[CI226453]

Advanced collaboration and Cost Calculation with InfraWorks

[Øystein Knutsen Løvdal]
[Bane NOR – Norwegian Railway Administration]

[Arne Moe Lysaker]
[Norconsult AS]

Learning Objectives

- How does preliminary railway planning work in Norway?
- Why use BIM as a base for preliminary planning?
- Implementing costs in Infraworks.
- How to reach stakeholders and the young generation with your project using Infraworks, gamification and web design.

Description

This class will cover how InfraWorks software could be used for efficient planning, collaboration, and cost calculations. The class will give you insights from the consultant's perspective, as well as from the project owner. Bane NOR, the state-owned company responsible for the Norwegian national railway infrastructure, had a challenge: How could the industry change established workflows and be able to present cost estimates earlier in the plan process? How could they present the design to the public and be able to interact with stakeholders? Norconsult took the challenge, and we are here together with Bane NOR to show how scripting solves problems, how Bane NOR involves all the stakeholders and public by using web presentations, and how Norway will get more and better rail infrastructure than ever before.

Speaker(s)

Øystein Knutsen Løvdal are working for Bane NOR (The Norwegian Railway Infrastructure Managers) as engineering manager. He has a wide span of experience from preliminary planning to detailed projects. Øystein is currently working on the largest infrastructure project in Norway, the new Ringeriket railway- and highway lines.

Arne Moe Lysaker are working for Norconsult as a BIM-manager in the InterCity railway project Tønsberg – Larvik. He has experienced the shift from 2D-drawing based projects to advanced collaboration in BIM. Arne also led the group who tried to do something new in preliminary phase, showing the project to the world using Gamification and Web design.

Introduction

Bane NOR (The Norwegian Railway Infrastructure Managers) and consultant Norconsult has developed a demo version for part of the 40-kilometer Tønsberg-Larvik project by integrating cost estimation in Infraworks.

By combining Infraworks with cost estimation we will save money. Potentially a lot of money! With our experience in the lengthy traditional cost estimation process we needed and wanted to come up with a new way of working. The Tønsberg-Larvik project had already been designed in Infraworks, which is a decisive factor for both effective planning and communication with all internal and external stake holders in the project. The Infraworks model was ready, and all we need to do was to combine it with the manual cost spread sheet. The demo is for about 10 kilometers for one of three alternatives.

The solutions that were chosen was not done at the expense of any disciplines but was done in cooperation between the disciplines to find the best alternative and solutions. By easily visualizing the complete project in Infraworks, all disciplines saw and understood that a less costly solution could work. All disciplines including agriculture, the value of nature areas and ground conditions was included using interaction and cooperation and all disciplines got a better understanding of what their chosen design costs. The different disciplines challenged each other to a “competition” to find the best and less expensive alternative and solution.

With this demo version and a few meetings, we showed that the project could potentially save huge amounts of money on a 10-kilometer section. Bane NOR is planning and building 270 kilometers double track railway. The potential for savings is enormous!

It is important to emphasize that including cost estimation in Infraworks does not exclude cost estimation work sessions or the discipline knowledge of cost estimators. But it gives us a cost estimation from day one in the models. Easily and visual! In addition, the result is an Excel files that can be used as an input to the cost estimation work session. It is no longer necessary to start the work session using drawing to manually measure the length of each category of tunnels, bridges and tracks – that is already completed using cost estimation in Infraworks.

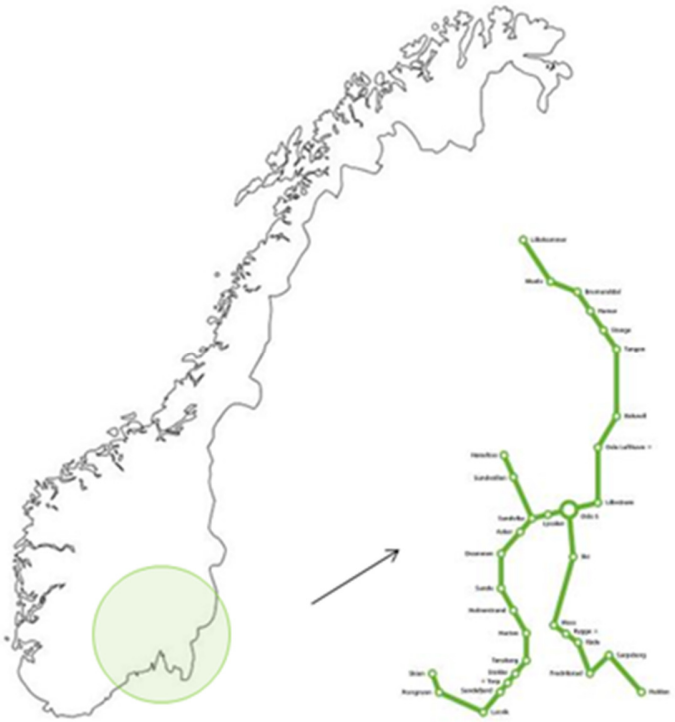
Preliminary railway planning in Norway

The Norwegian Railway Infrastructure Managers, Bane NOR 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

