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

Cecilie Irgens and Magne Ganz
Digital Collaboration Manager | BIM Development leader
Agenda

• Project intro
• Common data environment
• BIM processes
• Applied BIM and Open BIM
• 4D and 5D
• Model based execution
• Automation
• Involve the whole organisation
About The Speaker

Cecilie Irgens | Digital Collaboration

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.
About The Speaker

Magne Ganz | BIM-Specialist

Magne 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 only with VDC and BIM the last 9 years, gives Magne the perfect background for contribution to Digital Collaboration and BIM-approach to this mega metro project.
Project Intro
Welcome to Oslo, Norway
Fornebubanen - Project Intro

- New metro line
- From city center to outer suburb in 12 minutes
- 8 departures per hour
- 8000 passengers per hour vs 3000 today (bus)
- Largest metro project in Oslo in 20 years
- Project owner: Oslo municipality agency Fornebubanen

Link to video
Project Scope

Build an 8.2 km tunnel, with 6 stations and technical infrastructure along its path

Client: Oslo municipality agency Fornebubanen (FOB)

Construction period: 2020-2027

Total cost: 16.2 billion NOK / 1.8 billion USD / 1.6 billion Euro
The Tunnel

The path is not straight in any direction.
6 Stations + Operational and Maintenance Base

The stations have different expressions, varies in size, shape and function.
Technical Infrastructure

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 within the same area.
- Approx 2 million m³ of rock, soil and sludge is to be removed
- Complex stakeholder structure
- The project scope is gigantic – it's a mega metro project!
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.
Design Team
Design Team

- PG Fornebubanen (PGF)
- Joint Venture of Multiconsult and COWI
- 383 engineers, controllers and project/design managers
- 12 disciplines
Interdisciplinary functions are embracing the core design team

Ensure uniform methodology in the assignment

Digital Collaboration team

Organization and Why
Digital collaboration team

The function of the digital collaboration team is to standardize work tasks and processes, automate time thieves and implement processes and technology.

The work of the digital collaboration team involves:

- **Develop and maintain**
  - Project Execution Plan
  - BIM Framework
  - Script, addins and apps

- **Support work and processes involving**
  - BIM
  - GIS
  - Basemaps
  - ICE
  - Cloud solutions / databases

- **Identify and lead digital innovation opportunities**
- **For all of the above, communicate and implement processes and technology**

The team consists of experts in BIM, GIS, VDC/Lean, R&D, methodology and technology.
Common Data Environment
Design Software In Use

- Civil 3D
- Revit
- Tekla
- NovaPoint
- Architectural
- Structure
- Geotechnical structures
- HVAC
- Electrical
- Fire
- Acoustic
Dataflow Diagram

Dataflow diagram – Typical Station
CDE – Common Data Environment
Additional Services

BIM Collab – BIM issue Management

dRofus – BIM information management

PIMS – The client’s construction management system
Workflow and Folder Structure

Design basis – existing situation – reality capture – survey data

Design basis models – models based on data captured

Design models – Work-in-progress

Design models – deliveries – exported models (IFC, DWG, NWC, FBX)

Container models – collection of discipline models (a grouping - nwd)

Coordination models – The models commonly used / viewed in meetings, at construction site etc.

Drawings
## Permissions Overview

<table>
<thead>
<tr>
<th>PGF-Roles</th>
<th>Client</th>
<th>Architects</th>
<th>External stakeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role 1</td>
<td>Access</td>
<td>Read</td>
<td>View + Download</td>
</tr>
<tr>
<td>Role 2</td>
<td>Read</td>
<td>Write</td>
<td>View + Download + Upload</td>
</tr>
<tr>
<td>Role 3</td>
<td>Write</td>
<td>Edit</td>
<td>View + Download + Upload + Edit</td>
</tr>
<tr>
<td>Role 4</td>
<td>Read</td>
<td>Read</td>
<td>View + Download + Upload + Edit + Control</td>
</tr>
</tbody>
</table>

**Legend:**
- **NO ACCESS**
- **View**
- **Download**
- **Upload**
- **View + Download**
- **Upload + Edit**
- **View + Download + Upload + Edit**
- **View + Download + Upload + Edit + Control**
Permissions settings in BIM 360
BIM Framework

BIM strategy
• The goals for use of BIM and related processes
• The effect of reaching those goals

BIM execution plan
• Roles and responsibilities
• Overall guidelines and process diagrams

Digital production manual
• Specific requirements
• Software specific procedures, checklists and guides to fulfil the requirements
BIM Strategy Highlights

“BIM is the key information element in our collaboration”

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

“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.”

