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Unite! Innovative BIM Workflows for Industrialized Construction.

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Learning Objectives

- Gain insight into the Scandinavian way of developing projects using industrialized construction by integrating innovations.
- Learn step by step how to prepare a project for future implementation of industrialization BIM methodologies.
- Learn how architects' and engineers' desired workflows have been translated to functionalities of the new technologies.
- Learn how these innovative workflows and new technologies can be applied to other projects (hotels, schools, office buildings, etc.).

Description

Industrialized construction is becoming a household name within the building industry due to its advantages in improving productivity, quality, accuracy, and efficiency. To succeed in industrialized construction, applying innovative BIM workflows and using advanced technologies through all stages from design to production has been one of Nordic Office of Architecture's most important strategies. In this class you will gain insight into the Scandinavian way of industrialized construction, and see how a cross-disciplinary collaboration with the software development team of Project Frog has enabled new possibilities to aid in DfMA and BIM workflows. We will showcase both a large-scale hospital and a smaller-scale set of high-end prefabricated housing. This collaboration reflects on the challenges that architects and engineers have faced in the presence of repeating information, and provides a step by step workflow for similar projects (hotels, schools, office buildings, etc.).

Speakers

Soren Shen-Lung Lin

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Soren Shen-Lung Lin completed his second master's degree in Built Environment at Royal Institute of Technology in Stockholm in 2007. He is a qualified architect and specializes in built environment analysis and industrialization methodology. He is passionate about applying innovative methodologies and advanced technologies to large-scale projects. In Norway and abroad, Soren has worked on different large-scale projects including New Stavanger University Hospital, LHL Hospital Gardermoen and Oslo Airport T2. He was one of the key specialists creating the industrialization methodology for the New Stavanger University Hospital project which won Autodesk's AEC Excellence Awards in 2018.

Bridget White

Senior Architect / BIM Director at Nordic Office of Architecture

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Bridget White is originally from New Zealand, and completed an honors degree in Architecture at Victoria University in 2006. After beginning her career working in New Zealand, she moved to Norway to start at one of the country's largest practices - Nordic Office of Architecture. She is a senior Architect, BREEAM AP, BIM manager, and BIM Coordinator for large-scale airports, hospitals, schools, national governmental facilities and transportation hubs. She is the leader of a team of experts at Nordic using a wide range of Autodesk products and implementing new office workflows involving complex analysis, virtual reality, industrialization, integrated sustainability, and streamlining the flow of information between architects and the building industry.

Steve DeWitt

BIM/VDC Manager at Project Frog

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Joining Project Frog in 2014 as the BIM Manager, Steve DeWitt has 20 years of experience in design software and is a certified Autodesk Revit® professional. His current focus is the development, utilization and implementation of KitConnect both internal and external to his company. Steve is a contributor to several AEC groups such as SF Computational Design Institute, Revit user Group (all over the US), TAP's and Autodesk University. His recent position has allowed him to explore everything from how Revit can drive CNC machines to how Forge can drive intelligent collaboration methods.

The New Stavanger University Hospital

This new university hospital project is located in Norway's oil capital – Stavanger. Off-site, industrialization and modulization which are widely used to build up oil platforms have been important inspirations for the project team since the start.

The first phase of the New Stavanger University Hospital project, scheduled to open in 2024, has 140,000 square meters in size. Four buildings with internal courtyards connected by a ring of glass bridges emphasize the connection to nature and natural daylight for enhancing patient recovery. The layout is standardized to a high extent for flexible use, patient safety and adaptability, allowing a giant Lego-like construction with a combination of modular and panelized components assembled both on-site and off-site. The second phase of the project, scheduled to open in 2030 has 65,000 square meters in size, while the parking facility has 25,000 square meters in size in addition to the first and second phase of the project.

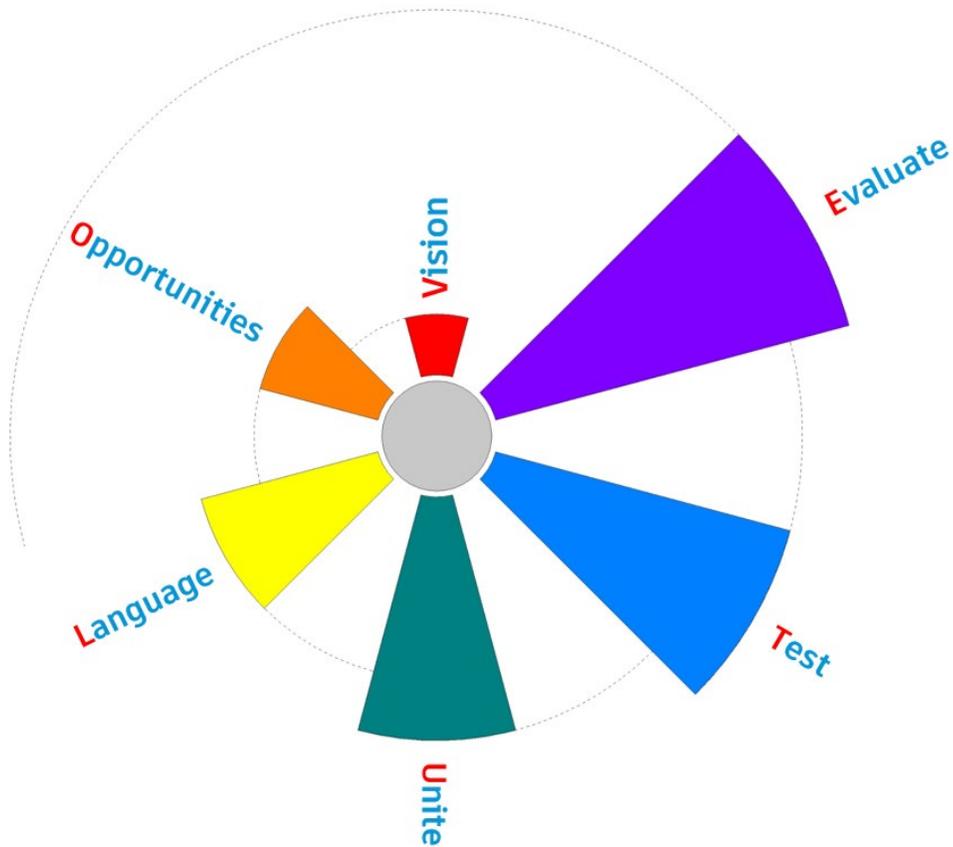
The project team comprises two architecture firms - Nordic Office of Architecture and AART, two structural-engineering firms - COWI and AAS-JAKOBSEN, one MEP-engineering firm - COWI and one landscape architecture firm - SLA spreading across Norway.

In a giant hospital project like this, there are hundreds of patient rooms, bathrooms and the same types of elements repeating in many of the rooms and buildings, thus creating a right methodology to simplify the workflows, keep the project team in sync, take more advantages from industrialized construction by integrating innovative BIM workflows and advanced technologies is crucial.



V.O.L.U.T.E. - A Step by Step Workflow

A step by step workflow called V.O.L.U.T.E. has been set up to help the project team with making decisions, defining modules, and creating the right tools. This workflow consists of 6 steps including Vision, Opportunities, Language, Unite, Test and Evaluate.