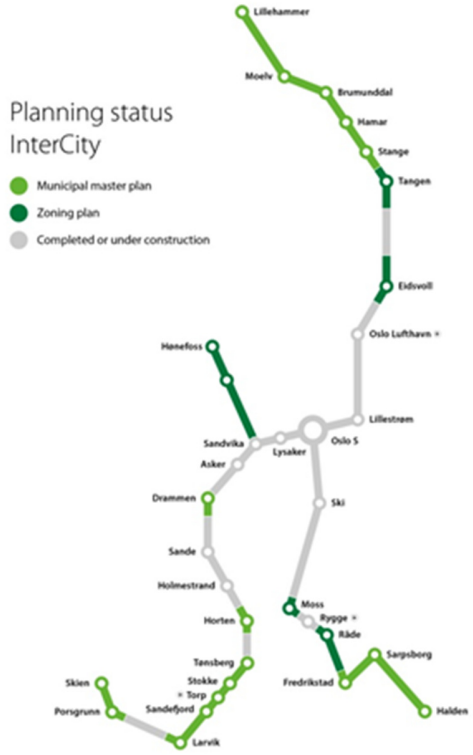


The InterCity-project in Norway and population in major cities

- 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 for the concept study was approximately 12.5 billion USD
- National Transport Plan 2018-29 approved by Parliament
- 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 eight subprojects. The first four subprojects are planned to complete in 2024, and the rest in 2034.

All eight subprojects are awarded to major Norwegian and Nordic consultant companies based on tenders. The contracts are open regarding hours but are fixed on hourly rates.

The Tønsberg – Larvik project

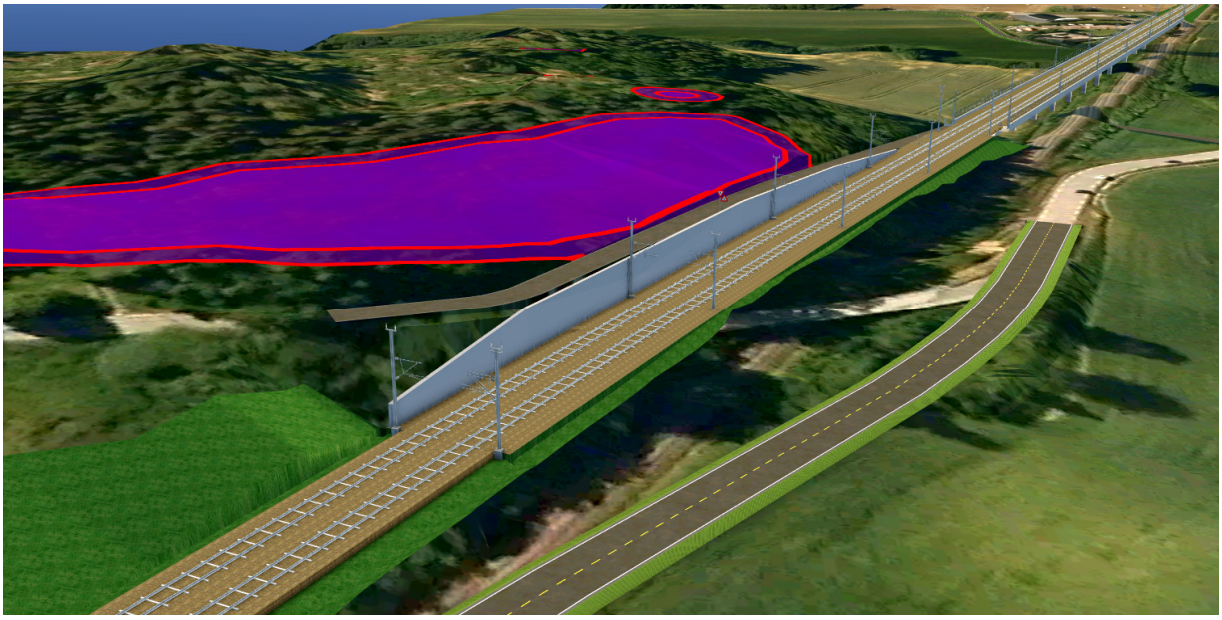
One of the larger sub projects is Tønsberg-Larvik. Approximately 40 kilometers long, the project is very complex as we need to build new stations in the center of four cities. The project is in an early plan phase and we seek the best alternative for placing the railway track between the four cities. In addition, the ground conditions are among the most challenging in all of Norway with large areas of marine clay. The project is cost estimated to about 3,7 billion $, which makes cost control essential but challenging. The project uses Autodesk Infraworks for modelling.

BIM as base for preliminary planning

The Tønsberg-Larvik project is as mentioned in an early plan phase and the building will not commence for about 5-6 years. Our main task is to design a project that is both socioeconomic sound and will influence the surroundings as little as possible.

Visualization is essential in creating understanding and accept for a project from both deciding authorities and other stake holders. For that reason, all projects within the InterCity project is designed in 3D models. All our projects are very complex, multi discipline projects. That demands that everyone in the project team must have an extensive understanding on how each discipline influences all other disciplines and surroundings. Using models reduces the number of drawings as well as a shorter approval time by deciding municipalities. Time and money are saved in every phase moving from drawing to complete visualization. The potential is years saved!

Infraworks is in our opinion an invaluable tool in this regard. With Infraworks as our base we have made films, animations, mounts for communications externally and accept for the chosen solution within our own organization.



Using a shared collaboration model with all disciplines represented enables everyone in the project to be informed at all time of the status. Here we see a picture from Infraworks showing cultural heritage areas (Purple), new double track line, concrete walls and new roads.

Implementing costs in Infraworks

The InterCity-project has high focus on good and effective planning processes as well as cost efficient solutions for a long project life span.

A major challenge in projects like this is the division of the planning processes and the cost estimation discipline. The means that the planners does not get information on what their chosen solution will cost. As the project is in an early plan phase we are evaluation several alternatives and traditional cost estimation is time consuming and complex and include many disciplines and as many as 10-15 persons in large cost estimation work sessions that may go on for 3 to 4 days. This means that the project organization has work on the different alternative up to six months before we know the cost of the different alternatives. That is too late in the process and cost a lot of time and money. We may have worked on alternatives that could be excluded earlier. But the worst is that good alternatives may never be considered due to the time-consuming cost estimation work process.