“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 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 for Design

Describes in general how to achieve the goals in the BIM Strategy

- **BIM Framework**
  - BIM Strategy
  - BIM Execution plan

- **Roles and responsibility**
  - Client Organization
  - Design Team Organization

- **Way of work**
  - WBS
  - ICE
  - Last planner

- **CDE and file formats**
  - Data flow
  - Information security
  - Design tools

- **Model requirements**
  - Principles of model-based deliveries
  - Model maturity
  - Model information

- **5D - BIM, Quantity Takeoff and Cost**

- **4D – BIM and Construction Scheduling**
The digital production manual goes into detail of all BIM requirements. Software specific procedures are created as separate documents for each topic.

- BIM organization
  - BIM roles
  - BIM responsible per discipline and coordination model
- Basis data and basis data responsible
- Software and software responsible
- Common data environment
- Collaboration platforms
- 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 - WBS
- 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
BIM Execution Plan for Construction

- The hierarchy of the models
  - Models, detail models and drawings
  - Model maturity - element status
  - Model naming
  - Model information

- Models in the tender phase
- Models in the construction phase
  - Work packages
  - Delivery routines
  - Revision management

- Contractor requirements
  - Software and equipment
  - As-built capture
    - Laser scan
    - Survey
  - Design by supplier - requirements

Describes how BIM is utilised during construction instead of traditional drawings. It also sets demands and requirements for the Contractor regarding BIM knowledge, survey data and how to collect and deliver “as-built” data back to the design team.
The Greater Purpose of Metadata

Structure, Inform and Communicate
Q: How do you eat an elephant?
A: Bit by bit -> WBS

Q: Where are my model elements located?
A: Left front foot -> WBS

Successfully implementation of WBS in BIM is when WBS is also location oriented, so the “where is it?” can be visualized in the BIM.
Model Element Design Status – “Are you ready?”

Communication of model maturity is important. It help us understand how the element can be treated.

What is reliable data and are we according to plan? Are you ready?
- For coordination
- For tender
- For construction

In this project we use model element status to communicate “readiness”.

<table>
<thead>
<tr>
<th>Status Code</th>
<th>Color</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>S0</td>
<td></td>
<td>Identified</td>
</tr>
<tr>
<td>S1</td>
<td></td>
<td>Preliminary</td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td>Ready for coordination</td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td>Freeze</td>
</tr>
<tr>
<td>S4</td>
<td></td>
<td>Ready for bidding</td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td>Ready for production</td>
</tr>
<tr>
<td>S6</td>
<td></td>
<td>As built</td>
</tr>
</tbody>
</table>

- **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.

- **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.

- **Freeze**
  - Geometry: Issues found in coordination are corrected. Model element has final geometry and positioning. Further 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.

- **Ready for bidding**
  - 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: OA as described by procedure for BIM delivery.

- **Ready for production**
  - 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.

- **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.
Classification – “What?”

The purpose of classification codes is to group model elements of same kind. This is so software downstream for quantity estimation, cost calculation and 4D simulation easily can sort the elements based on “what it is”.