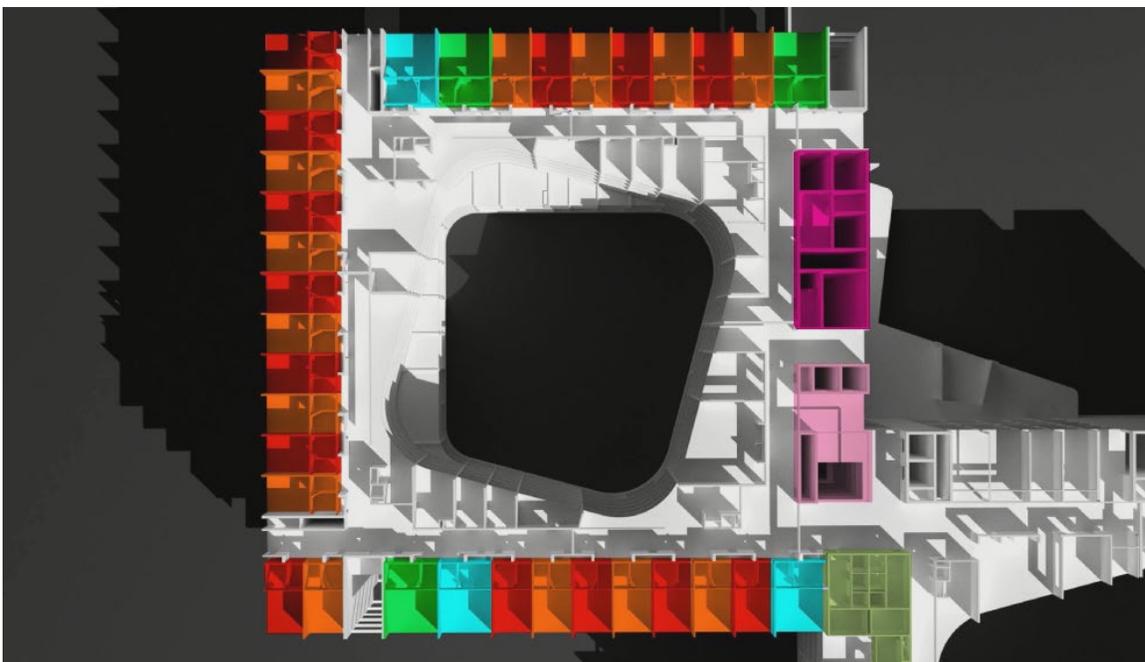
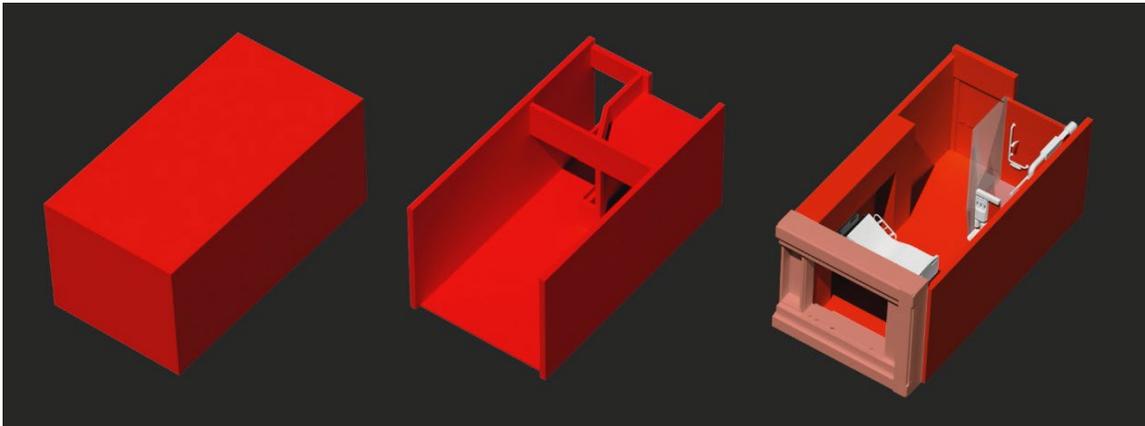


Step 1 - Vision

The project team's vision for BIM workflows in this giant industrialized construction has been to get the modeling process faster, more efficient with less frustration for Revit users of all levels. Since we are living in a world where a lot of great things can happen at the click of a button, why not just create our own tool(s) to automate and speed up the modeling process?

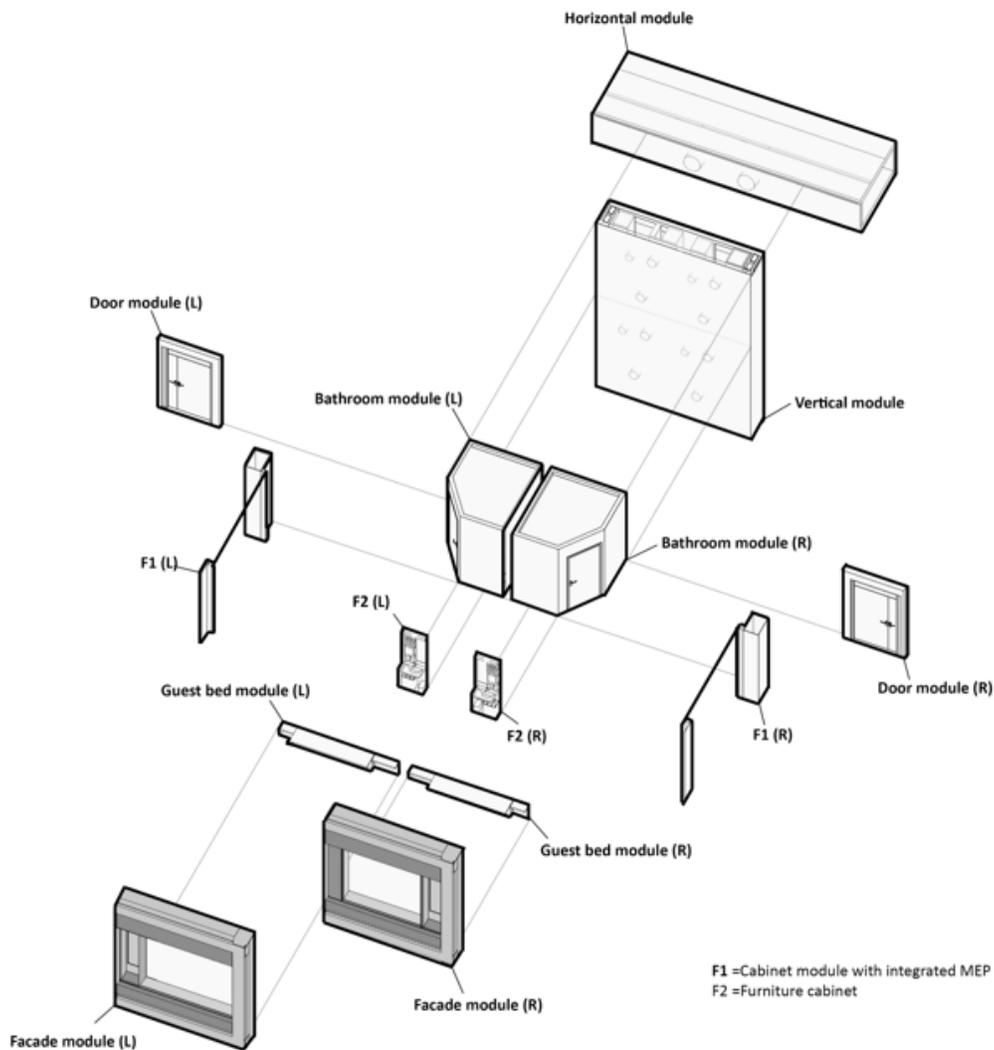
The main concept for the tool(s) is very straight forward:

All the repeating rooms and modules in the models are regarded as packages of parts, and these parts can be from one discipline or multiple disciplines. In this way, a room is no longer a room, it is only a package of parts which can be automated, identified, replaced, listed and calculated at the click of a button. If it is not one click, then only few clicks. The fewer clicks the less frustration for the users.



Step 2 - Opportunities

Patient rooms, façade panels, bathrooms, shafts, vanity units, cabinets, doors, etc. have been the possibilities for the New Stavanger University Hospital project. After long discussions, the opportunities have been systemized and set in to two big categories. The first category is Modules for Prefabrication. Modules are going to be produced as flat packages of parts. There are hundreds of shaft modules, bathroom modules, guest bed modules, and more than 2000 vanity units in the project now. The second category is Design Repetitions (repeating rooms) which are not for prefabrication.



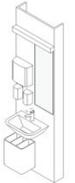
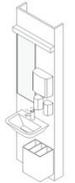
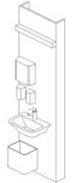
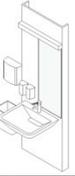
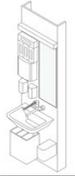
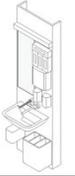
Step 3 - Language

Once the opportunities have been chosen, it is important to categorize them with a common language - a logical and cross-disciplinary coding system.