The cost estimation methods on projects in early plan phases Bane NOR uses a cost estimation method based on calculation the cost per meter for different categories. The categories are track railway on cut or fill, tunnels and bridges in addition to station areas. In additions the categories are divided into sub categories based on rural or city areas and ground conditions. A standard, but manual spread sheet in Excel is normally used for the calculation.

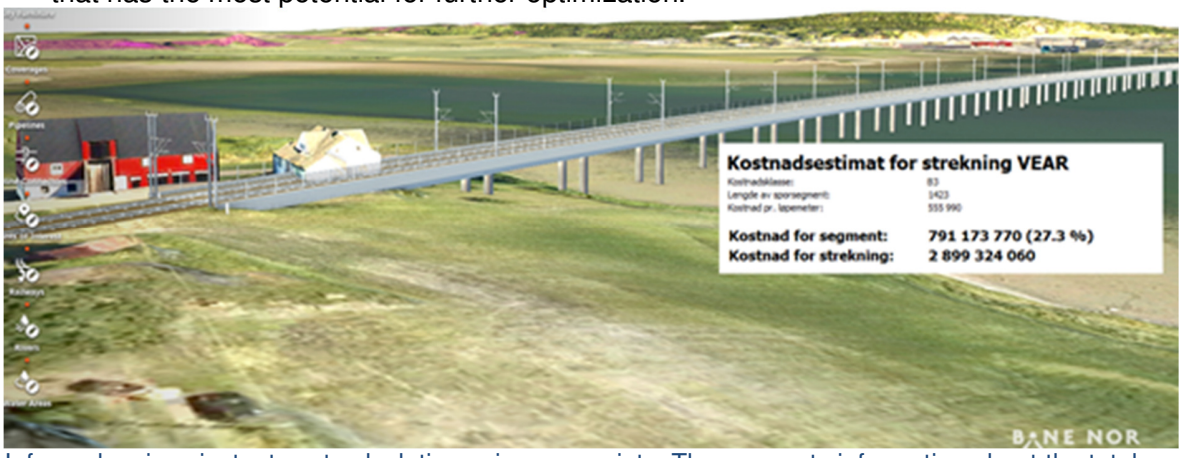
Kostnadsklasser - strekninger 2015-kr — 250 km/t

A1	**Daglinje dobbeltspor, liten eller ingen bebyggelse / enkle byggeforhold**		
	(Gjennomsnitt for dagstrekninger med lite bebyggelse)		
	Skjæring/fylling, gj.høyde 5 m inkl. frost-/forsterkningslag, drenering og føringsveier/Kryssende mind	lm	23 000
	Tosidig gjerde/Støytiltak, antatt 10% av traseen trenger støyskjerm/tiltak	lm	4 500
	Geoteknisk tiltak, gjennomsnitt	lm	5 000
	Landskapsbehandling, tiltak for natur- og kulturminner(hovedsakelig arkologi)	lm	3 500
	Infrastruktur veier, antatt omlegging av 0,3 m vei per lm ny jernbane(5 m bred vei)/Omlegging kommu	lm	4 500
	Kryssende kulverter/bruer, antatt 1 per 500 m ny bane	lm	8 500
	Jernbaneteknikk unntatt signanlanlegg	lm	19 000
	Signanlanlegg	lm	8 000
	Sum entreprisekostnad, eksludert uspesifisert samt rigg og drift	**lm**	**76 000**
A2	**Daglinje dobbeltspor, middels tett bebyggelse / middels byggeforhold**		
	(Gjennomsnitt for dagstrekninger med middels tett bebyggelse)		
	Skjæring/fylling, gj.høyde 5 m inkl. frost-/forsterkningslag, drenering og føringsveier/Kryssende mind	lm	25 000
	Støttemurer antatt en side høyde 2 meter	lm	10 000
	Tosidig gjerde/Støytiltak, antatt 60% av traseen trenger støyskjerm/tiltak	lm	9 000
	Geoteknisk tiltak, middels omfang	lm	20 000
	Landskapsbehandling, tiltak for natur- og kulturminner / reetablering av hager etc.	lm	4 000
	Infrastruktur veier, antatt omlegging av 0,5 m vei per lm ny jernbane (7 m bred vei)	lm	10 000
	Kryssende kulverter/bruer for 7 m vegbredde, antatt 1 per 400 m ny bane	lm	14 000
	Omlegging kommunal teknisk infrastruktur per lm ny jernbane	lm	16 500
	Jernbaneteknikk unntatt signanlanlegg	lm	19 000
	Signanlanlegg	lm	8 000
	Sum entreprisekostnad, eksludert uspesifisert samt rigg og drift	**lm**	**135 500**

Excerpt from the Excel sheet for different cost categories such as A1, A2, etc.

Having cost estimates early in the project the alternative tracks can more quickly be placed in areas that will lower the cost and hopefully avoid difficult ground conditions and adjusting the horizontal or vertical alignment can be evaluated. Eventually everyone in the project and quickly and easily see the result of choosing another alternative.

Our cost estimation solution in Infraworks gives a total cost for the whole alternative and cost per segment both in sums and as percent. This makes it easier to focus the effort on the section that has the most potential for further optimization.