![Classification Codes Example](image-url)
Applied BIM and OpenBIM
Model and File Format Overview

1. Coordination model
   (Includes also design basis models, terrain, rock surface, existing buildings etc.)

2. Work packages / Container models
   Solibri and/or NavisWorks

3. Discipline Model Deliveries

4. Design Models – Work in progress
   (Not a delivery, unless needed for design by supplier)

5. Special formats – Separate export on request
Model Coordination

For everyday coordination both Navisworks and Solibri are in use. In order to have a manageable file size of coordination models, they are divided per station:

MAJ – Majorstua
SKY – Skøyen
VEK – Vækerø
LYA – Lysaker
FBP – Fornebuporten
FLY – Flytårnet
FBU – Fornebu station and base
TUN-BAN – Coordination model for the whole tunnel with focus on tunnel and rail disciplines.
NavisWorks and Solibri

NavisWorks Manage:
Pros:
• Robust 3D Viewer for large models
• Can show textures (i.e. terrain with orthophoto)
• FileReader for most formats
Cons:
• Not ideal with OpenBIM (slow and has some errors)
• NWC export from Revit does not have User defined Psets
• Does not manage information as dynamic as Solibri
• Maintanence of appearance override and Saved views are manual

Solibri Office:
Pros:
• Reads OpenBIM (IFC) very good
• Great with information (Classifications and ITO’s)
• Customizable Rules and Rulesets, not only clash detection
Cons:
• Does not read dwg and fbx
• Can not publish to web viewer
Her is a generic time schedule or workflow between two milestones.

- Milestone in this project is identified as a **Quality Level**.
- Each Quality Level have specific demands to model elements of every discipline regarding status.
- Quality Level is accepted or denied through a gate review.

Model coordination is carried out as a continuous process with coordination meetings and issue management at steps defined by the design manager in between two milestones.
Rules and Clash Detection

In Solibri clash checking rules are customized to check:

• Discipline X vs Discipline Y
• Per WBS-location
• Only Elements with Status S2 and above.

This is done through a combination of Classification Groups and Rule Parameters.
Clash Check and Visual Control

In Navisworks we can run clash check on disciplines not able to deliver IFC.

Navisworks is also the software used for visual control of the coordination models.

Example: Water and sewer (dwg) vs Structure (IFC)
• Identified clashes and other issues are synchronized to BIMCollab Cloud
• The person assigned to the issue can sync the issue-information to his/her design software and fix it.
• BIMCollab have add-in (BCF Manager) for all the design and coordination software involved
• It is easy to keep track of every issue
Room Data Base and Asset Management - dRofus
Room Data Base and Requirements

Requirements for all rooms in the stations are managed in a database.

- One database for the whole project subdivided into projects per station
- Similar rooms inherit their requirements from template rooms.
- Key data like room-ID, Number, Name and Area are synchronized with Revit
Asset data is synchronized between Revit and the dRofus database:

- There are more data connected to Door (and other Items) Types / Instances, than what is manageable to handle within Revit
- A database where users are invited and grouped by access rights helps a great deal to:
  - keep track of requirements,
  - standardize Items
  - collect information for Operation and Maintenance
4D and 5D – Time and Cost
Construction Visualisation – “Semi-4D”

With use of Infraworks and the concept proposals used as phases
Construction visualization – “semi-4D”

With use of Infraworks and the concept proposals used as phases
4D – Construction Simulation

Model elements with their WBS-Code are matched with tasks and processes in the schedule with their WBS-Code.

The result is a 4D simulation of the construction sequence.
4D-Video from Contract K4

MGA: Klipper inn videoer etterpå i Camtasia, så Powepointen ikke blir så stor å jobbe med.
5D – Cost calculation

BIM
• WBS
• Classification
• Type
• Quantities

OpenBIM
• IFC
• PropertySets
• Properties
• Values

ISY Calculus
• Import IFC
• Config File
• Recipe

Results
• Cost
• CO2
• LCC
Model elements

Recipe database

Receipe

Cost Sum

Viewer
Cost, LCC and Co2 Model Based Approach
Model Based Execution
Customised Models

Models are customized for the task of execution:

- Georeferenced discipline models (Euref 89 NTM)
- Information: Contact, WBS, Process codes, quantities and more grouped into Property Sets
- General arrangement model
- Detail section model
- Customized Coordination model per Contract with search sets and saved views
Possible Use of “New” Technology

It is very much up to the contractor to make the most out of the model-based approach in execution:

