AUTODESK UNIVERSITY

TR21354

# BIM Success for InterCity Railway

# Setting the Standard for Model-Based Delivery

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## Learning Objectives

- Learn why the mandate for model-based project delivery is changing the future of railway projects in the Nordics
- Learn the necessary requirements for effective BIM-model-based delivery mandated by the governmental agency in charge of the project
- Understand the benefits of moving away from traditional delivery to model-based delivery
- Witness a successful project from the eyes of a stakeholder, and see how you would use this in your business

## Description

The Norwegian infrastructure manager, Jernbaneverket (JBV) has set a new standard for model-based project delivery. JBV now requires that all subject disciplines deliver models—at all levels of detail—and that all construction will be done using these models.
In this class the Building Information Modeling (BIM) manager for Norway's InterCity Project will discuss the benefits and lessons learned, and will provide a demonstration of this concept using InterCity as the example. The InterCity-project is a complex 250-kilometer alignment of high-speed double-track railway through 22 towns and cities. Adding to the complexity, the project was split into sections and awarded to different consultants, which required keen coordination and collaboration under the direction of the Railway Administration. An agnostic approach to software and model creation is used—because it is only the resulting model that matters most to the Administration.

## Your AU Expert(s)

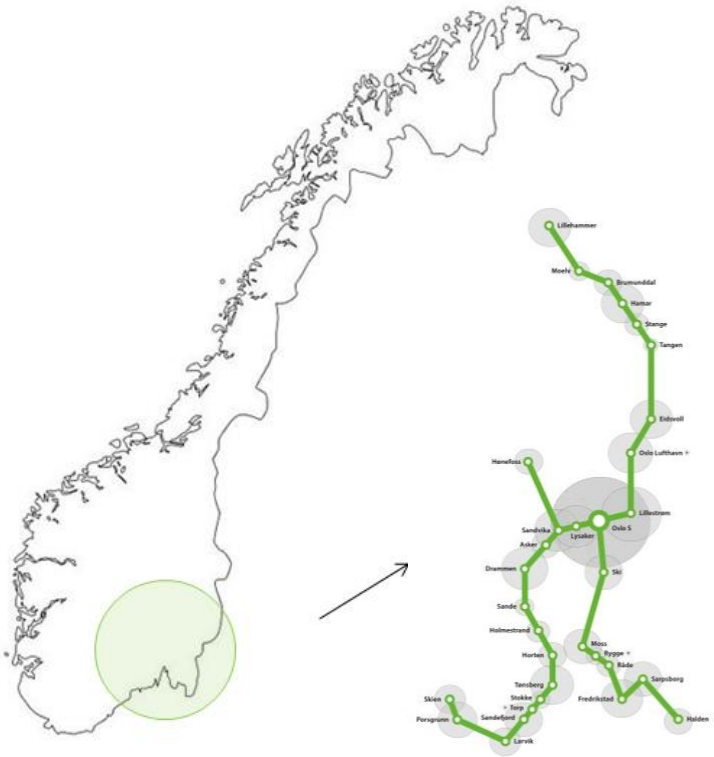
Kristin Lysebo is the Building Information Modeling (BIM) deliverables manager for the InterCity-project in the Norwegian Railway Administration, and she is a key leader in the Nordics for BIM standardizations and initiatives and infrastructure. She is a firm believer in common standards for road and railway modeling, and in the benefits of model-based projects. Prior to her work with the Railway Administration, she was an infrastructure engineer and training manager at a large infrastructure software company in Norway for more than 20 years.

The Norwegian Railway Infrastructure Managers, Jernbaneverket (JBV) is the government office for all railway activities in Norway, including building and maintaining all railway infrastructure.

## Background for the InterCity-project

Challenges:
- Strong growth in population expected in Oslo area
- Fastest growing capital in Europe
- Affliction in the city areas
- Little space for roads

