SPU_Geotekniske-tiltak.ifc" discipline="Structural" shortname="RIG" />

<!--- Open Classifications -->
<openclassification file="N:\02_PLANDATA\03_ARBEIDSOMRAADE\00_BIM_FELLES\01_BIM_OPPSETT\04_SOLIBRI\03_Classifications\Felles\FOB_Eksistensstatus.classification" />
<openclassification file="N:\02_PLANDATA\03_ARBEIDSOMRAADE\00_BIM_FELLES\01_BIM_OPPSETT\04_SOLIBRI\03_Classifications\Felles\FOB_Entreprise.classification" />
<openclassification file="N:\02_PLANDATA\03_ARBEIDSOMRAADE\00_BIM_FELLES\01_BIM_OPPSETT\04_SOLIBRI\03_Classifications\Felles\FOB_Fase.classification" />

<!--- Open Ruleset -->
<openruleset file="N:\02_PLANDATA\03_ARBEIDSOMRAADE\00_BIM_FELLES\01_BIM_OPPSETT\04_SOLIBRI\01_Rulesets\PGF - RIB Faglig ModellKontroll.cset"/>

<!--- Save Solibri Model smc -->
<savemodel file="C:\Users\magneg\Desktop\Autorun\U_F_GEO_FLY_BIM.smc"/>

<!--- Run The Checker -->
<check/>
<autocomment zoom="TRUE"/>

<!--- Create Presentation -->
<createpresentation/>

<!--- Create Reports -->
<bcfreport file="C:\Users\magneg\Desktop\Autorun\Reports\BCFReport.bcfzip" version="2"/>
<generalreport pdffile="C:\Users\magneg\Desktop\Autorun\Reports\PFDReport.pdf"/>

<!--- Save Solibri Model smc -->
<savemodel file="C:\Users\magneg\Desktop\Autorun\U_F_GEO_FLY_BIM.smc"/>

<!--- Close and Exit -->
<closemodel/>
<exit/>

</target>
</batch>
```

Figure 51: Solibri Autorun instruction – XML

The BAT-file that starts Solibri and the instructions, looks like this:

```bat
@ECHO off

ECHO Thank you for using Autorun
ECHO Autorun is running
ECHO Example with one discipline, classification, checking and reports

REM You can modify the line below to suit your needs.
"C:\Program Files\Solibri\SOLIBRI\Solibri.exe" "C:\Users\Autorun\Open_Classify_Check_Present_Save_Close.xml"