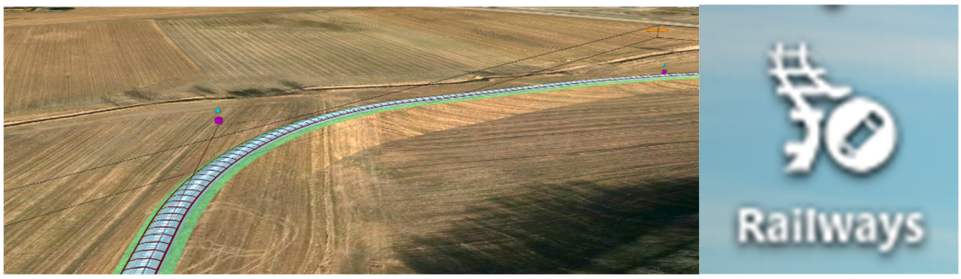


Infraworks gives instant cost calculation using our scripts. The user gets information about the total costs as well as the cost for a specific segment and its length.

Infraworks is among the best model-based software for projects in and early plan phase and is used by all consultants on the InterCity sub projects in that plan phase. That is why it is very important for us to connect cost estimations and have a visual control of costs.

Railway in InfraWorks version 2018.2

Unfortunately, Infraworks has reduced functionality in version 2018.2 concerning railway design. This is something many project hope will be implemented in later versions of Infraworks since Infraworks has become the most important tool for preliminary infrastructure planning in Norway.



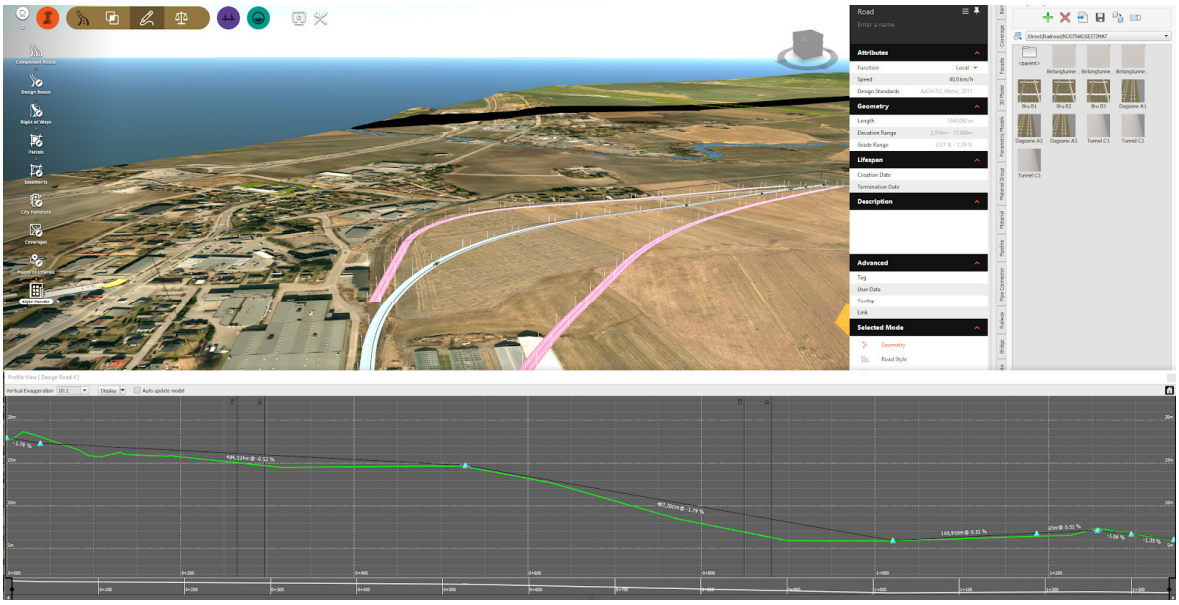
Alignment design for railway is not supported in the current version.

Our solution to this limitation is to use ROADS shown as a railway. Alignment design is done in other tools, such as Civil 3D or Novapoint. From there the alignments are imported to Infraworks where content to the alignment is added. Content can be tracks, sleepers, constructions and sublayers just to mention a few. Below is a picture of a railway in Infraworks from an alignment made in Novapoint.

Infraworks provides a flexible way of showing different profiles in 3D.

In our project we created a library in STYLE PALETTE under the category ROAD with plenty of different profiles for single and double track railway.

As mentioned, it is not possible to perform detailed alignment for railway in Infraworks. However, using Infraworks DESIGN ROADS for railway design as sketching tool might prove to be a useful approach. For example, in meetings with stakeholders, looking to find alternatives.



You can quickly sketch many alternatives by using DESIGN ROADS to show a span of possibilities in a meeting with stakeholders. Detailed alignment design must be performed in another tool like Civil 3D or Novapoint.

Using Infraworks as shared collaboration model, a workflow to get railway shown in the program might be:

1. Detailed railway alignment drawn in Civil 3D or Novapoint

2. Alignment made in to 3D-polyline in AutoCAD
3. Dividing the polyline into segments for the different profiles (bridges, tunnels and so on) in AutoCAD
4. Export the divided polyline to an .sdf file with information about the layers in AutoCAD
5. Import .sdf file to Infraworks
6. Use STYLE RULES in Infraworks to give desired profile to the different segments of the .sdf file.

This method has proven to be relatively fast and functioning. Unfortunately, the method has a one-direction process where changes in Infraworks cannot be made on alignment. All the steps above must be performed again and again as the alignment is being changed during the project.

Including cost estimation as a discipline in a shared collaboration model

Implementing costs as a discipline in Infraworks was a natural step in the process of getting all disciplines represented in the collaboration model. Why should cost estimation be a process kept outside of BIM in preliminary planning? Bane NOR and Norconsult decided to find a solution together.

To make this work we had to make a link between Bane NORs cost bank and Infraworks using scripting.