Solution:
- Modern railway and wise use of hubs

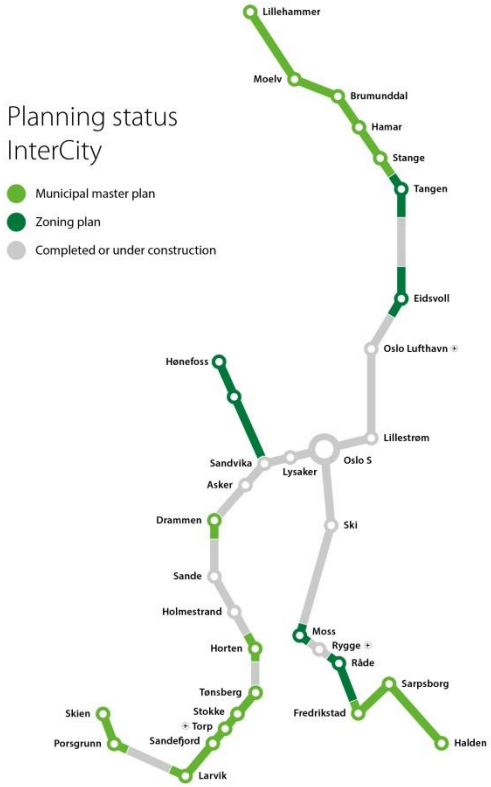



*THE INTERCITY-PROJECT IN NORWAY AND POPULATION IN MAJOR CITIES*

- The InterCity strategy was developed in the early 1990s. Some sections are finished, and some under construction. 270 kilometers double track railway and 22 new or changed station areas remains.
- Concept study for the InterCity corridors was completed 2012. Success criteria are: centrally located stations and development of surrounding areas, comprehensive service upgrades, not small improvements of existing services; much shorter journey times, frequent services, high punctuality levels, predictability
    - Investment costs: Approximately € 12.5 billion
    - National Transport Plan 2014-23 approved by Parliament, June 2013.
    - InterCity-project organization established

## Plan phases

The InterCity-project follows the Norwegian planning law that defines three major planning levels, and that the municipalities have authority to approve the plans. Some subprojects of the InterCity-project go through two or three municipalities, which give an added complexity.




The InterCity-project is divided into seven subprojects. The first four subprojects is planned to complete in 2024, and the rest in 2030.

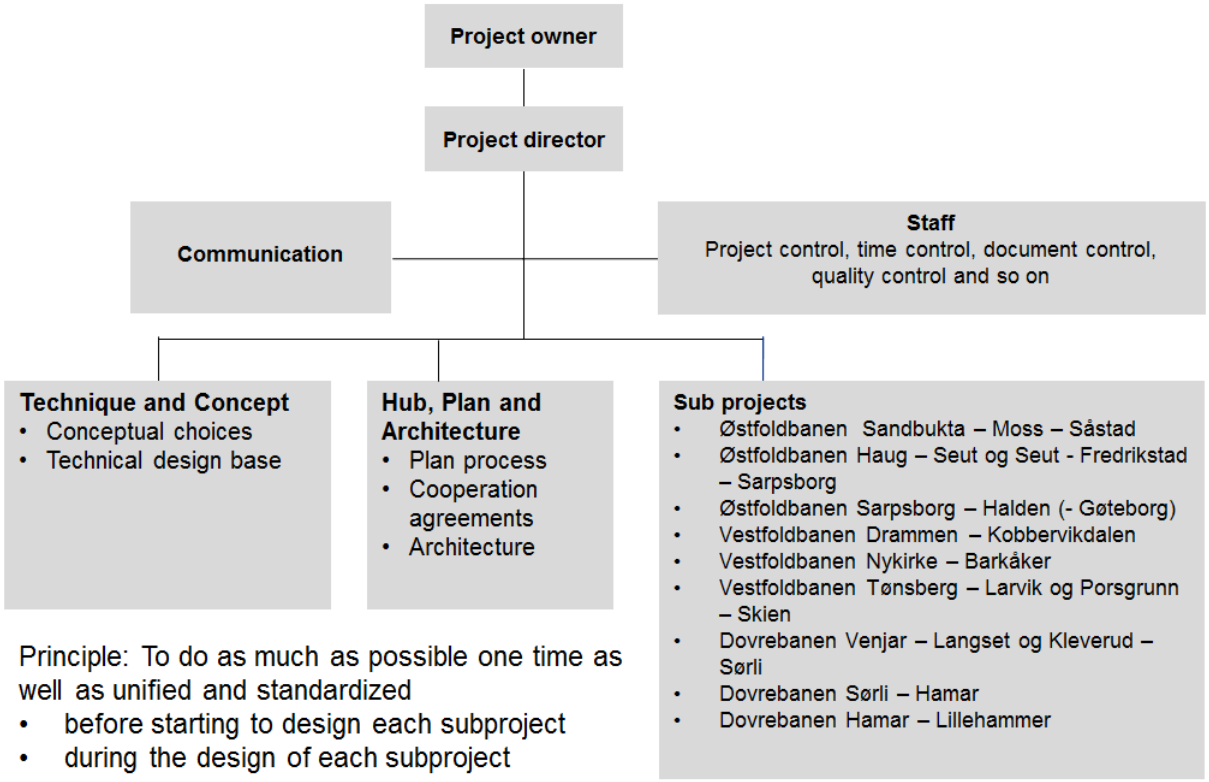
All seven subprojects are awarded to major Norwegian and Nordic consultant companies based on tenders. The contracts is open in regards to hours but are fixed on hourly rates.

## The InterCity-project organization

The InterCity-project is separate project organization directly under the assistant railway director, and today employs about 65 persons.