exit
```

Whilst Navsiworks FileToolsTaskRunner runs in the background, Solibri Autorun opens the Solibri Application window. Then the commands are executed automatically. As for all bat-files, you can run it by double click or add it to Windows Task Scheduler. The Autorun.log will document what has been done and how long time it took per task.
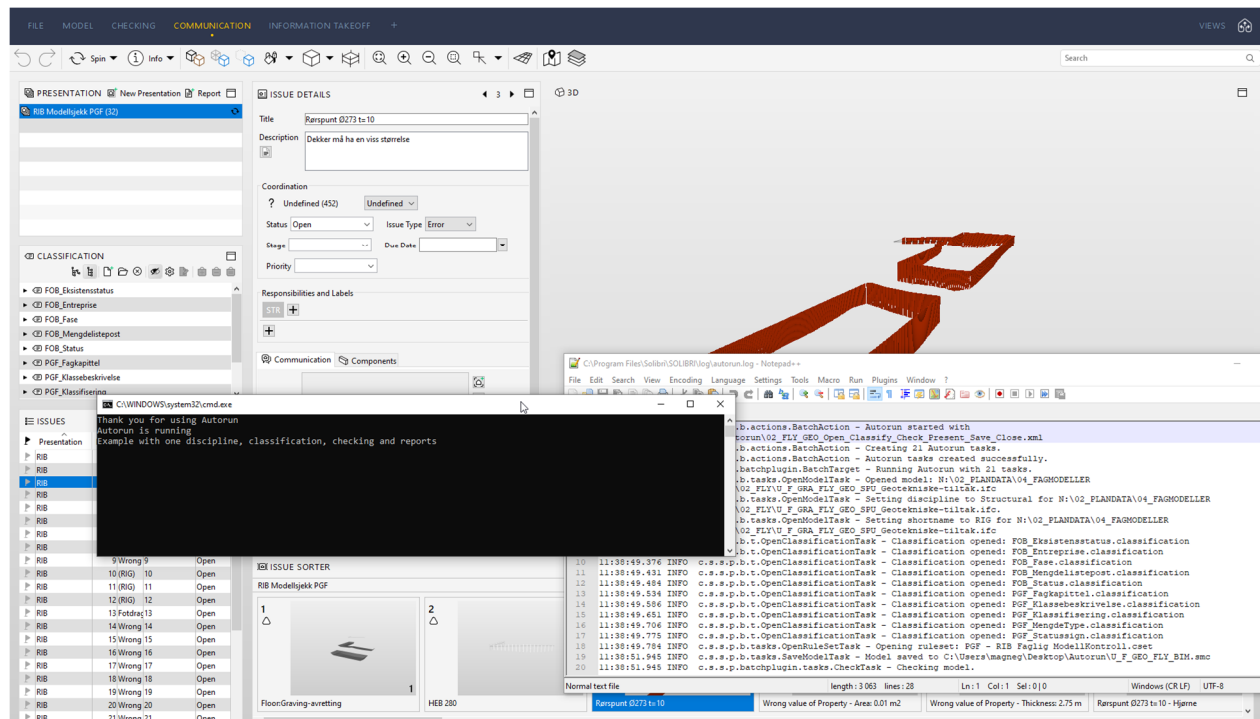
Figure 52: Solibri Autorun in action

Windows Task Scheduler

Now we have three types of automations which can be set up as a repetitive tasks:

- 360 Sync
- Navisworks Batch Utility
- Solibri Autorun

The only thing you need is a PC or Virtual PC on a server, that is available for you. I have N'Sync. N'Sync is a laptop at the project office, always up for new tasks. N'sync is remotely controlled via Windows Remote Desktop Connection. Useful now in Covid-19 days.

Windows Task Scheduler is a built in software in Windows. The purpose is to …. *drumroll* … schedule repetitive task that the computer can execute by itself. Adding a Task is quite easy. Just click "Action – New Basic task" and the Wizard will guide you through the process. Basically you point to a BAT-file and specify at what day and time the Task should be executed.

The 360 Sync routines (N'Sync) looks like this.
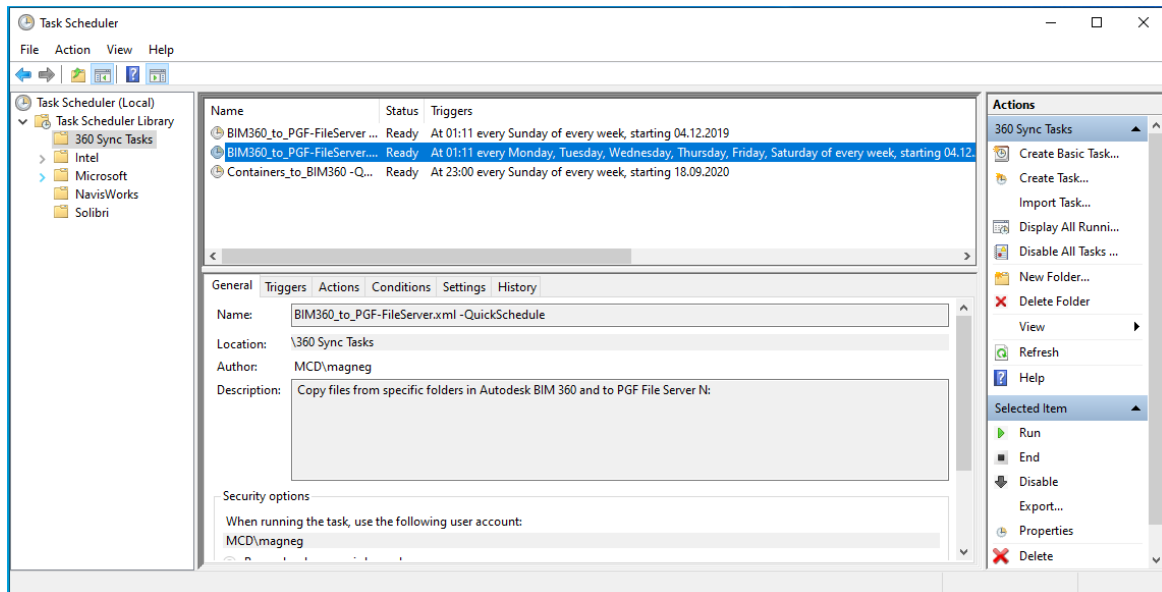