The New Stavanger University Hospital project is comprised of professionals from all over the world. A logical and cross-disciplinary coding system created for this project is the common language for all the team members and suppliers to understand when it comes to industrialized construction (modules and design repetitions). No matter where you are from, which language you speak and which discipline you are in, this coding system is the language for all, all members from architects, engineers to suppliers, and all phases from design to production. A complete code for a module or a design repetition describes Type, Deviation (for example height difference), Orientation and Material/Colour.

	dRofus Main group	dRofus Undergroup 1	dRofus Undergroup 2	dRofus Undergroup 3	Auto generated serial number in dRofus
	Module Type				
	8 + Module Category	Type Running Number	Deviation	Orientation	Material / Colour
	8B=Bathroom Module	01=Type 01	A=Standard, No deviation	R=Orientation Right	001=Material / Colour 1
	8C=Cabinet Module	02=Type 02	B=Deviation B	L=Orientation Left	002=Material / Colour 2
	8D=Door Module	03=Type 03	C=Deviation C	N=Orientation Neutral	003=Material / Colour 3
	8G=Guest Bed Module	04=Type 04			...
	8H=H-Module	05=Type 05			
	8S=Vanity Unit Module	06=Type 06			
	8V=V-Module	...			
Module Code in dRofus	8X01 / 8X02 / 8X03 ...		A / B / C ...	R / L / N	001 / 002 / 003 ...

Here are the module codes for Left Oriented Vanity Units and their variants - Right Oriented Vanity Units.

					
8501.A.L.001 Vanity Unit Module 01_ Patient Care_H=2400mm_Left	8501.A.R.001 Vanity Unit Module 01_ Patient Care_H=2400mm_Right	8502.A.L.001 Vanity Unit Module 02_ Administrative Area, WC_H=2400mm_Left	8502.A.R.001 Vanity Unit Module 02_ Administrative Area, WC_H=2400mm_Right	8503.A.L.001 Vanity Unit Module 03_ Operational Area_H=2400mm_Left	8503.A.R.001 Vanity Unit Module 03_ Operational Area_H=2400mm_Right
					
8504.A.L.001 Vanity Unit Module 04_Bathroom_H=2400mm_Left	8504.A.R.001 Vanity Unit Module 04_Bathroom_H=2400mm_Right	8505.A.L.001 Vanity Unit Module 05_HCWC_H=2400mm_Left	8505.A.R.001 Vanity Unit Module 05_HCWC_H=2400mm_Right	8506.A.L.001 Vanity Unit Module 06_ Patient Care with Manifold Cabinet_H=2400mm_Left	8506.A.R.001 Vanity Unit Module 06_ Patient Care with Manifold Cabinet_H=2400mm_Right

Step 4 - Unite

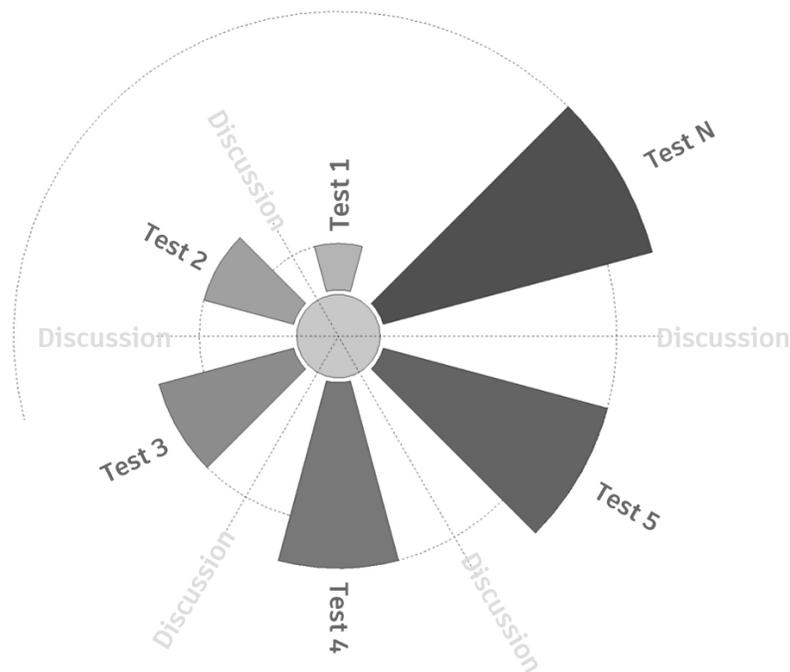
We have chosen to unite with the professionals like programming team and software development team to overcome the defined challenges. Because technology needs what we need to be developed in a right direction and we must start with the project team's needs and then work backwards to the technology. We cannot start with the technology or get as many programs as possible from the market and then try to figure out where we are going to put them in our project. If we can only use 1 or two programs to overcome the challenges, why do we need more?

Here are the defined challenges in the project:

- How to audit changes and update them in all the building models at the same time?
- How to control mirrored type of a module?
- How to make cross-disciplinary modules instead of linking elements from other disciplines?
- How to take better advantage of duplication?
- How to switch a set of elements within a module (group or nested family) for making new types?

Step 5 - Test

Test the custom-made technology created by the programming team and software development team. The procedure includes several rounds of tests and discussions.



Step 6 - Evaluate

Workshops are arranged for evaluating the outcomes of the new tool(s). If this new tool meets the project team's expectation, start to use the tool in the project.

From V.O.L.U.T.E. to 2 Custom-Made Plugins

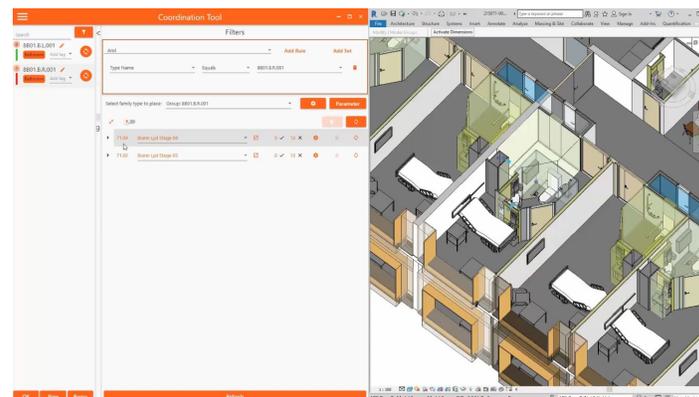
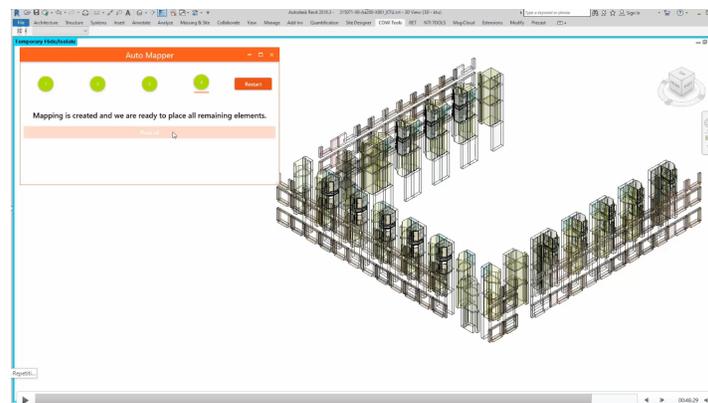
There are two custom-made plugins, COWI Tools and KitConnect, created for the New Stavanger University Hospital project. Both the programming team of COWI and the software development team of Project Frog have received insights into the project team's desired workflows for industrialized construction and have directly translated these into the user abilities and functionalities of the new technologies. This cross-disciplinary collaboration has enabled new possibilities to aid in DfMA and BIM workflows.

COWI Tools

COWI Tools has been created by the programming team of COWI based on the New Stavanger University Hospital project team's desired workflows overcoming the defined challenges:

1. Placing the modules and design repetitions should be automated cross disciplines.
2. Updating the modules and design repetitions should be automated cross disciplines.

The following images show how COWI Tools looks like.