In addition to the administration and communication departments, each of the seven subprojects has a team of 3-7 persons with a total of 24.

Two larger departments, Technique and Concept with Hub, Plan and Architecture, employ about 25 persons and include lead personnel for all railway technical disciplines. These two departments work for all subproject to standardize all technical and practical requirements – to help make the decision process for each project easier.




## 3D modelling in JBV

JBV approved a handbook for all digital projects in 2012. This handbook sets the requirement for all model based projects as well as drawings. The handbook:

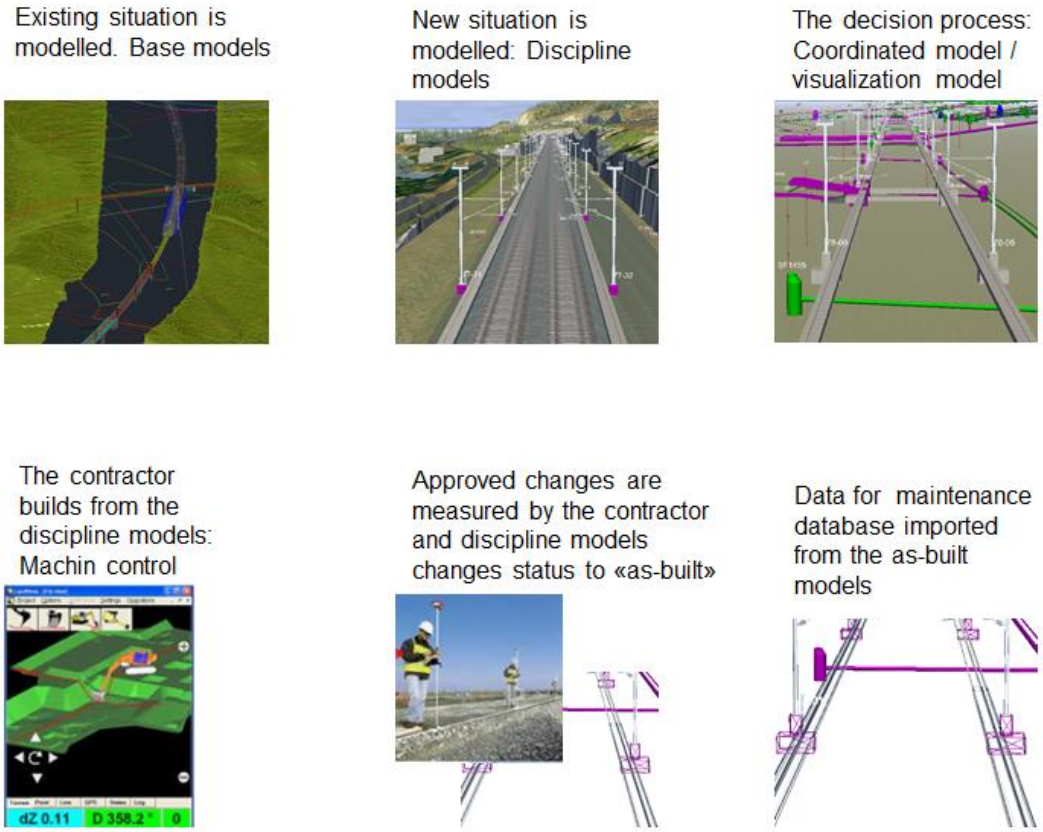
- do not specify witch programs to use, but the primary format for all models is DWG format
- states the types of models to be used and the contents of each type of model

that the coordinated model and the presentation model must be in a license free software defines all object is described both as a volume object with the stake out data as points, lines or volumes

- states that all object are general, none supplier specific in early plan phases. As soon as a supplier is chosen in the construction phase all object are redesigned with the specific objects and the inter discipline conflict control is updated

- has resulted in a 3D object library that is open for all
- defines that all existing data is modelled as base models, data both above and below the ground level
- states that all disciplines shall model their new objects in 3D
- states that the coordinated model references both the base models and the discipline models and is updated with project defined intervals. This model is the base for all conflict control between disciplines. The primary goal is to fix all inter discipline conflicts before we start building the project.
- states that a presentation model is based on the coordinated model. This model is primary used for visualization and communication within the project organization and with all external stakeholders in the project.
- states that the contractor must use the discipline models to export stake out date directly to machines and updates the models to as-built status

JBV is currently working on a 3D/BIM strategy for all future projects.