- Machine guiding (GPS) for excavation, piling and drilling
- AR and/or VR for the craftsmen at site
- Other use of handheld devices
Automation of Tasks
GIS Web Portal for order Basis Data – Reality Capture

- Web based system to keep track of:
  - All data captures that have been collected
  - Easy to create a new order for reality capture
    - Draw a polygon
    - Enter what kind of data needed
Grasshopper and Tekla for Tunnel Structure

With the help of Grasshopper and parameter controlled cross sections in Tekla, tunnel structure is generated with the input of

- Rail centerlines (north bound and south bound)
- Geological information (Excel)

This saves around 60% of time used and creates a more accurate design.
Dynamo and Civil 3D are used for different modeling tasks in the geology discipline:

- Visualisation of drilling samples
- Modelling weakness zones in rock
- Modelling rock anchoring

Being able to visualise this information has a direct effect on project cost, when choosing rail center line and placing stations.
Dynamo and Revit

WBS-Coding of elements

Jetpiles extend to surface

Model 3D escape zones along rail path

BIM’ification of rail sleepers

Over 30 Dynamo scripts in the project. Here are some..
Automatic Model File List with Attributes

BIM 360 Docs with default and custom attributes

A web app based on Autodesk Forge that filters, sorts and exports

The exported model list as Excel
The ‘NSync

Not all software can use BIM 360 Docs or Design as an integrated workflow.

For example:

- Navisworks
- Tekla
- Solibri
- Novapoint
- Discipline specific software

Therefore we synchronize files from BIM 360 to the PGF-file server. The file server is mapped to the directory N: -> ‘NSync
Navisworks Batch Utility and Solibri Autorun

Navisworks Batch Utility combine discipline models (dwg, IFC and FBX) into Container models nwd-files, that are used in the Coordination models.

Solibri Autorun can load/update IFC-files, load Classifications, Rulesets, Run checker, create Presentation and save the coordination model.
Task Scheduler

With a little help from our friend ‘Nsync and Windows Task Scheduler both the 360 Sync, Navisworks Batch Utility and Solibri Autorun is executed outside office hours.

Synchronize files every night.

New Containers and Solibri models every Monday.

<- The real N'sync
Involve the whole organization
How to get to: «That’s the way we do things here»

- Change management
- Communication

Non-stop work in progress

Kübler-Ross model / Five stages of grief

How people react when introducing new methodology and software?
Project Execution Model (PEM)

**QL0:** Basis
**QL1:** Design premises and layout
**QL2:** Basic premises, outer volumes and interface freeze
**QL3:** Interdisciplinary detailing freeze
**QL4:** Tender
**QL5:** Work documentation ready
**QL6:** As built
**QL7:** Ready for operation
Planning and execution

**Project Execution Model**

**ICE-sessions**
- Strict agenda
- Correct resources
- Preparations required

**Last Planner System (LPS)**
- Used for detailed scheduling
- Temporary digital solution in excel on BIM360

**Preferred practice**

**Covid-19 style**
Viewers for everyone

- Navisworks
- Web GIS

BIM is the key information element in our collaboration
- We use a simple user interface with easy accessibility
- There is a low user threshold, and necessary training is provided to everyone in the project
- A digital model is actively used in communication with the project’s stakeholders

Vision

«The metro of the future is created by innovative collaboration»

Goals and success criteria for collaboration

Collaboration generates innovation
- We work actively with innovation in the project through a defined innovation process and our own workshops
- It is safe to put forward proposals
- We focus on efficiency and think "Lean" in solution development and design

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Insight and recognition of each other’s roles and competencies will permeate the collaboration
- We work integrated and interdisciplinary
- The project organization and the various roles are clearly defined
- We are good at giving and receiving constructive feedback
Overview - Progress at a glance
Reported status in all coordination models
Compare and control
The future
The future

• BIM for requirements (Fire, acoustics, safety, environment)
• Welcome entrepreneurs – Feedback time: fruitful collaboration or learning by doing?
• Gamification (includes VR)
  o Evacuation in emergency situation
  o Testrun of track
  o Universal design
• Facility Management (using BIM-data in operations)
• Digital twin
Thank you!