KitConnect

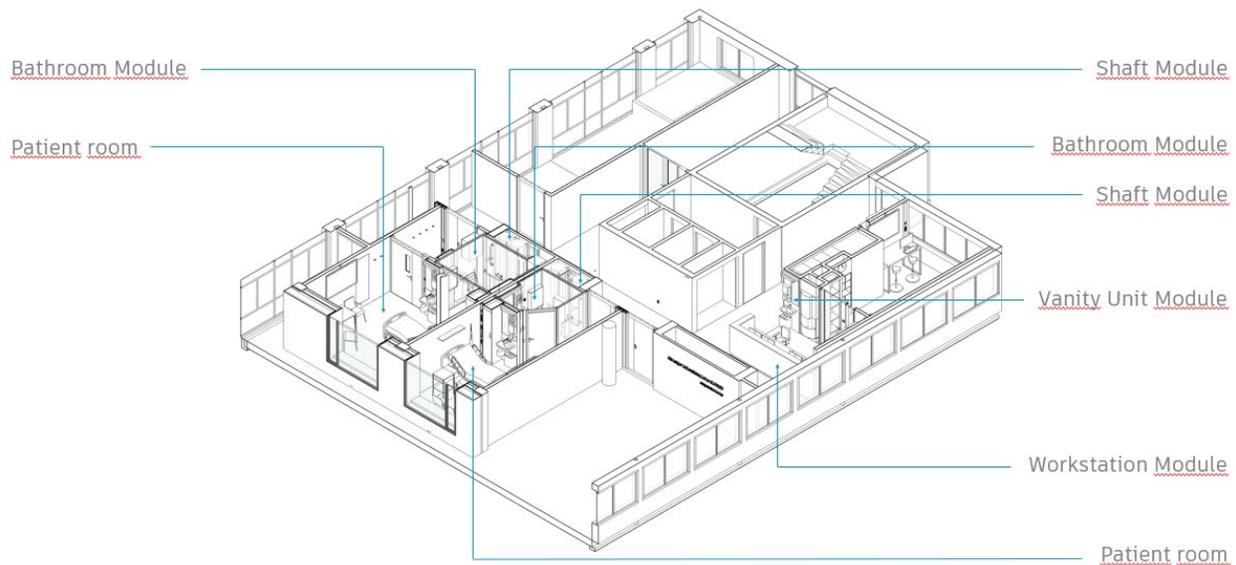
KitConnect has been created by the software development team of Project Frog based on the New Stavanger University Hospital project team's desired workflows overcoming the defined challenges:

1. Better way to make cross-disciplinary modules instead of linking elements from other disciplines.
2. Better way to switch a set of elements within a module for making new types.
3. A cloud library of modules to share cross disciplines.

The difference between COWI Tools and KitConnect is that COWI Tools offers an innovative way to place/duplicate modules and design repetitions in Revit models, while KitConnect is a cloud-based plugin offering an innovative way to model, catalogue and configure modules. KitConnect users have been assigned different roles and access limits for using, modeling and controlling the modules.

The Mockup

The Mockup including a physical setup on-site and a Revit model is the test-ground for both modules and BIM workflows. The project team and suppliers use The Mockup to coordinate, test and ensure the qualities and feasibilities of the modules and new BIM workflows before they are transferred to the whole project.

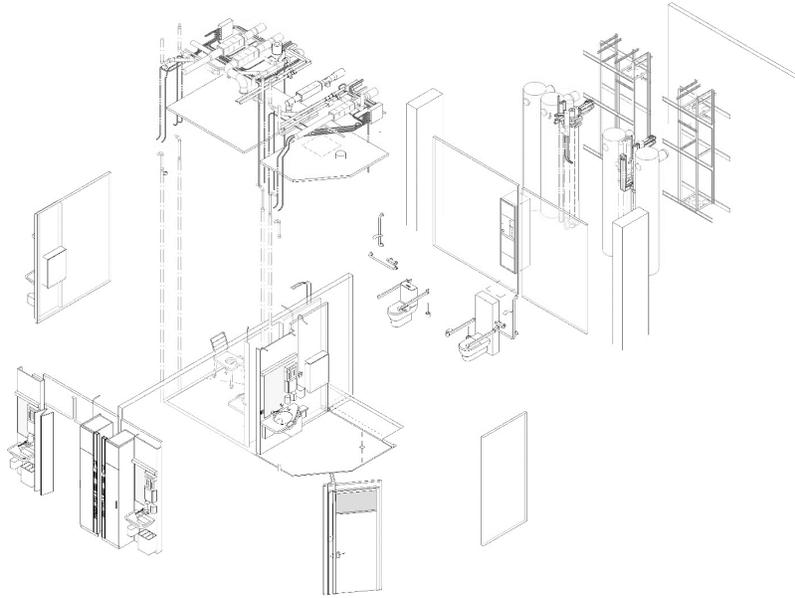


Modules in The Mockup

Some people have negative impressions of pre-assembled modules, for instance, bathroom pods, since there are size restrictions to fit manufacturing and transportation, the modules might look boring and cheap. Moreover, it is neither competitive during tendering nor flexible for renovation with using pre-assembled modules.

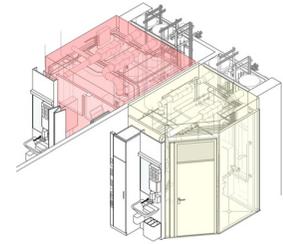
Instead of pre-assembly, flat-pack has been focused on in this project. Here is an exploded view showing how we break down the modules into different parts – architectural parts and MEP parts. Each part is based on the project’s needs, and each part is designed for manufacturing and ease of assembly on-site, known as DfMA. In the design phase, these parts can potentially and flexibly be combined for making new module types and variants. In this way, the project team has a better overview of what make up a complete module, has a better control of interfaces between modules, and has more design flexibility in size, shape, and quality. Moreover, these flat-pack modules are easier for transportation and easier to dismantle for renovation and future re-layout.

Parts for a module can be from one discipline or multiple disciplines, and it is possible for more contractors to involve in one module for achieving the quality the project team wants. Typical modules and their parts are tested and coordinated in the Mockup.

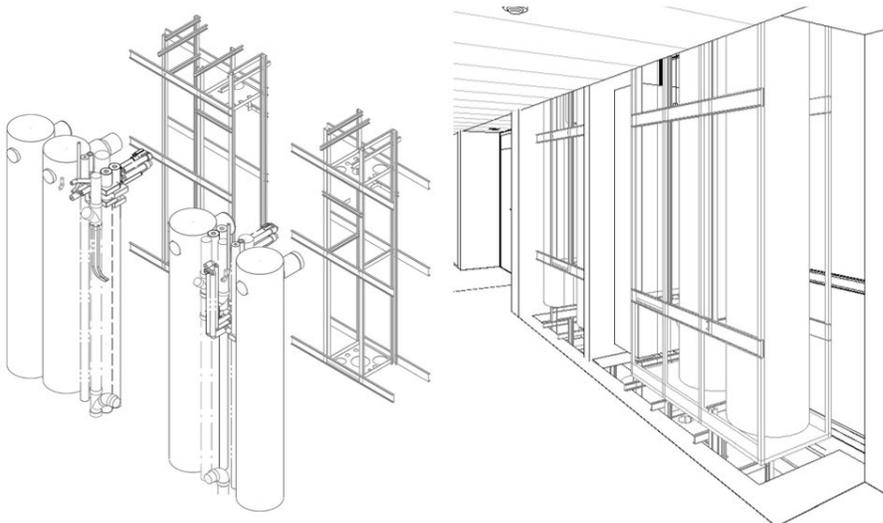
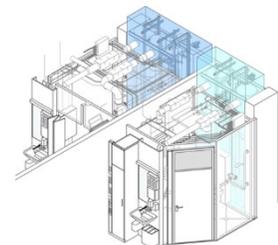


Flat-pack modules - Exploded view

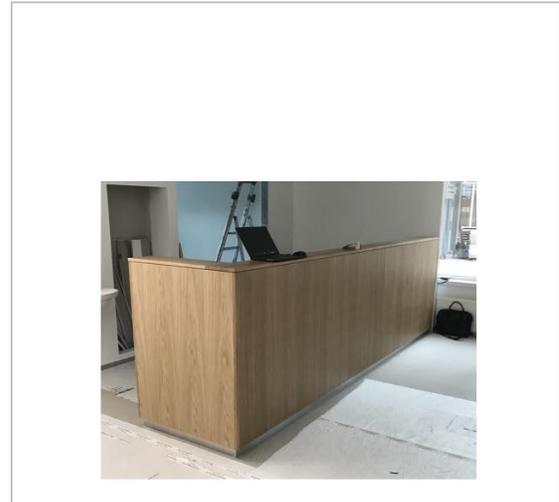
With breaking down modules into parts and defining clear interfaces between modules and contracts, assembly instructions have been designed for the on-site workers to assemble the modules. The following images show some of the modules in the mockup model and the quality we have achieved in the mockup on-site.