*THE WORKFLOW IN MODEL BASED PROJECTS*

## Motivation for using 3D modelling in the InterCity-project

Our main motivation for using 3D models in the InterCity-project is:

- Better control and quality will give us more cost effective projects
- Better focus on information for the existing situation in an early plan level makes it easy to re-use and enrich information through increased demands for level of detail all plan level
- Sharing data and knowledge with everyone within the project organization and all external stake holders
- Easier to visualize and highlight inter discipline problems and challenges for everyone involved in the project
- Building competence in JBV, and be a leading organization for standardizing model based project and work flow in infrastructure projects

## 3D modelling in the InterCity-project

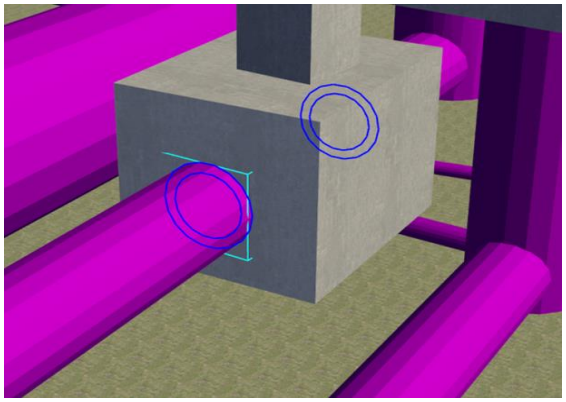
The InterCity-project has taken the principles in the handbook, gone a few steps further and has defined and overall 3D strategy.

- All subprojects in the InterCity-project shall be planned and designed in 3D from the earliest plan level to the completed built projects using the handbook “Håndbok digital planlegging i Jernbaneverket» and the «BIM manual for the InterCity-project»
- Discipline models and a coordinated model is created adapted to the necessary detail level for each plan level
- The 3D models will seamlessly go from one plan level to the next while enriching and updating the detail levels of each base and discipline model
- The contractor will build the project using the models, while updating the models to the state of as-built model
- The as-built model will be used to export all objects and lines to JBVs maintenance database and the technical archive for maintenance documentation

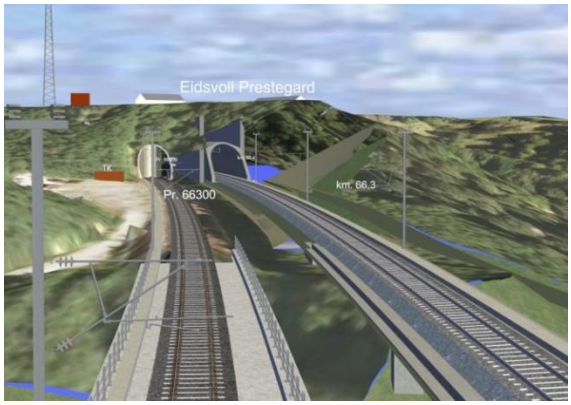
We have created a discipline reference group for BIM with participants from all the subprojects. Together we work to include all necessary specification and details we need to include models in all aspects of the project.

The types of models used in the InterCity-project are:

- The existing situation (terrain, infrastructure over and below the ground surface, sub surface layers as rock and soft clay) are modelled as base models
- All new objects, lines and volumes are modelled as discipline models. A discipline model includes all elements for that specific discipline. Each element is described as a volume object and stake out data as points, lines or volumes
- The coordinated model is a combination of the base models and the discipline models. This model is used for inter discipline conflict control and communication within the project organization.
- The presentation model is used for communication both within the project organization and with all extern stake holders
- The as-built model is a documentation of how the project was really built



*EXAMPLE OF A COORDINATED MODEL*




*EXAMPLE OF A PRESENTATION MODEL*

## The BIM manual for the InterCity-project

All details needed for the subprojects in the InterCity-project regard 3D/BIM is included in the BIM manual. This manual is supplied with news themes and details every time a need occurs.

The manual includes details regarding:

- Codes for each subproject
- File names, types of models and definition of models used
- Layer names for base models and discipline models
- Standardized code list for layer names and stake out data
- Coordinate reference system
- Level of detail for base models for each plan level
- Level of detail for discipline models for each plan level
- Descriptions and specifications for new models like environment, RAMS and so on
- Specifying which discipline model to produce for each plan level
- Defining the number of drawings for each discipline and plan level
- How to create and credit films and other presentations
- Delivery format for each discipline in regard to models and design tools

Base models

In the InterCity-project we have defined the following base models:

- Terrain surface
- Subsurface layers
- Constructions
- Water and sewer
- Cables
- Other existing objects
- Administrative information
- Existing tracks
- Themes