Cost estimation in Infraworks is not replacing the cost discipline and competence necessary to make decisions. It is a tool that gives cost in preliminary planning a voice in modern BIM based projects.

What the cost model provides is a day to day estimate based on the knowledge available. Questions such as “what is the consequences of moving the railway line out of an avoidance zone, which leads to 30 % more constructions?” can now quickly be offered. Not in precise number, but as a rough estimate.

Example 1: Cost of avoiding cultural heritage
When a new railway line conflicts with cultural heritage areas (Purple) it might useful to quickly find a rough cost estimate of the cost of making tunnel instead of open zone in early phase. By using this method, one gets a rough estimate which gives the participants in the project a focus on costs.

Example 2: Comparing many different alternatives in preliminary phase
Say you have 16 different alternatives and you want to remove all alternatives which are much more expensive then the rest without having the time or means to have a 2 day seminar with 30 people. Using the cost model together with a smaller team enables the project to find the most expensive alternatives and show to the client that these are not recommended.

Example 3: Cost development of a railway line
When working in preliminary projects the horizontal and vertical data of the railway line might change dramatically as the project develops. New information might cause changes. Using the cost model and running the script, every time the alignment changes geographical position, enables a timeline view of the cost development. This combined with a description of the reason for change gives a powerful tool for documentation of the alternative's development.

Each pillar shows the cost of an alternative before changes where made. One can clearly see how the costs are changing as a function of time.

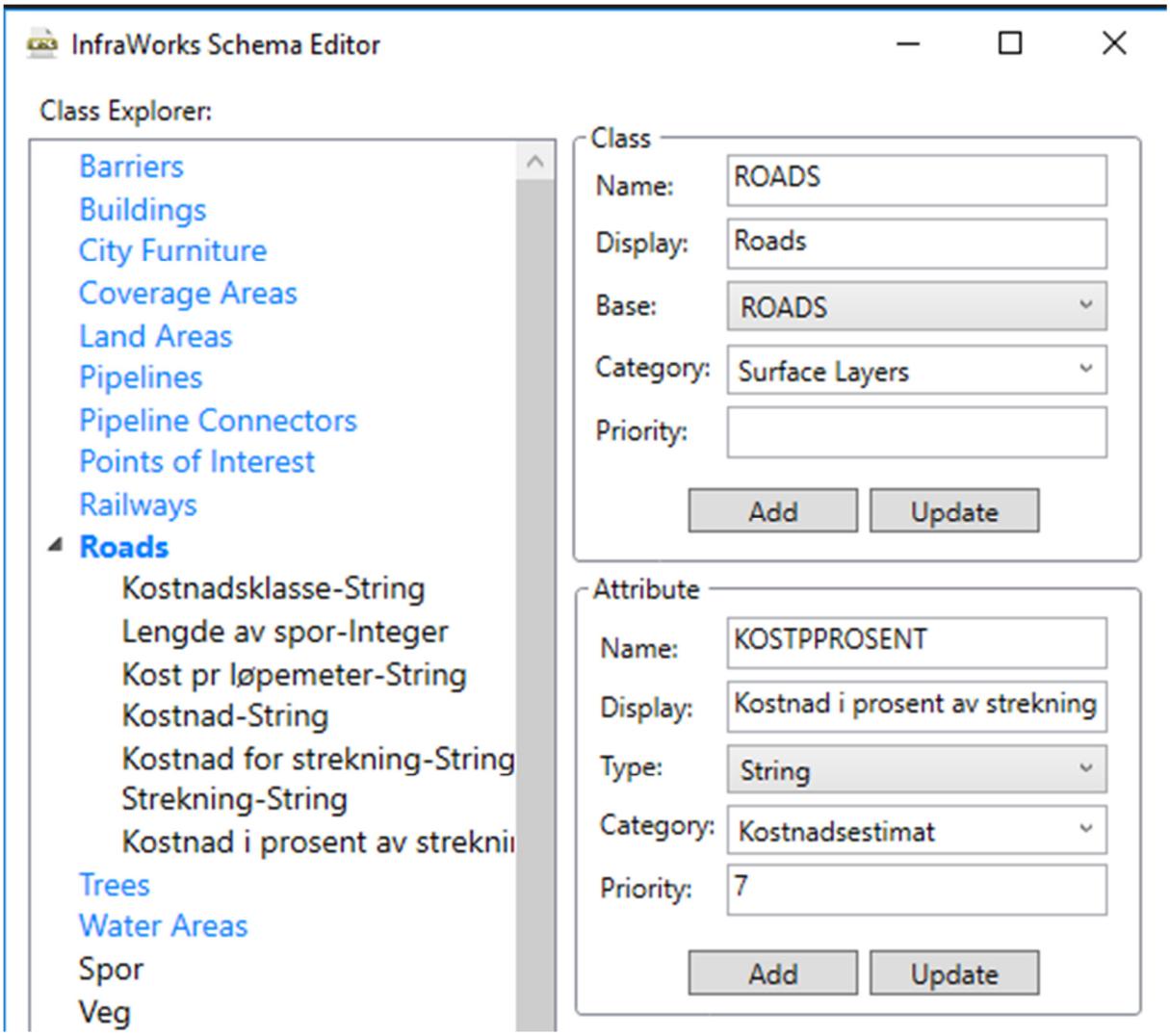
Getting technical – How to get it work

This chapter provides a description of how you can implement costs in Infraworks. Important Keynotes are:

- Infraworks scema
- Excel cost bank
- Infraworks railway library
- Scripts and cost estimate

Infraworks scema

It is necessary to give attributes to the ROAD category in Infraworks in order to ad the cost calculation to the import files. This can be done using SCEMAEDITOR or Notepad ++. Attributes such as length, cost class and total cost must be added.