Figure 53: N'Sync Windows Task Scheduler – 360 Sync

The Navisworks Batch Utility Tasks looks like this.
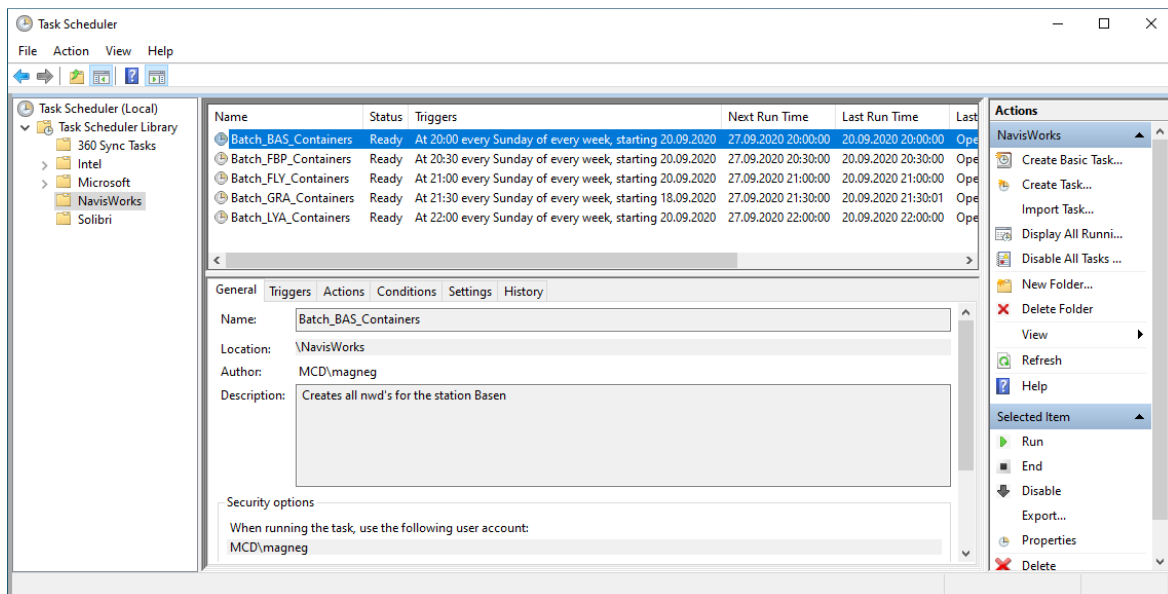
Figure 54: N'Sync Windows Task Scheduler – Navisworks

So now N'Sync plays a very important role in the project, both synchronisation of files connected tour CDE, ans also automating tasks connected to model coordination.

Involve the whole organization

How to get to «That's the way we do things here"

All these initiatives are not up to the digital organisation to carry out by them selves. For the digital team, communication is key.

We will not get far without close interaction with disciplines and management. Implementation of new methodology in the entire organization may require painful change to how we are used to work in a project.

In order to be successful in involving the entire organisation, we need to check all of the boxes below

Now, technology implementation, change management and having the team drive in the same direction, is a whole different presentation.

But we should mention that being two companies working together in the design team, with several architects, sub contractors and multiple stakeholders to involve in a project that is both an infrastructure and building project, the project needed its own Project Execution Model (PEM).