This is an example of the definition of some of our base models for two of the plan levels:

| Discipline | File name | Municipal plan | Zoning plan | Description |
|---|---|---|---|---|
| Terrain surface | NN_G_TERRENG_XX | Established based on 1 meter contours, road and rail lines and water lines.<br><br>Alternatively based on laser data with 2 point / m2. | Terrain surface from precious plan level supplied with land survey line or more accurate laser data according to requirement from JBV geodata department. | Must show existing terrain surface based on map data, laser data and/or land survey data.<br><br>Terrain surface as triangulated surface. |
| Sub surface | NN_G_GRUNN_XX | Assumed rock surface established from survey maps and geotechnical surveys. Must be updated through the plan level as more geotechnical survey data is available<br><br>Other sub surface layers, like soft clay, that can be established from the geotechnical survey. | Continuously updated with new geotechnical survey data. | Based on geological maps and reports.<br><br>Geotechnical survey, depth to rock surface, seismic survey and visual information. |
| Constructions | NN_G_KON _XX | All major constructions that may influence the choice of alternative. | All constructions that is conflicted by the project. | All relevant constructions as volume models.<br><br>Existing sub surface constructions, infrastructure, wells with in a ±50meters zone from the railway. |
| Water and Sewer | NN_G_VA_XX | All major water and sewer lines that may influence the choice of alternative. Example major water line to a municipality. | All water and sewer lines that is conflicted by the project. | Gather from municipalities and survey data. |

## Discipline models

In the InterCity-project we have defined the following types of base models:

- Track alignment
- Superstructure
- Sub structure
- Tele communication
- Catenary design
- Common electrical
- Signal
- Land acquisition
- Constructions
- Tunnels
- Tunnel geology
- Water and sewer
- Road
- Landscape
- Measures geology, geotechnics and hydrology
- Geo constructions
- RAMS
- SHA
- Plan
- Architecture / Hub
- Noise
- Inter Discipline planum

This is an example of the definition of some of our discipline models for two of the plan levels:

| Discipline | File name | Municipal plan | Zoning plan | Description |
|---|---|---|---|---|
| Track alignment | NN_F_SPOR_XX | Tracks<br>Switches from JBV object library. | As the previous plan level. | Alignments of all new tracks. Each track must have a separate file and track number. |
| Superstructure | NN_F_OB_XX | Correct widths and slopes. No need for the layers of superstructure. | All layers in the superstructure in addition to correct width and slopes. | Show all elements of ballast, tracks and sleepers. Also applies to switches. |
| Tele communication | NN_F_TELE_XX | Large tele communication stations / base stations requiring areas and access. | All tele communication areas, cable canals. Base station areas outside the railway area including access areas. | Tele communication equipment including internal and external cable canals. |

| | | | | |
|---|---|---|---|---|
| | | | Cabinets in tunnels. | |
| Low voltage | NN_F_LSPENNING_XX | | All objects requiring areas. | All low voltage objects and elements. Lighting, cabinets, warming equipment for switches with all cables. |
| Catenary design | NN_F_KL_XX | Presentation model: Catenary masts and foundation from JBV object library. Fixed distance of 60 meters. | All objects requiring areas. | Catenary design equipment. Masts, foundation, cables. |
| Inter discipline planum | NN_F_TRAUBUNN_XX | | | A common inter discipline model that shows the common lowest levels for the contractor will use for digging. Established in construction phase. |

NN is the subproject code

XX is free text

## Models and drawings

For each type of drawing we have gone through several discussion to ascertain which drawings the different participants in the project need in addition to models.

We have reduced the numbers and types of drawings.

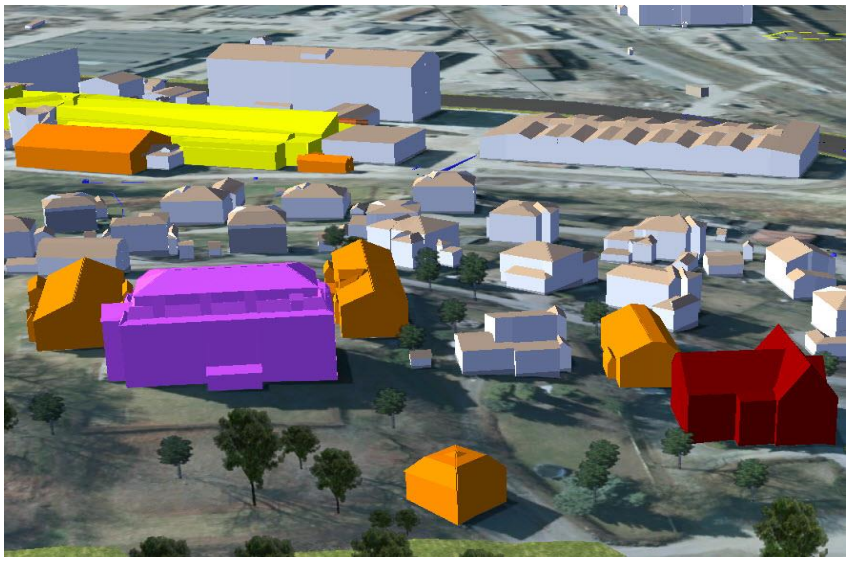
- Some drawings has been cut absolutely, one example is all cross sections drawings
- Other drawings is needed based on internal approval process in JBV, one example in schematic signal drawings
- Other drawings are still need because the information in the drawing is not implemented in the drawings. One example in plan- and profile drawings that shows radiuses, transition curves, cant, slope for vertical alignment. We will continue to influence software suppliers to include this information in the models
- Reducing the number of drawings will continue to have great focus in our project. We will continue to produce the drawings we need, but will challenge ours selves asking why we need certain drawings and we will look into some approval processes and see if changes can be made.