Bathroom Modules in the Mockup model and the Mockup on-site



Shaft Modules in the Mockup model and the Mockup on-site



Workstation Module in the Mockup model and the Mockup on-site



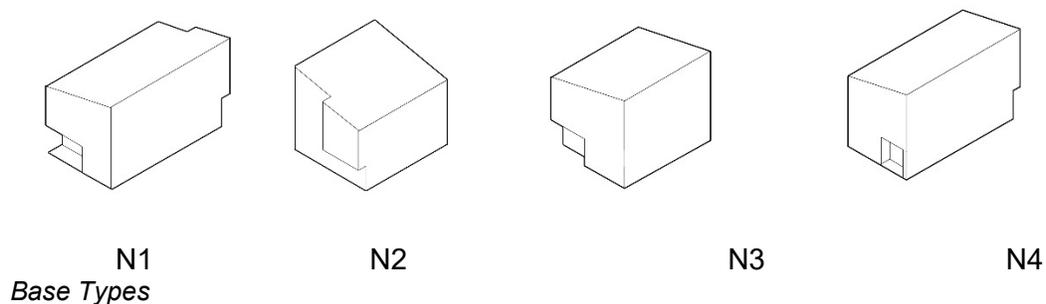
Guest Bed Module in the Mockup model and the Mockup on-site

High performance housing development

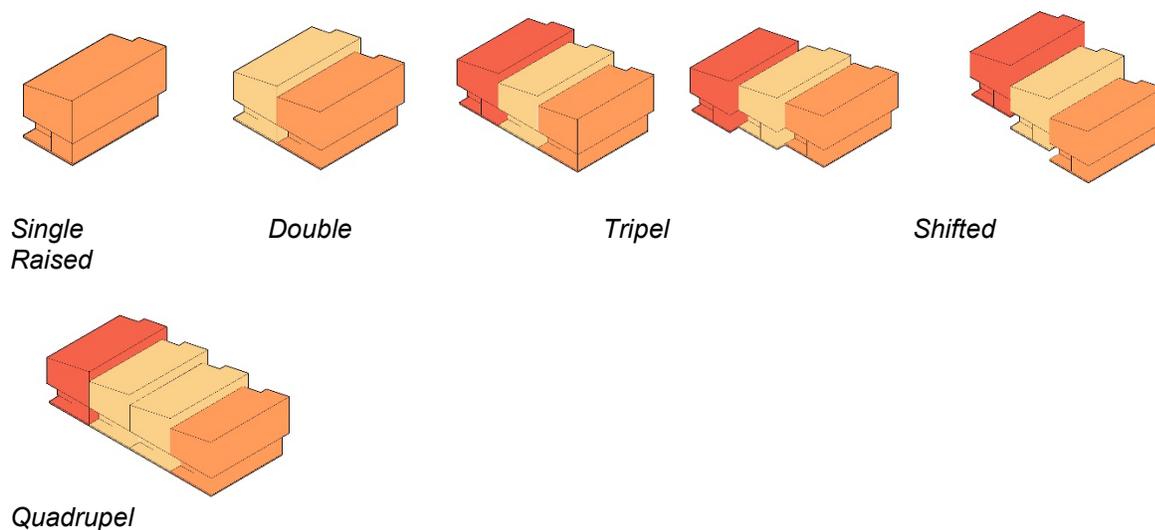
Learning from the previous work done in SUS, we looked at other types of projects, and their potential for more advantageous BIM routines for industrialization and repeated design.

Nordic is currently involved in a number of high-end housing developments which involve the design of several different residential unit typologies, and their repetition in alternative formations on a range of sites. This type of project brings similar BIM challenges previously faced in Stavanger, and outlines the potential for a better, more efficient, quality assured workflow.

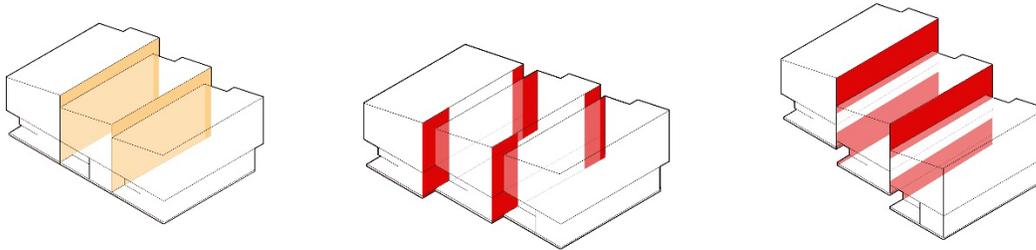
The residential units are categorized into base types, and their combinations can vary from one house to clusters of four houses. In this case we will showcase 4 base types for analysis, the N1, N2, N3 and N4.



Alternative clusters or arrangements possible on different sites:



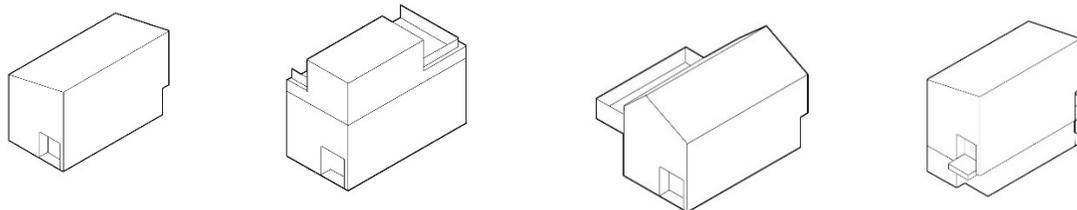
In assessing the different possible clusters, it is evident that the only real discrepancies between a house on the left middle or right is the conjoining conditions between the exterior walls.



Areas of deviating parts per unit

Other than these areas the residential units are identical (not considering client customization which comes in at a later time).

Within each design base type there are several configurations available which include additional elements and certain deviations (carports, basement levels, extra windows or doors, longer base plans and terrace levels) which we call the sub types. In analyzing the design at both a base type level and sub type level we can see a high level of design repetition, an identified potential for modular construction and subsequently an improved BIM process.



N4-A (original)
Subtypes N4

N4-T (terrace)

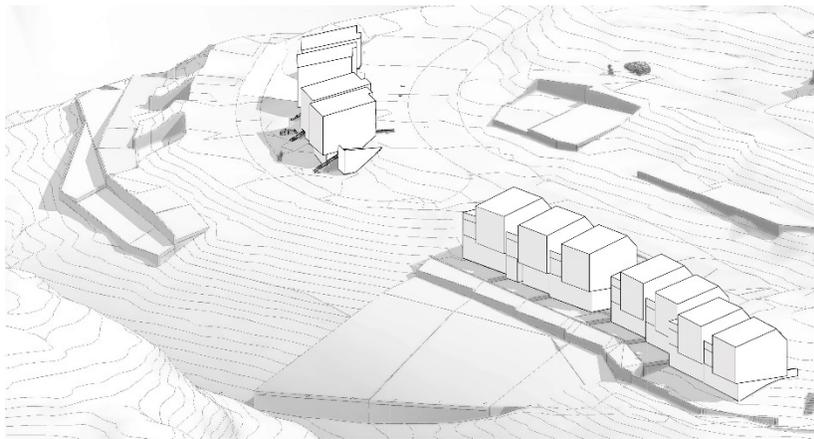
N4-C (carport)

N4K(kjeller/basement)

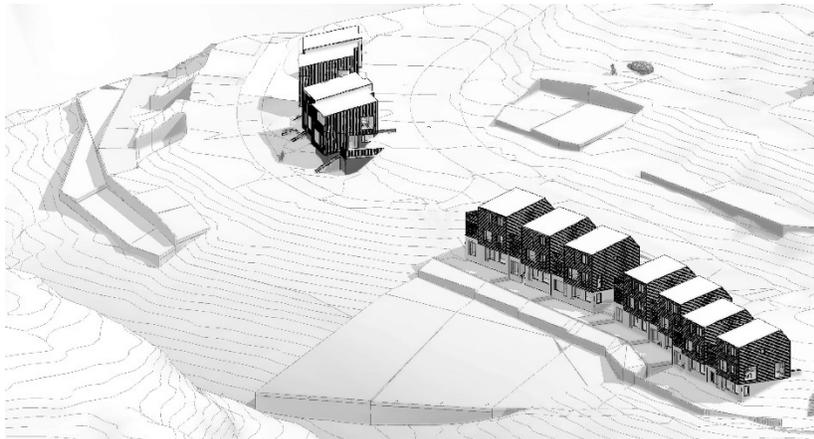
The usual BIM organization of these types of projects is chaotic. If you can imagine – several architects involved at different times and with different developments, some for the design of the isolated residence base and sub type designs, others the clustering of housing on particular sites, and then others responsible for the customization of the residences to suit the particular site and client.