Project Execution Model (PEM)

PEM splits the project into seven levels of quality, taking the design team from start to the delivery of a finished Metro.
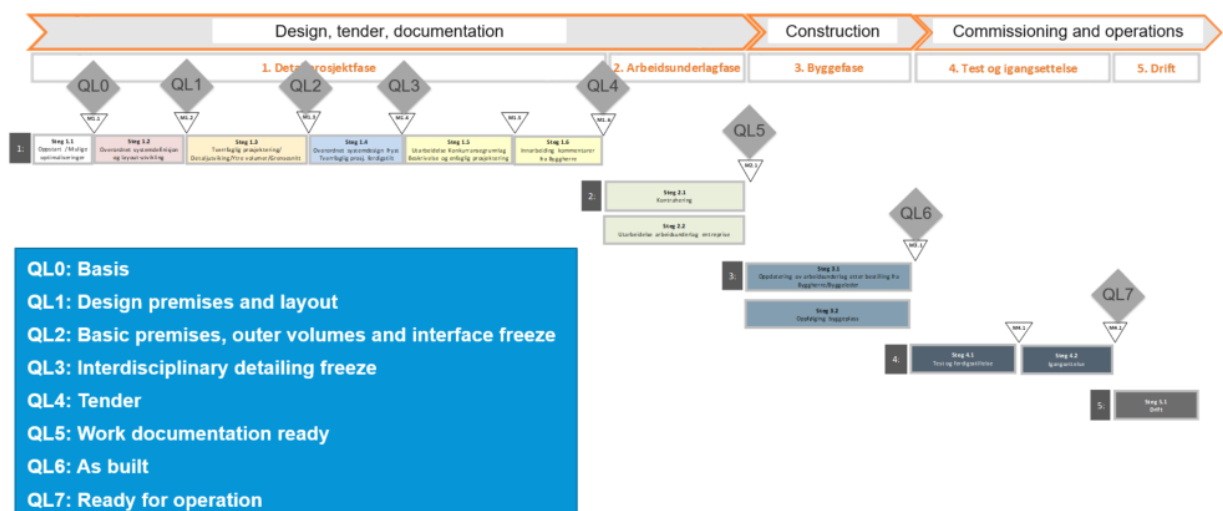
Last Planner System (LPS)

Having long term plans established, we use LPS to schedule deliveries in detail. This has shown good effects in how people commit to the plan. It's not just the objects using this for the engineering team, the digital collaboration team uses it as well. This allows us to break down our work and communicate with the rest of the design team how we prioritize tasks. We prefer to work with LPS with post-its on a physical board, but the last couple of months this has not been possible.

As we have yet to invest in LPS software, our post-its on boards were digitalised in excel. We must be able to use the same excel sheet simultaneously, and in March 2020 there really was no other option than BIM360. We are aware of BIM360 Plan, but when we evaluated the functionality to other software and cost, it didn't make the podium. Using Excel to keep track of our schedule works OK

Last Planner Covid-19 style: Excel in BIM360 Documents.

ICE-sessions

The project has decided to follow a structured approach to interdisciplinary teamwork in both planning and implementation. This means we prefer the methodology of ICE sessions.