## New types of base models and discipline models

### Base models

The InterCity-project has in additional to physical disciplines set the standard for creating and delivering discipline models for non-technical disciplines such as several environmental themes. These are not traditional 3D disciplines and the themes is in some models presented as 2D data draped over the terrain surface. Examples are protected areas and building, flood analyses, areas with possible danger of landslides, endangers species and plants and so on.

*THE RESULT OF THE FLOOD ANALYSIS IN PRESENTED IN THE MODEL*



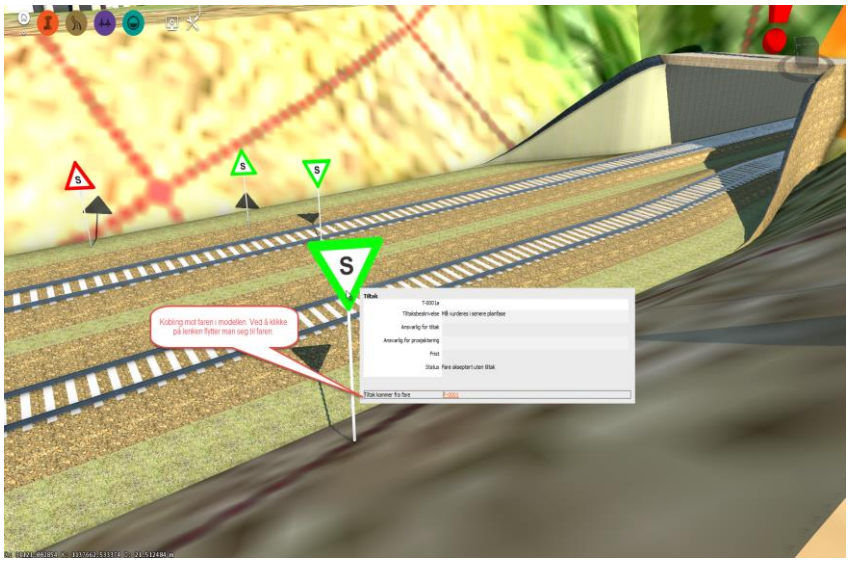
*EXAMPLE OF COLORS USED TO PRESENT CLASSIFICATION OF PROTECTED BUILDINGS*


*EXAMPLE SHOWING PROTECTED AREAS WITH STANDARDIZED COLORS DEPENDING ON CLASSIFICATION*

### New discipline models

The InterCity-project now also requires using models for none-physical object disciplines like RAMS.

The RAMS (Reliability, Availability, Maintainability, Safety) process in JBV is a clearly defined process analyzing all aspects of a project from the earlies plan phase clear through the maintenance phase. The result is defined actions points in an Excel spread sheet. These action points are now implemented in the 3D models with standard symbols with a link to the excel file. A large advantage is that the RAMS process now is visible to everyone in the projects organization.




*AN EXAMPLE OF RAMS PRESENTATION MODEL*

We have just started working on the requirements for modelling the SHA (Safety, Health and Work environment) discipline.

### Reference groups

Based on recommendation from earlier project a reference group for 3D was established quite early in the project. This reference group includes 3D discipline leaders from all the seven subprojects.

The most important job this group has done so far is implemented in the BIM manual for the InterCity-project. In addition the main goal it to share information and experience between the companies with open discussions on all topics regarding models.

We also challenge the software suppliers to make them prioritize the functions we miss in the different software we use.

The steps ahead is to specify new discipline models for land acquisition and construction completion, in addition to further specification of routines for inter discipline conflict control. Later on we start testing 4D and look at necessary drawings and documentation for the maintenance phase.

Other disciplines such as signals, catenary design, RAMS and environmental themes have established similar reference groups.

### The main focus so far for 3D in the InterCity-project

- Get all disciplines to deliver in 3D
- The models shall be a tool in the design process and will give all stake holders, project members and management a more complete overview of all challenges for the different alternatives and help in the design of alternative track solution
- Using the models continuously from one plan level to the next and enrich the level of detail in all disciplines. This ensures no loss of data.
- Standardized and unified models for a discipline across all subprojects.
- Efficiency in reducing the number of drawings will give faster design process, less errors and better inter discipline design.