Excel cost bank

The databases used as input consists of the different classes of railway and an associated cost per meter for each class and a description of all the classes.

Infraworks Style name	Kostnadsklasser	Kostnad per løpemeter
Street/Railroad/KOSTNADSESTIMAT/Dagsone A1	A1	76000
Street/Railroad/KOSTNADSESTIMAT/Dagsone A2	A2	135500
Street/Railroad/KOSTNADSESTIMAT/Dagsone A3	A3	190000
Street/Railroad/KOSTNADSESTIMAT/Bru B1	B1	219000
Street/Railroad/KOSTNADSESTIMAT/Bru B2	B2	377000
Street/Railroad/KOSTNADSESTIMAT/Bru B3	B3	527000
Street/Railroad/KOSTNADSESTIMAT/Tunnel C1	C1	207000
Street/Railroad/KOSTNADSESTIMAT/Tunnel C2	C2	242000
Street/Railroad/KOSTNADSESTIMAT/Tunnel C3	C3	326000
Street/Railroad/KOSTNADSESTIMAT/Betongtunnel D	D2	417200

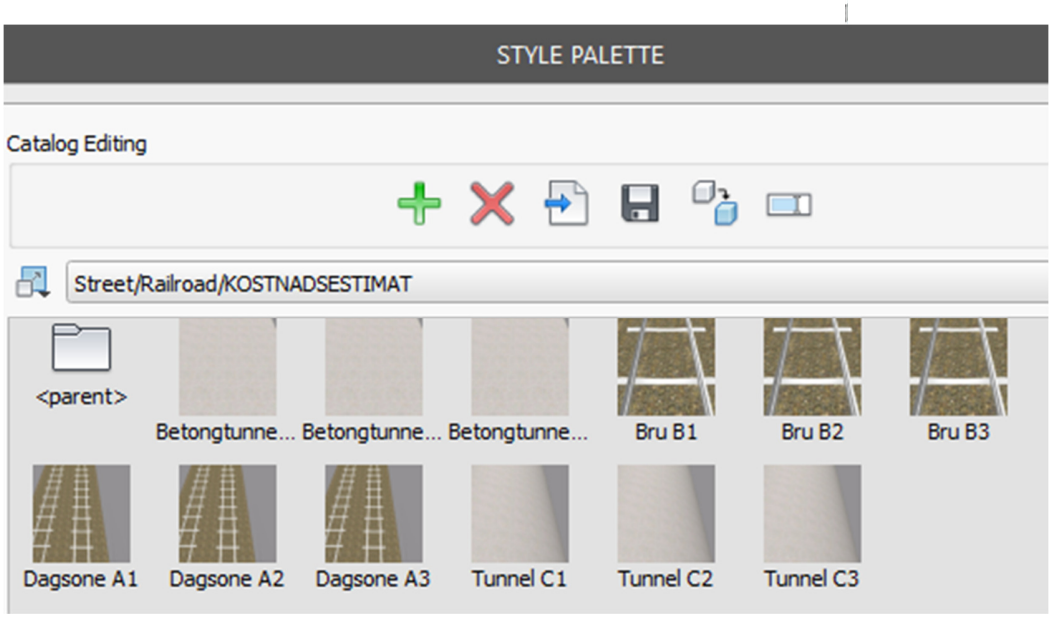
Example: a simple database in .csv format showing the different cost classes of railway. Column to the left shows reference path to Infraworks style (described below). Column in the middle showing the cost class and the column to the right gives associated cost per meter.

Klasse	Beskrivelse
A1	Daglinje dobbeltspor, liten eller ingen bebyggelse / enkle byggeforhold
A2	Daglinje dobbeltspor, middels tett bebyggelse / middels byggeforhold
A3	Daglinje dobbeltspor, tett bebyggelse bystrøk småhus / vanskelige byggeforhold
B1	Bru dobbeltpor, små spennvidder/enkle forhold
B2	Bru dobbeltpor, moderate spennvidder/ middels byggeforhold
B3	Bru dobbeltpor, store spennvidder/ vanskelige byggeforhold
C1	Tunnel dobbeltspor, enkle byggeforhold
C2	Tunnel dobbeltspor, middels byggeforhold
C3	Tunnel dobbeltspor, vanskelige byggeforhold
D1	Betongkulvert dobbeltspor, utenfor bebyggelse / enkle byggeforhold
D2	Betongkulvert dobbeltspor, i bebyggelse / moderat byggeforhold
D3	Betongkulvert dobbeltspor, i bebyggelse / vanskelige byggeforhold

Example: a simple database in .csv format with description of all the cost classes such as Day zone, Bridge and tunnel with different levels of difficulty. Column to the left gives name of cost class and column to the right a description and criterias of the different cost classes.

Infraworks railway library

It must be made a railway library which is corresponding to the cost classes in the excel database.



Example: Railway library which are corresponding to cost classes in excel.