An ICE session is a limited period of time where you work together as a team in order to solve interdisciplinary challenges.

The sessions are planned in detail and follow a strict agenda. Only the correct resources are summoned. Preparations are expected prior to the sessions.

Viewers

Accessible BIM viewers for everyone.

WEB - GIS

Project participants are given access to the GIS portal. This gives us the opportunity to view the entire project, and zoom into the areas of specific interest.

In the GIS portal, information such as subject models, zoning plans cadastral data, cultural monuments and other data in 3D and 2D.

Also, basic data such as scans and land measurements can be ordered through the GIS portal.
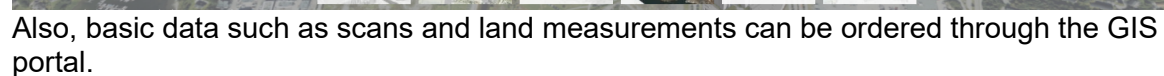
Progress – How we measure

The approach to measuring progress in BIM at project Fornebubanen is done in the following way

- The project has <u>phases</u> with corresponding targets
- Each phase has <u>steps</u> with defined targets
- The maturity of the design increases with every <u>step</u> and <u>phase</u>
- Progress according to plan is measured and controlled by activities in each step.

The plan for BIM is shown below in our Model status plan. Every object use the wbs structure to split their steering object into smaller pieces.