### Our experiences so far

#### Challenges:

- It has been a challenge for some subprojects and disciplines to deliver base models as early as we have wished. One example is sub surface layers as rock and soft clay.
- All disciplines now delivers, also new none technical disciplines as environmental themes, RAMS and SHA. The advantage is that those disciplines are now literally visible to all other disciplines. This has given them more focus within the project organization and that has been useful in building inter discipline knowledge.
- We continue to focus on the principle that all models should at all time show the status of the project. A project manager can at all time open a coordinated model and see the status of each discipline. We don’t manipulate the models, if something is now completed it will show as an open area in the model. Normally the models are updated before each projects meeting. This has gotten better, but still needs focus.

- Some disciplines now deliver design in an earlier plan level that before. One example is sight to signals. This is now done on the municipal plan level instead of in the construction phase, and is used to assure the placement of tracks and switches.
- Agreeing on level of detail for each discipline for each plan phase
- Getting everyone to use models (project managers, discipline leaders and so on)
- Using models in every meeting both internal and external

### Advantages:

- Communication, especially in meeting with external stake holders. This is very important in all contact with properties owners and municipalities
- Gives us a better inter discipline concept
- Increased focus on base models and base information for design
- Reducing the numbers of drawings produced
- JBV now demands all data on both delivery format and original formats which gives us a great advantage in using the models as basis for tender documents and cost estimates
- The work on models in early plan phases will give us an direct cost effect in the building phase in conflict control, stake out data and building with machine control
- The consultants gives us positive feed back because the InterCity-project are very clear in our requirements. This pushed both the consultants and us in building competence and experience.

## Competence regarding 3D/BIM in JBV

Our competence department is planning to make a basic course for 3D/BIM. This course will be available to everyone in JBV. The InterCity-project is working with them to decide on the program and find the best qualified lecturers.

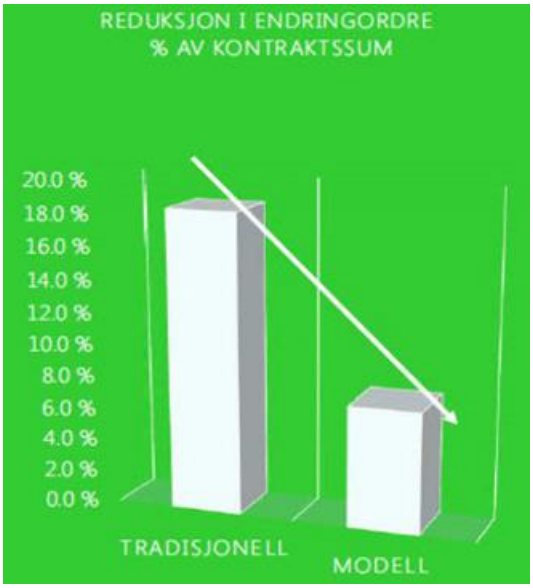
It is important that JBV work to share information and experience between departments and project. This work has already started, but need even more focus in the coming years.

Some consultants and contractors also need to build up more knowledge and experience in working with model based projects. One way JBV can contribute is with clear and concise contracts.

## Positive effects with model based projects

- The overall goal is better control, higher quality and fewer inter discipline conflicts – the overall goal is zero conflicts during the construction phase
- Modelled based projects will reduce the number of errors and missing information/ objects in the design basis. This will make it faster to build the project and reduce the cost
- Greater focus on the quality and detail of the information and objects in the base models, and specifically the sub surface models can reduce the number of unforeseen change orders during the building phase
- Avoiding outdated drawings by building directly from the models. Several infrastructure projects now build directly from the models with only a few drawings. In the joint project of E6 and Dovrebanen, the first part of the project was built using iPads and machine control and no drawings

The road administration (Vegdirektoratet) ran a survey a few years ago where they measured the number and size of change orders on drawing based projects and model based projects. What they found was a reduction on 11% from drawing based to model based projects. JBV has reason to believe we will find a similar trend on our projects.




*TRADISJONELL IS DRAWING BASED PROJECTS AND MODELL IS MODEL BASED PROJECTS.*

## Estimated cost reduction so far in the InterCity-project

- We control the requirements and level of details across all the subprojects.
  - Advantage: more effective engineering and same level of detail for subproject with the same plan level
- We evaluate and control the need of drawings in addition to the models for the different plan phases
  - The number of drawings is greatly reduced
  - We produce the drawings we need for internal control, but have dropped many types of drawings
  - Advantage: reduces unnecessary drawings which saves time and reduces cost. As an example a subproject in an municipal plan phase we reduces the number of drawings with 50%
- We control the delivery of project based data for each discipline.
  - Advantage: this ensures that the project have all the data in our technical archive when we transfer the project to the development departments in JBV or if we should wish to select a different consultant.