Without well-organized data routines a lot of repeated work and wasted time occurs where some team members are using groups, or design options and others preferring links. Mirrored and unmirrored.... 🤖

The standard out of the box workflows also do not allow for an appropriate level of detail at each phase to suit this type of project. After the development of the initial types, the combinations are then conceptually placed in subdivision formations and it is beneficial for us to show volumes here in these early phases. Ideally these volumes would act as placeholders for the developing designs which can be worked on simultaneously in another arena or file. In many situations we are required to change between a volumetric design and a detailed design to show the right information at the right time.



Volumetric massing



Detailed design

In approaching the team at Project Frog to discuss our project and the potential for kit connect to adapt to the demands of our proposal we had the following wish list:

- Ability to show both volumetric representation and detailed design in the same arena
- One source of truth (one place where we know the information is correct and up to date.
- Break down the residential units into master modules and be able to create deviations or presets that were intelligent in the way they would be updateable
- Allow the potential for modules inside modules (residential unit = module, and groups of components inside module can also be modules)
- Potential to create quantitative totals, price and CO2 emissions
- Ability to work on the same modules from design through to construction (contractor involvement)

Some things on the list were already possible and others would require future development.

In approaching the client, we proposed a methodology for assessing the project based around these focus points:

- How can we save time on drawing things that are duplicated and be sure that the information is the same in every entity?
- How can we better manage deviations inside duplicated sets of elements?
- Can we prepare the model in a way which saves the contractor building up a new model for construction?
- How can we align our model to the way the project will be constructed – proposing modular.

Step by step process

Analyze – find opportunities for taking advantage of duplicated design and identify areas that could be considered for industrialized construction or modulation.

Systemize - divide the different packages which were a result of the analysis phase. Find a robust system that can cope with eventual changes and developments in the project.

Categorize – make a code system that can be used to describe the duplicated design or industrial packages, and which can tolerate new types and deviations.

Test phase – Integrate and test proposed methodology for improving project workflows associated with design repetition and industrialization. (in this case new technology – kit connect - for the cloud-based handling of geometry and data).

Summary – Compare the new workflow with the original workflows used previously and evaluate to form a list of pros and cons. Conclude and recommended way forward.

In the analysis of the N1, N2, N3, and N4 base types we could see repetition in layouts and the potential for optimizing construction methodologies.

As each base type could conform to 4 different sub types, we analyzed the 4 sub types of one base type (the N4) and aimed to be able to provide the same strategy for the other base type examples. In comparing the N4 sub types we could begin to configure a potential breakdown of repeating and potentially industrialized parts, that we could capitalize and align to using BIM.

The modules were separated by their potential to be industrialized or simply just act as repeated design. The modules were also chosen both because of their size (what can be transported from off-site factories) and adaptability to be used in other N housing layouts.

The modules chosen were –

Shell – separated on the first and second level. Potential for penalization

Stair – Could be prefabricated offsite

Bathroom – Cross disciplinary pod built offsite

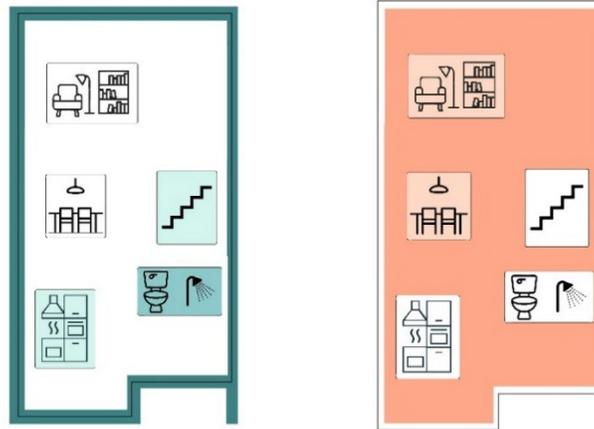
Kitchen – flat packed

Interior – first and second floor separated, design repetition

Carport – evident in the N1-4C sub types.

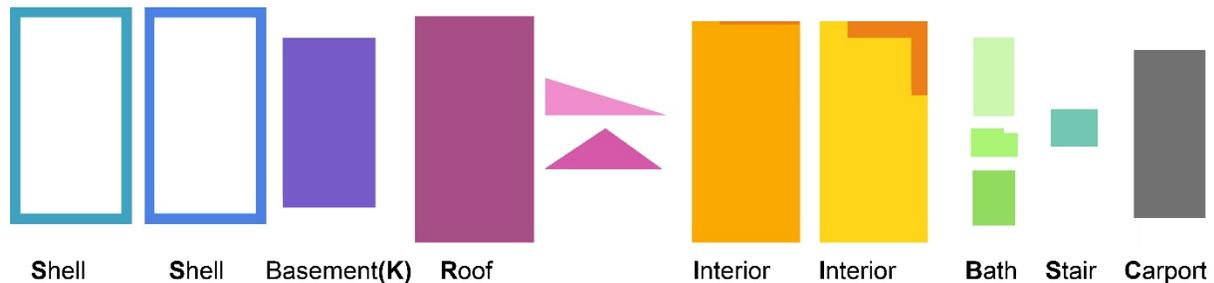
Basement - Built on site, evident in the N1-4K sub types

Roof – Three variations – tilted roof, A pitch roof, terrace roof.



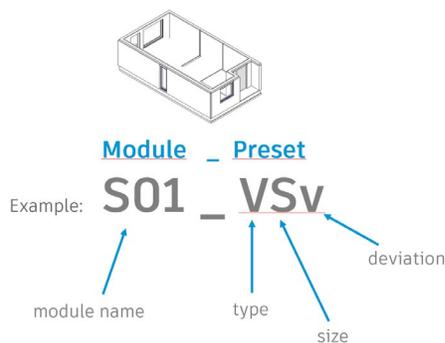
Important factors here were that the different modules could be used across base types, and that we would have the ability to update one module and then choose to automatically update all the other base and subtypes.

The next task was the systemization and categorization of the system so that the concept would show to be robust in all combinations and deviations.



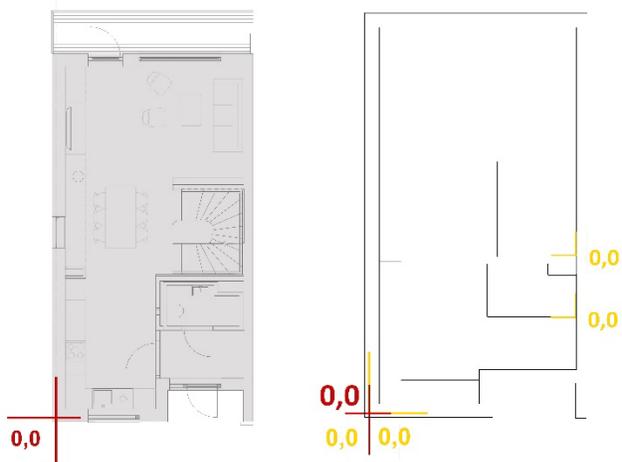
Division concept with code letters to indicate module name.

A coding strategy combining the module name (and level if appropriate) with orientation 'left' (the type), the size of the module 'standard', 'large' or 'small', and any deviations for example an extra window or any other type of component.

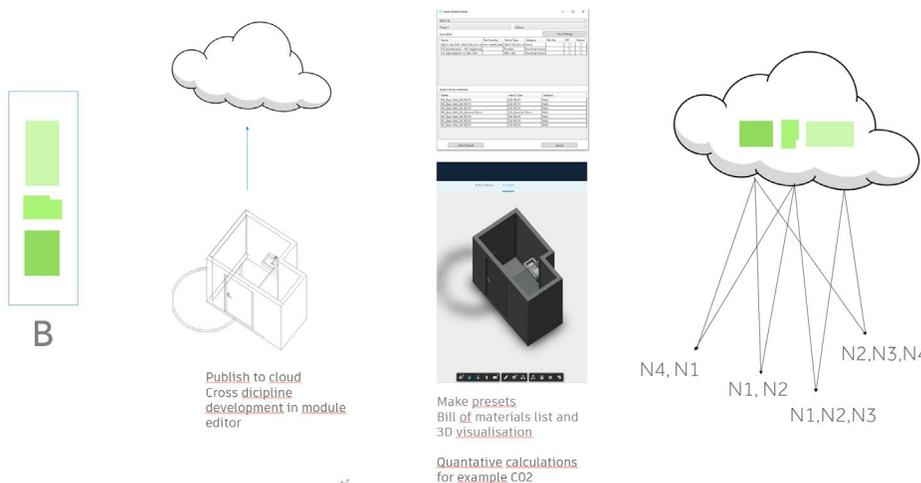


After the system was in place, we could begin testing by first publishing all the elements as parts into the cloud-based library before publishing the modules. System types (most but not all) and family types can be published. It is important to be aware of which elements and categories can be published before considering elements for modules.