Using Status as an important parameter in BIM, our models can give us an overview of how we are doing.
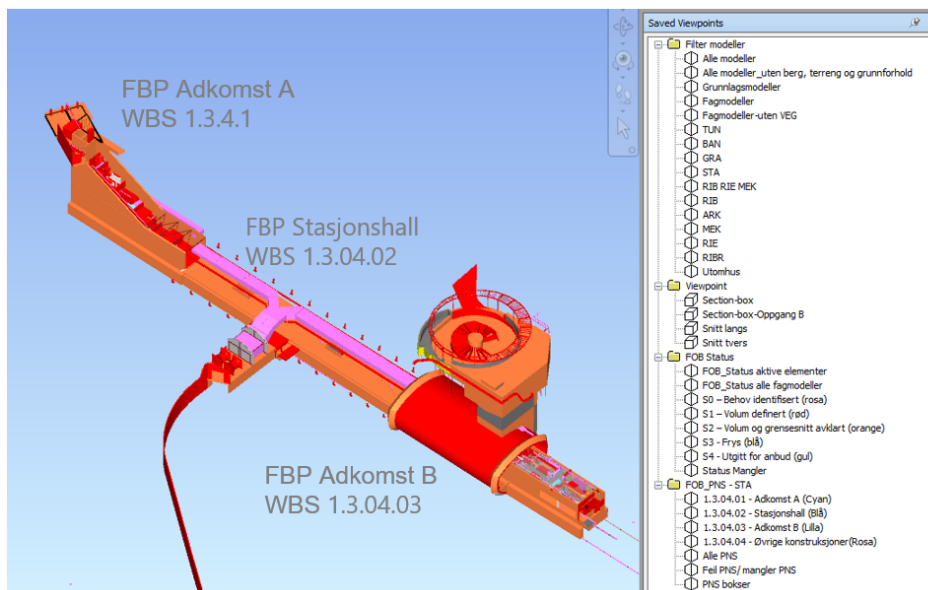
We have shown project managers colourful sections of our BIM models for years, but when we in addition could give them pie charts presenting the same information in a different way, the mood really changed. Appearantly project managers just love pie charts!

Using Properties + in Navisworks, BIM coordinators of each object creates .csv files containing common parameters on a weekly basis. The .csv files are used as datasets in Power BI, where we can easily update and distribute dashboards to everyone. The picture is showing how a dashboard of an object looks like.
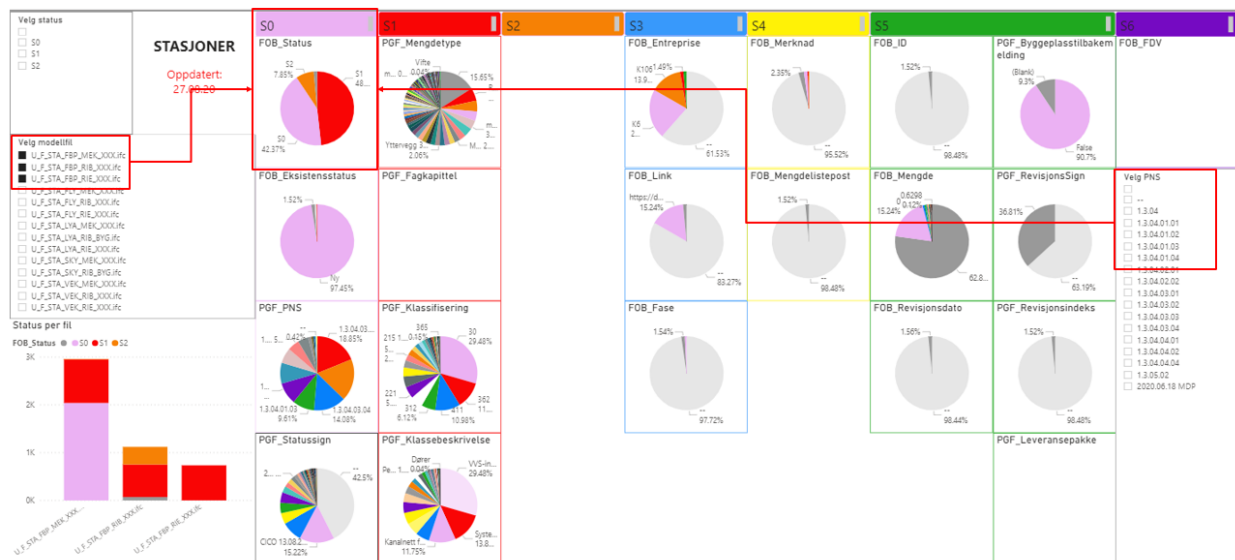
Slicers on Status, model and WBS allows us to narrow our search and compare actual progress with planned progress in the model status plan.

Other technologies (VR/Gamification)

Up until this point the use of VR and Gamification in PGF has been just short tests. Amongst one of the architects VR is frequently used for collaboration and coordination. The group A-Lab and Zaha-Hadid use Vrex for this on a regular basis due to split-location.