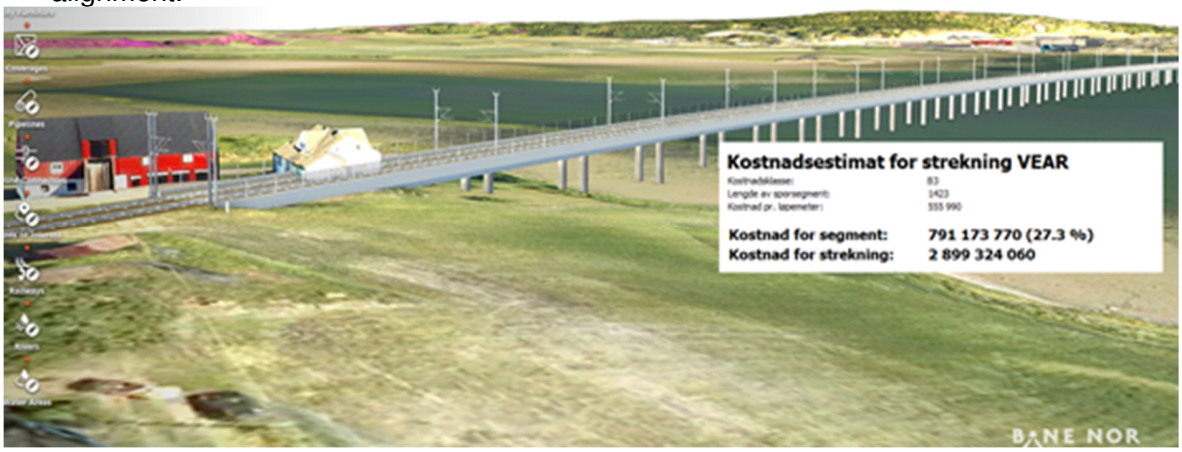
Scripts and cost estimate

When all above is ready you are ready to use the scripts.

It is developed two scripts:

1. UPDATE COST ESTIMATE (1)
2. EXPORT COST ESTIMATE (2)

Script 1 looks in all your proposals and calculating the cost of your different alignments in Infraworks and adding a tooltip showing the cost of the segment and cost of the whole alignment.

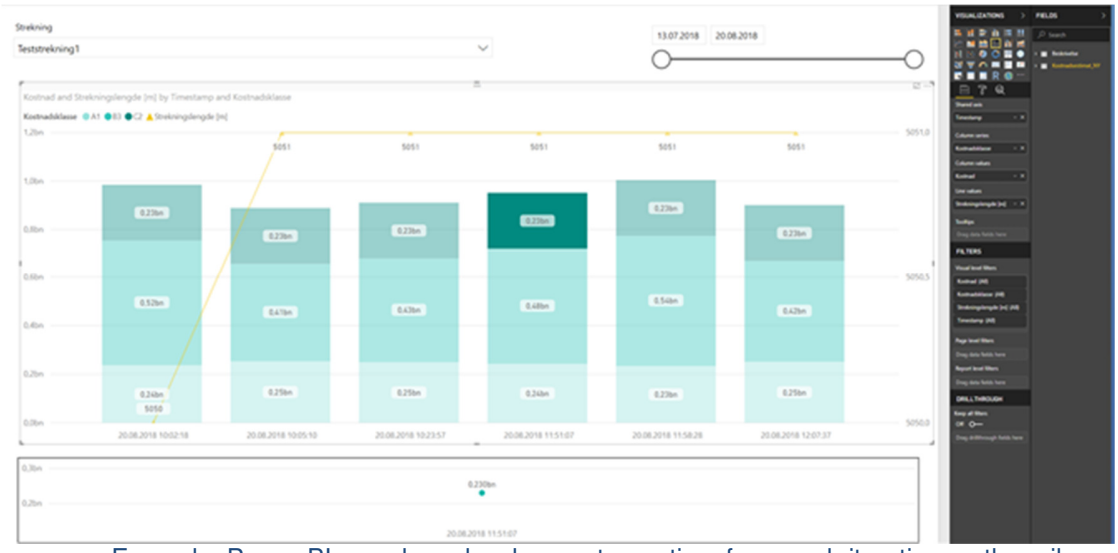


Tooltip gives instant cost calculation after running script 1. The user gets information about the total costs as well as the cost for a specific segment and its length.

Scripts 2 exports all information from the attributes on your alignments in infraworks with a timestamp so that you get a development of the cost over time.

	A	B	C	D	E	G	H	I	J
1	Alternative	Cost class	Cost per meter	Length	Cost	Proposal	Modell	Timestamp	
2	Vear 2017	B3	555 990	1423	791 173 770	Vear	IC-TØNSKI Tønsberg - Stokke	01-10-2018 16:00:16	
3	Vear 2017	B2	397 740	43	17 102 820	Vear	IC-TØNSKI Tønsberg - Stokke	01-10-2018 16:00:16	

From script 2 the user can analyze the data as she wishes, using other Excel sheets or Power BI, just to mention some examples. Using Power BI works well as a tool to see development over time.



Example: Power BI can show development over time from each iteration on the railway

How to reach stakeholders and the young generations with your project?

When planning large infrastructure projects information and sharing of knowledge to stakeholders and people afflicted is a major challenge. Holding back information might be just as harmful as sharing it. The new railway will be finished in 2032, many years from now. Who are making the important decisions concerning design and choice of alternative? Traditionally this has been the elder ones, as seen on the picture bellow.