It is important to also ensure the models are drawn in a way which enables the modules to be isolated – i.e. disallowing joins where appropriate and ensuring all components that need to be published exist. A zero point strategy also needs to be considered. Each module will contain a relationship to a zero point or insertion point, and this should be placed at a location that will remain constant. An example of this is at the corners of framing. Modules can be swapped in and out relating to this point.

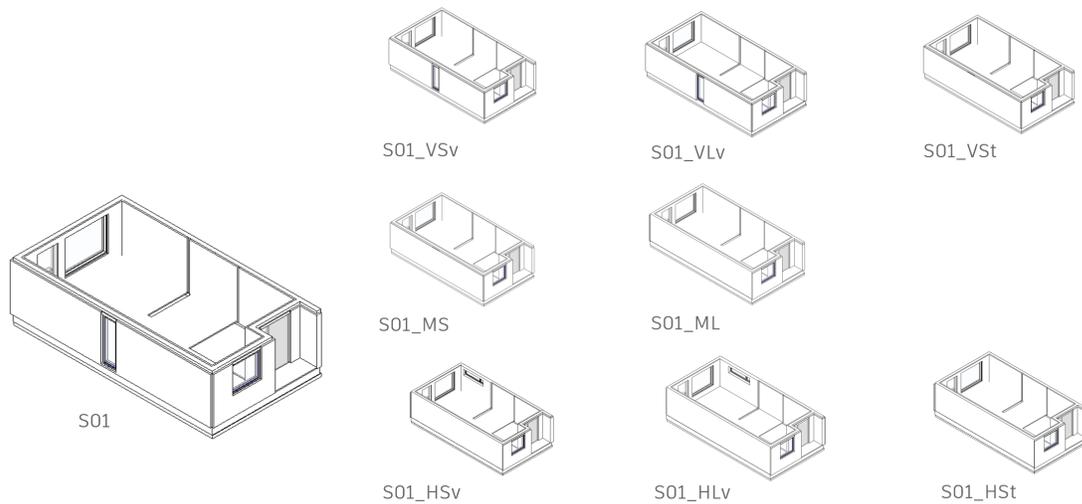


When the module is ready for publishing the below workflow outlines kit connects main concepts of development. The modules are hosted in the cloud and can be shown in 3D or reduced to a bill of materials. The module is then available for use in other projects and formations and when updated we can inform multiple buildings simultaneously and be 100% sure we are presenting the same module in each design. Once hosted in the cloud, those with the correct access can pull the module into the module editor and add their disciplines geometry.



Workflow – kit connect

Below you can see the creation of the S01 module (shell level 1 module) and its subsequent presets or deviating shells. These presets take into account the changes needed where the module sits at a left, middle or right position. The windows and doors are shared so can be swapped out or turned on and off in the preset modules. A robust coding strategy ensures that others can understand the populated library of modules.



S01 module

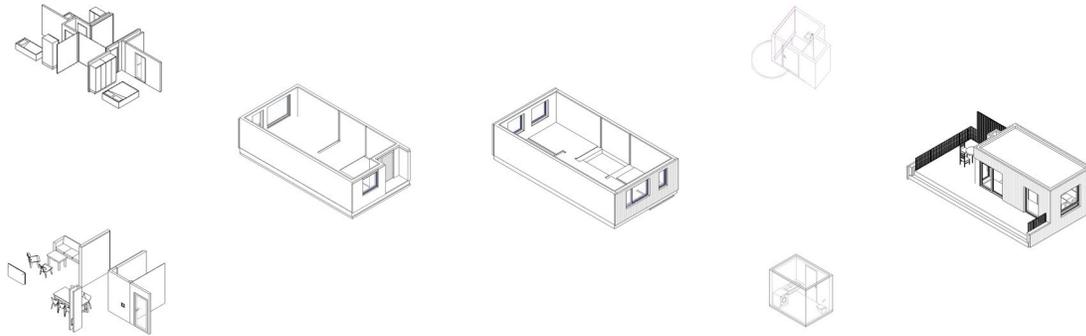
Presets

You have two different ways of viewing your modules in the project – as a conceptual volume or as a detailed module design, and this means you can go back and forth depending on what your project delivery requires.

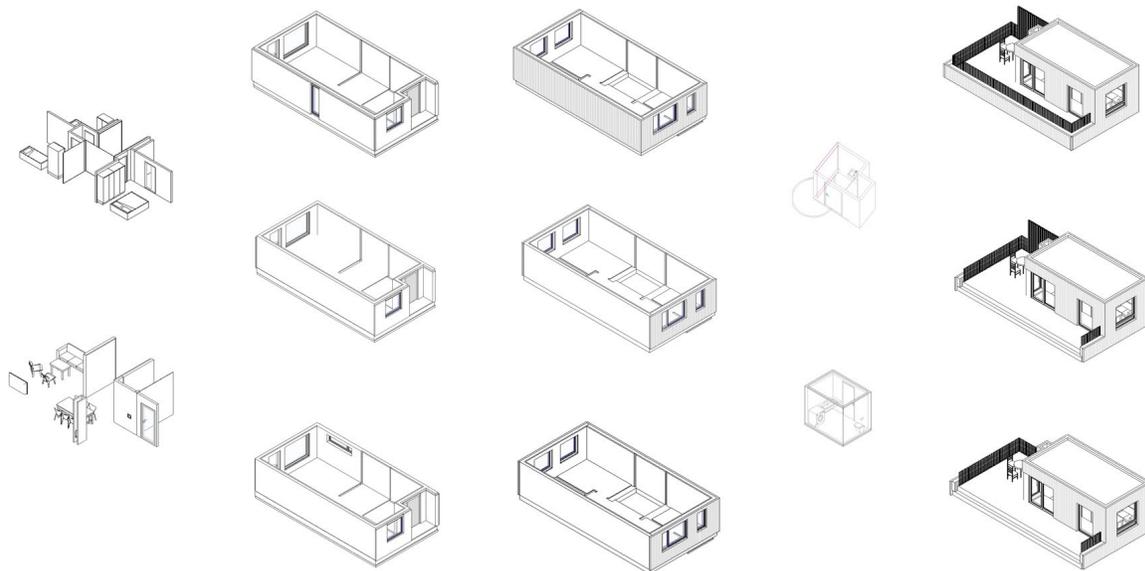
In the future we are also hoping for quantitative information to be present as attached quantitative data for example C02 emissions. Any occurring deviations can be taken up in additional presets using the coding strategy to ensure others can understand the populated library.

After all modules and presets were published to the cloud, we could run a test assembly of a project we already had on file. For this project we needed 7 modules and 6 additional presets.