In PGF we have tested som VR in both Revizto, VRex and Twinmotion. Twinmotion was used in a case where we had visitors from High School.

Figure 55: VR with Twinmotion and HTC Vive

Both gamification and VR is something we will address more in the future. We do need to have a higher model maturity before we transfer the models into a gaming environment, or it would be to much work to make it "pretty".

The use of gamification could be scenarios like:
- Evacuation of train or station in an emergency for instance fire.
- Training of personnel operating the train
- Different tests of universal design. How do you get around in a wheel chair?
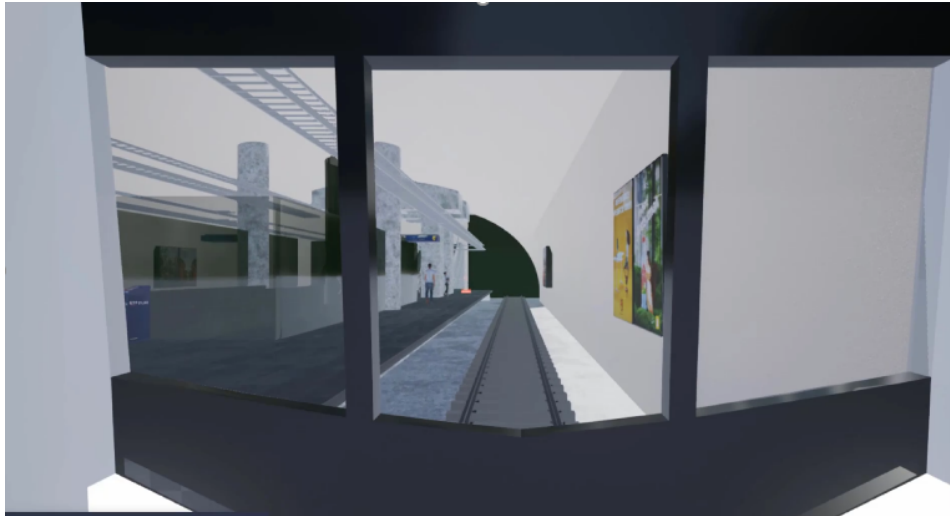
Figure 56: Gamification and VR with Unreal Engine

The future …

The first Contracts are starting up physical these days. We have already received some 3D scans from the contractor. Main focus for the coming years will be:

- Continue to feed the construction site with buildable BIM
- Update our design with "as-built" data both geometry and information
- Find ways to connect BIM with sensors
- Create a "digital twin" suitable for operation and maintance
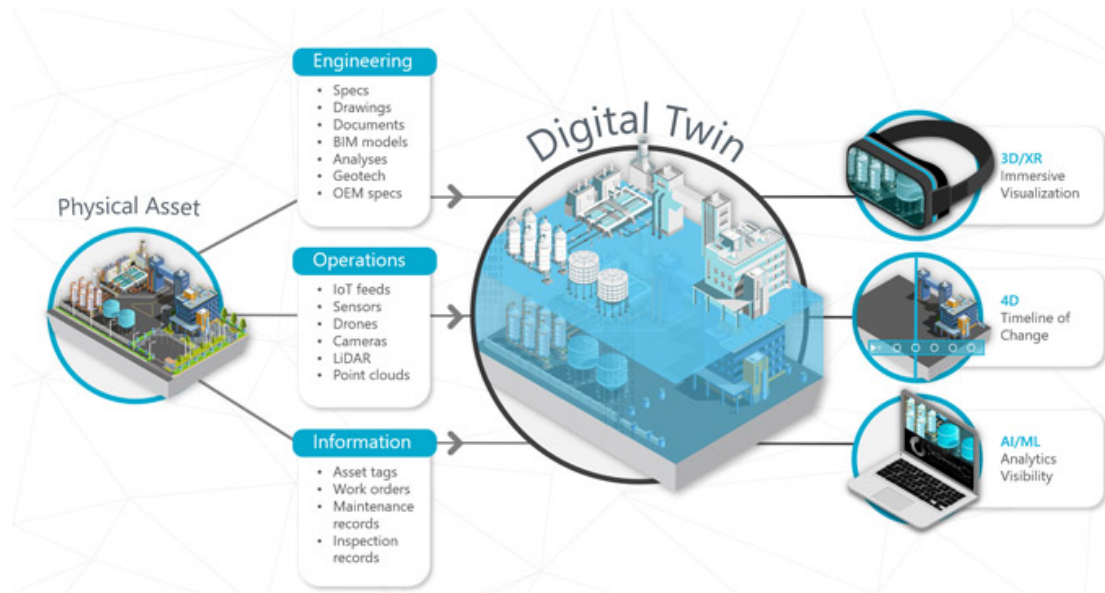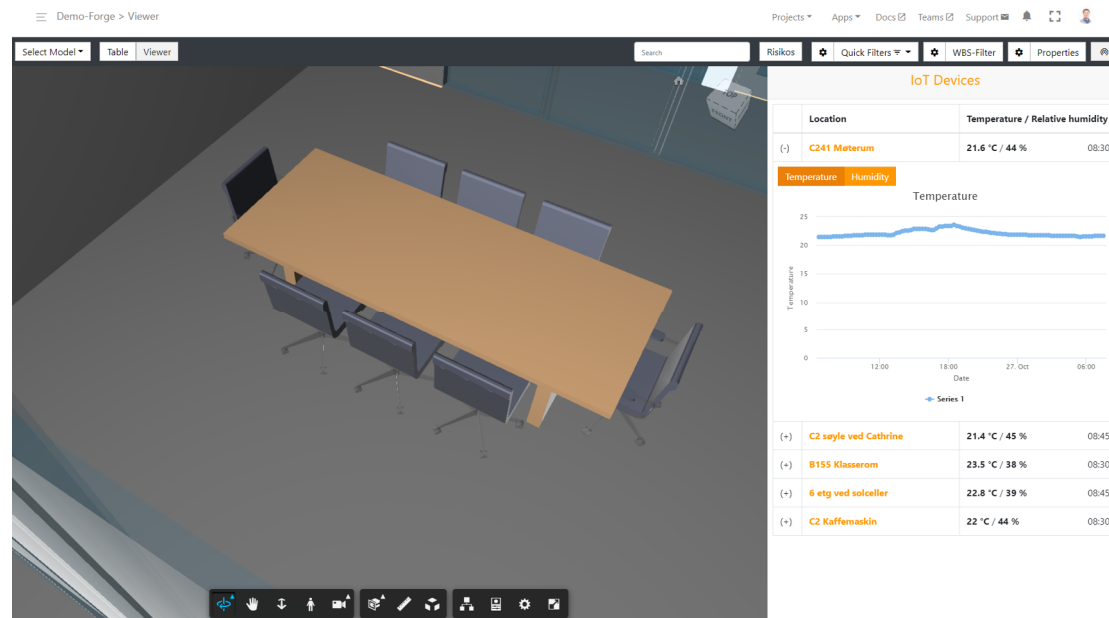

Figure 57: Curtesy of Bentley (image from web)

Figure 58: MCApps IoT, our inhous app based on Autodesk Forge – BIM connected to sensor