The planner's paradox: Why is it that people who might not be around to enjoy the new railway lines are the ones to decide design and function (left picture)? We wanted to aim for the younger generations who will be around when the project is finished (right picture)

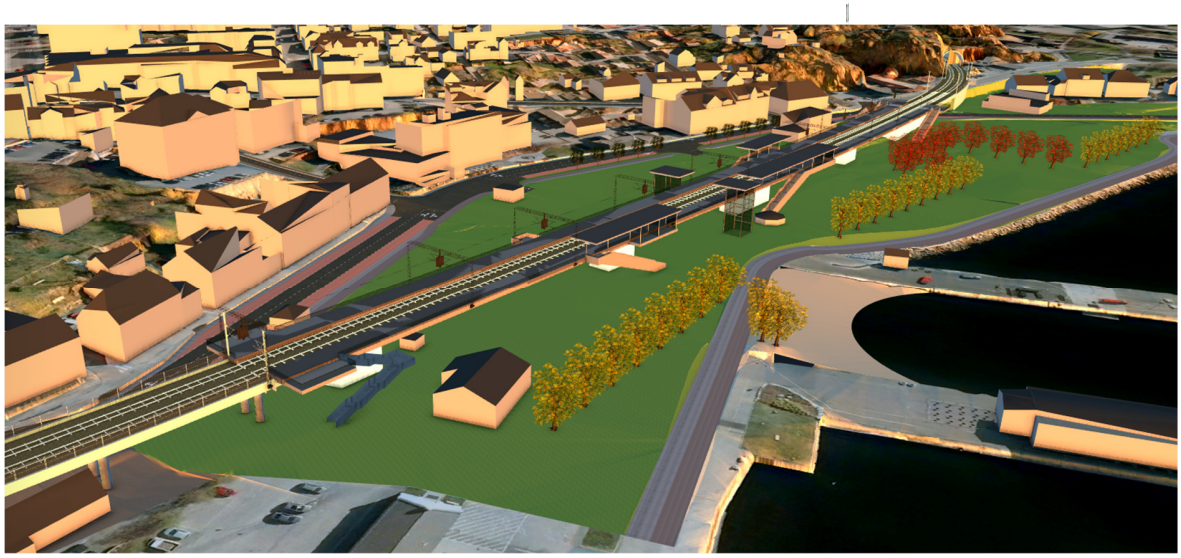
We wanted to make our project available to everyone, not just retired citizens showing up at public meetings. To do this, we had to be creative. We had to sort out the following issues to reach our Goal: Making our project accessible to everyone, and especially the younger generation who will be the future users of our product.

High detail level: Using BIM tools and modelling

Accessibility: Web - Phone, iPad and computers

Step 1: High detail level

A multidisciplinary team consisting of architects, city planners, graphic designers and BIM technicians made detailed stations for all alternatives in three cities, using Infraworks as shared collaboration model. The whole model is exported from Infraworks as an fbx-file. This file is then added to Unreal Engine for further visual improvements.



Infraworks model of future station alternative.

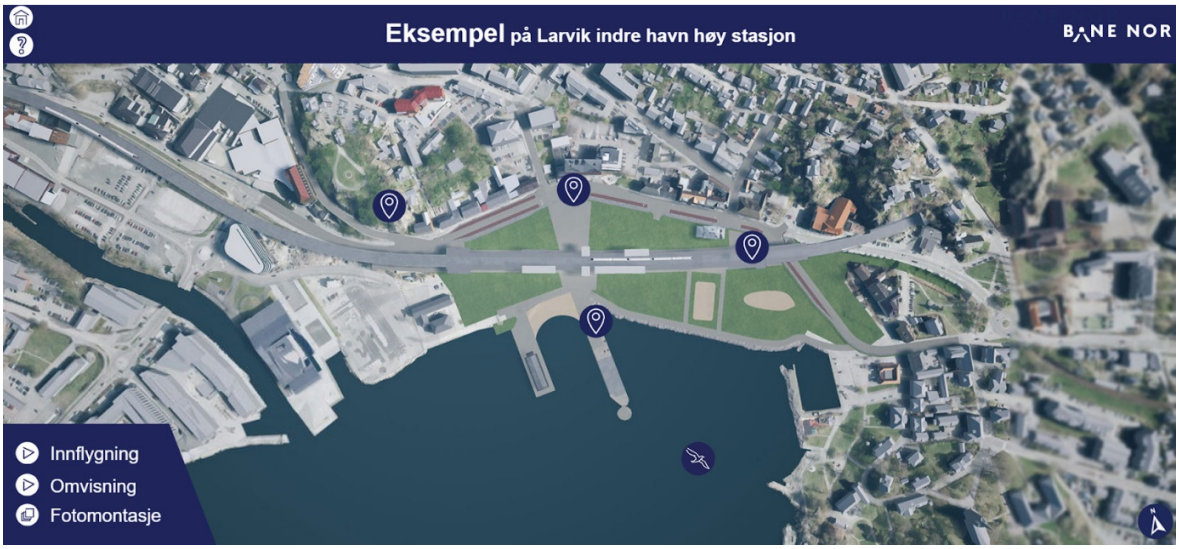
In order the get the desired visual quality and to bring the models “to life” we used Unreal engine. This program gives features such as animations and high visual quality just to mention a few. After finishing the detailed station models we were ready for the next step. Making the models accessible to everyone.

Unreal model of future station alternative, same as above.

Step 2: Accessibility

A team of web designers and BIM technicians created a website which was to be made publicly available. This website consisted of 360 views of the stations where the user could move between the different views as well as movie clips and images

First page with information and overview of the alternatives.



Second page with many options such as 360 views, movies and pictures

Third page in a 360 view. The user can look around, move to another location or turn on and of layers of city development.

Conclusion

In this project we experienced that showing people detailed solutions in early phase was not harmful, but a useful way to communicate with both politicians and all generations, especially. We learned that it is important to inform the people living in the influenced areas who are longing for information. Making detailed models and making these accessible proved to be a productive way of communicating our project to the world.

A next step in this development of sharing our project to the world can be to let the people using these models to give feedback on design. Imagine school children being able to test simulated alternatives and let the planners know what they need? Or young parents have a saying in how their family's future environment should be?

Using BIM and the possibilities which lies within the technology, you can do almost anything you want. You just need to think in new ways and have the guts to try it.