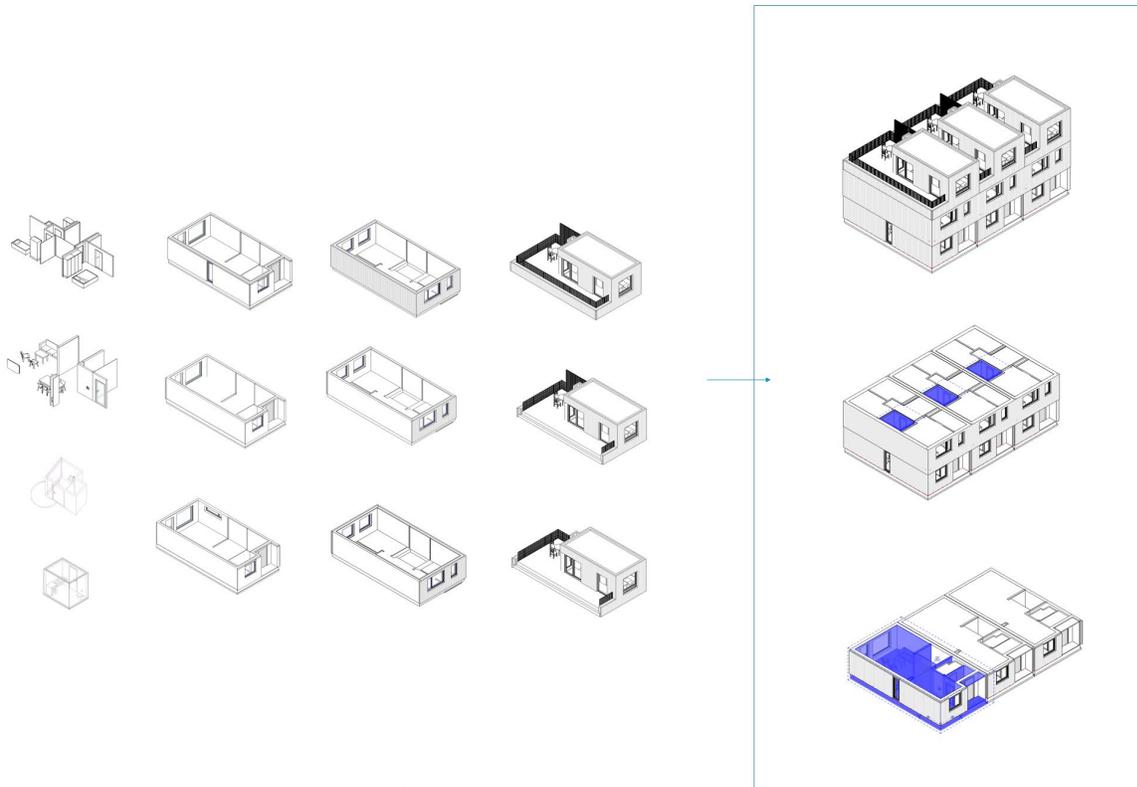
Main module types



Presets



Project formation



After the testing phase, it was important for the client to understand why the current working methodology did not meet up to our expectations and compare those routines with kit connect. Comparing our wish list and the focus area for the testing process we mapped the comparison of the use of links, groups, design options and kit connect. The result showed that kit connect covered many more aspects of our desired workflow than any out of the box tools.

Criteria	LINKS	GROUPS	DESIGN OPTION	KIT CONNECT
One source of truth	n	n	n	y
Needs also a regenerated model from contractors	y	y	y	n
Can work within one revit file	n	y	y	y/n
Other disciplines can also work directly in the same model	n	n	n	y
Works well with repetition (smart updating - one updates all update)	y	y	n	y
Works well with deviations - flexible	n	n	n	y
Works well with alternatives (swap in swap out)	n	y	y	y
Can be shown at different levels of detail (volume vs elements)	n	n	n	y
Easy to export to IFC	n	y	n	y
Extra costs involved	n	n	n	y
Needs a coding structure and strategi for repetition	n	y	y	y
Visual library of parts	n	n	n	y
Can isolate modular information	y (parameter)	y (parameter)	y (parameter)	y
Can attach special information for the use of contractors	n	n	n	y
The system works well long term (team swapping new team members)	n	n	n	y
Needs additional education (aside from revit usual use)	n	n	y	y
Extra time used in start up process to build up a system	n	n	n	y
Time saving in a long term sense (configuration on the site)	n	n	n	y

if collaborated on with contractor modules are edited in the module editor

positive answer based on usability

Summary - Practical tips and tricks

1. Important factors to consider – coordinating the edges in which a module meets another module or any other geometry.
2. Areas of potential change – try to predict any possible alterations, this will save you having to re formulate your coding strategy.
3. Features – not all our desired features are available, but we are looking forward to a potential release of more system families being able to be shared, a module within a module, and quantitative calculations.
4. At the moment the volume to detail change is module based, if it could be that modules could be imbedded in modules the residential unit could be a volume on its own.

Software Developers' Perspective

Customer name (row)	Project Frog	Nordic Cowi	Customer x	Customer y	Customer z	Customer..
Problem (column)						
Sharing arranged elements (KoP)	X	X	X		X	XXXXX
Audit arranged content	X	X	X	X	X	XXXXX
Constrain arranged content	X	X		X	X	XXX
User roles to edit content	X	X		X	X	XX
Communication to non-Revit users	X	X	X		X	XXXX
Part and configuration optioning	X	X	X	X	X	XXX
Multi trade collaboration	X	X		X		XXX
BOM/s	X	X	X	X		XXXX
I.C. logistics	X			X	X	XX
Level of Detail/Development	X	X	X		X	XXX
....	X	X	X	X	X	XXXXX

Data and discovery with customers in I.C.

1. Gathering and categorizing this data has defined KitConnect and its' path.
2. Discovery process unique (not limited) to;
 - a. I.C. process = accomadate company workflows and project specifics. Etc.
 - b. I.C. process = what will be fabricated offset, the logistics of fabrication, assembly and VDC/DfMA workflows. Etc.
 - c. Company workflows = what are the required internal BIM workflows. Etc.
 - d. Project specifics = timelines, delivery methods, client requirements, file structure, BIM workflows, how will collaborate be delt with. Etc.

How to begin

1. Create a KitConnect Project
2. Assign users to the project
3. Connect Revit files to the project

Build your content

4. Publish, arrange and apply rule sets to your content

Use your content

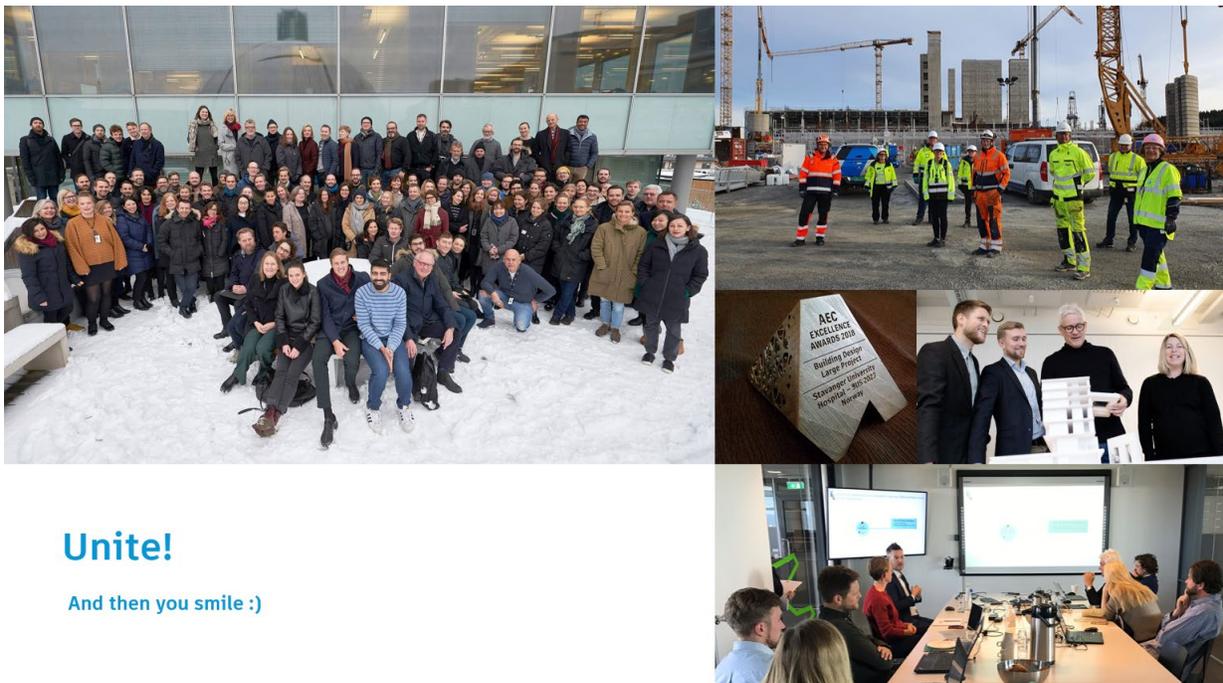
5. Use and edit your content in Revit projects

Conclusion

The collaboration with the programming team of COWI and the software development team of Project Frog reflects on the challenges that architects and engineers have faced in the presence of repeating information.

One of the crucial things about developing technology is that we must start with the project team's needs and then work backwards to the technology. We cannot start with the technology and then try to figure out where we are going to put it in our project. If we can only use one or two programs to overcome the challenges and 1 or few clicks to rule it all, why do we need more?

We have chosen to unite with the programmers and software developers to overcome the defined challenges in our projects. Starting from the New Stavanger University Hospital project and then being further developed for housing projects, our workflows and the experience of collaboration are highly recommended for similar projects focusing on industrialized construction, modular design and repetitive layouts (hotels, schools, office buildings, etc.)



Unite!

And then you smile :)