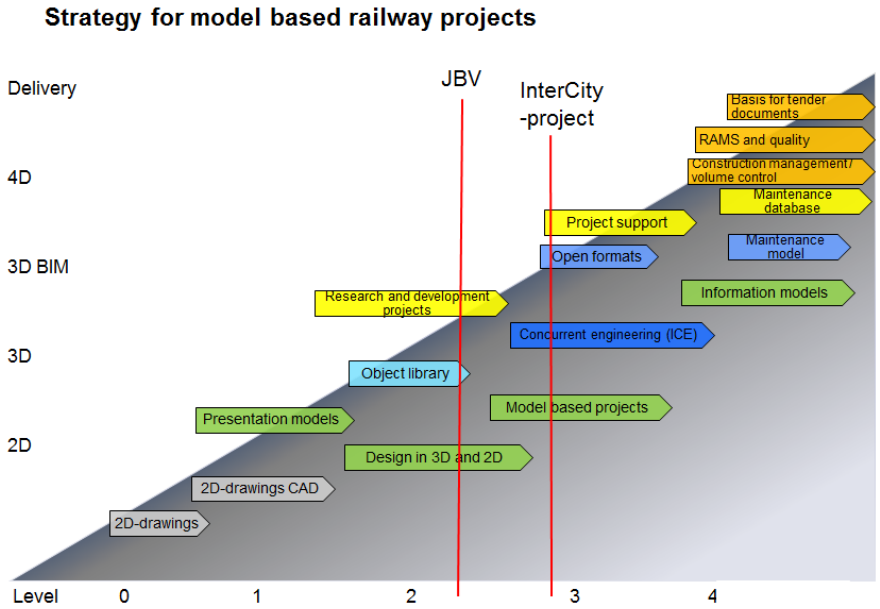
## On the track to full BIM

All the effects using 3D or BIM is not met yet. There is more effect to reap getting even more disciplines into models. Examples are more disciplines like:

- land acquisition
- quality control
- time estimates and control
- cost estimates
- inter discipline volume calculation for contractors and more….

In the next couple of years what will give the best effect is the work process of integrated concurrent engineering, a common handbook for road and railway in addition to Nordic BIM Collaboration.

On the track to complete BIM for infrastructure we need an open standard format similar to the IFC format for the building industry.




*THIS ILLUSTRATION SHOWS THE BIM DEVELOPMENT LEVELS AND WHERE JBV AND THE INTERCITY-PROJECT ARE TODAY*

## 3D research and development project in JBV

JBV has for the last four years had a research and development program for software design. This project has four parts.

- Design tool for 3D discipline
  - Catenary design – completed in 2015
  - Cable canals – completed in 2015
  - Signal – first version December 2016

- Export functions from as-built discipline models more directly to our maintenance database, Banedata. Today this is done manually in Excel. First version December 2016

- Developing a maintenance database for track alignment. This database will be connected to the main maintenance database. Test phase has started.

We are currently looking into the research and development program for the coming four years period.

## Integrated concurrent engineering

The work process in integrated concurrent engineering is new to infrastructure projects in Norway. In the start of 2016 JBV together with technical universities and several consultant companies has gotten a four years project for the public research department, Forskningsrådet. JBV is a part as we are using four of the subprojects in the InterCity-project as case studies.

Integrated concurrent engineering is defines as work sessions where complex inter discipline cased need to be solved, including all stake holders in the case. The work session need to be well plan, well defined and all involved must attend – also the decision makers. The major goal for a work session is to solve the problem, and make all necessary decisions during the work session.

The main goal of this project is to reduce the project calendar time by 50% and create a standardized process for integrated concurrent engineering in infrastructure projects.

*EXAMPLE OF A WORK SESSION ON THE SØRLI-BRUMUNDDAL PROJECT*

## Common modelling handbook for road and railway

We are currently in the process of revising our handbook, and that will complete later this autumn. At the same time we are discussing the possibility of a common handbook for both road and railway. The principles we use are very similar, and many disciplines like landscape, tunnels, constructions and so on are very much alike for both road and railway.

We hope to start the work on this in 2017.

### Nordic BIM collaboration

This is a new initiative that started in the end of 2015, and includes the BIM managers for road and railway public authorities in the four Nordic countries (Denmark, Sweden, Finland and Norway). It is an informal forum, we meet 2-3 times a year and our goal is to coordinate and help each other in all tasks regarding BIM. That includes contracts, open formats, education, standardization and so on.

### Is the anything we would have done different if we had started over?

In the early plan phase the major benefit in using models lays in communication as we visualize the alternatives, and the consequences of each alternative.

If we had started the InterCity-project again now we would clearly focus even more on getting the base models ready even earlier. Specifically the sub surface layers as rock and soft clay as well as the theme models for protected areas and endangered areas and species.  This is essential information in the decision process.

In addition we would demand even more clearly the use of models in every internal and external meeting, and focus even more on training project managers in using the models.