The design, build and operation of the new A-wing of University Hospital North Norway

Tromsø

Investigating the use of standards

and their impact on

innovation

Case report in the BISI project

Building Information Standards and Innovation

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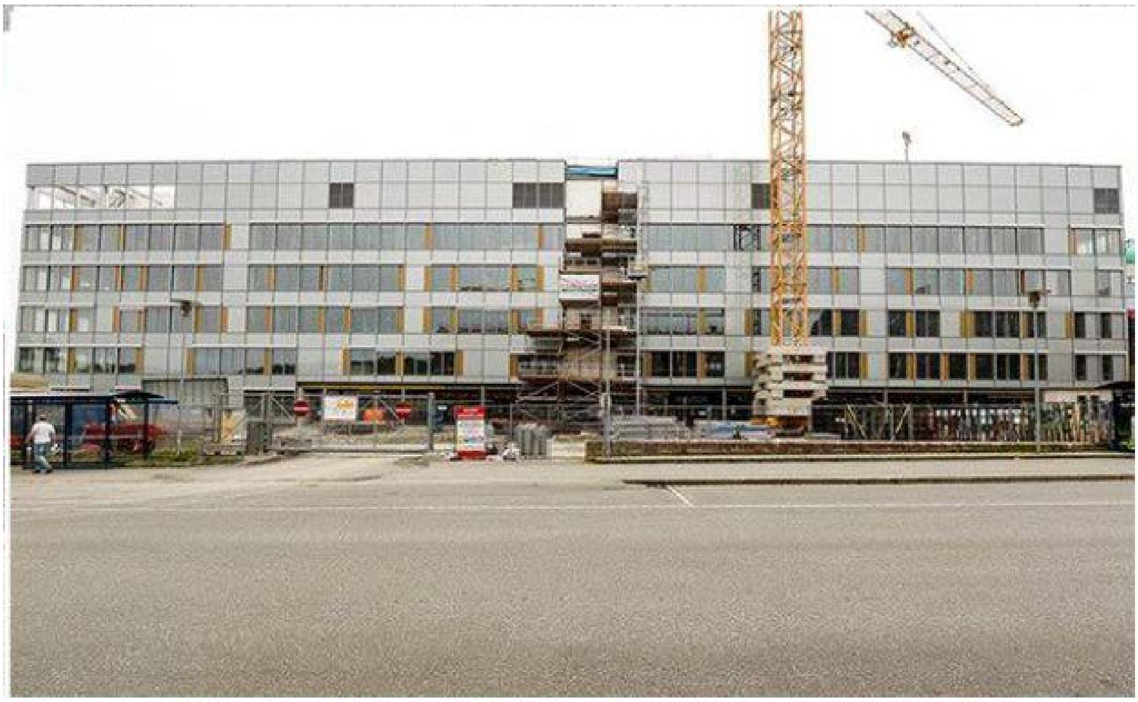
Contents



01 Executive summary

This case report covers design build and preparation for operation of a new hospital wing at the Unversity Hospital of Tromsø, Norway. The case report is part of the Building Information Standards and Innovation project financed by Nordic Innovation and the participants.

The process covered in this case report is roughly from 2012-2017. The construction is still ongoing per may 2017 and is expected to finish by November 2017. The hand over to the facilities management has been ongoing from some time. The process has involved a major restructuring when the client decided in 2014 to shift contract model to a design build contracting. The resulting process is an “in-between” hybrid between design-bid-built and design-built.

The BISI project has been limited in resources in studying this process. The method is a combination of interviews and documents study complemented with minor on site interaction.

The main result of this report is, that it has not been possible to document direct effects from the use of building information standards. However, as information standards are embedded in software systems, the effect of using BIM and other IT tools on innovation, can be understood as a result of a combination of standards, IT and human efforts. And this closely interrelated hybrid combination involves and leads to innovations.

Some integration between IT systems and BIM models between companies and client have been realised. Once entering the construction phase, 12 BIM models was used in a coordinated fashion. The IT use coexists with certain work tools that remains paper based. Work drawings, planning exercises and generation of bill of materials, are all examples of work done partly in a system and partly checked, read and used on paper.

The classifications in use are IFC for data transfer, room classification based on a Sintef system, NS 3240 for descriptions, a multidisciplinary component coding system TFM (Tverrfaglig merkesystem), and several other building component classifications systems. No process information standards have been in use. In this project two variants of TFM are involved: The version the client use and the version the architect develops during the design. TFM is maybe believed to have the functionality and authority to provide a homogenous and uniform classification, but using variants generated extra costs. The Architects BIM coordinator has been a central “fiery soul” (ildsjel) for the use and development of classification and the client and the design build contractor have benefitted from that. The client has chosen not to drive this issue.

The three most important innovations, that had some relation to the classification was a modification of TFM for work drawings, a system for monitoring production progression, and an app for reading the architectural BIM model. Many other innovations in the project did not have direct link to the use of building information standards. The most important was the conceptual change of the building demolishing more and changing steel, prefab and façade. Moreover, the use of lean management including daily huddles and takt planning is an important innovation. Further minor examples include a BIM hut on site for DB-contractor worker to read BIM models, a Work Environment inspection tool on a app, and the HVAC engineers using innovative ventilation principles. The project involves BIM and IT infrastructure broadly in line with contemporary solutions on the Norwegian building market, assured by the involvement of major players doing Norwegian hospitals. The project is also exhibits innovation of processes, products, organisation and business models. However, most innovations do not surpass what would be common on a Norwegian market or the Scandinavian market.

02 Introduction

This case report is part of the Nordic Innovation project "Building Information Standards for Innovation in Public Procurement of Buildings" (BISI). Below we will go through objectives, central definitions, timeline, terms and partners.

Objectives for the BISI project

The BISI project is a response to a call for research from Nordic Innovation. Nordic Innovation asked for studies of standards as a tool for business success, and for contributions to our understanding of the links between standards and innovation. The purpose of the Nordic Innovation call was also to develop concrete initiatives that show how standards contribute to innovation. And to study how new standards are created or implemented as a main driver for innovation within a specific sector. Scoping this to how standards are created or implemented as a platform for radical innovation or to drive incremental innovation. And documenting the innovation-enhancing effects, through studies in specific sectors and based on a concrete standard or a set of standards. Finally the call also communicated that Nordic initiatives with a European and international perspective was interesting.

On this background the BISI project was formulated with a point of departure in the recent new classification cuneco classification system developed in the Danish building sector context. The goals of BISI have developed from only focusing on one classification to looking at a constellation of standards active in the Nordic building sectors. The BISI goals are therefore

Aims of BISI project:

- Mapping and analysing the impact of building information classification on innovation processes in the building sector in Denmark, Norway and Sweden.
- Mapping and analysing changes in innovative direction in public procurement of buildings enabled by building information classification in Denmark, Norway and Sweden.
- Comparing the use of standards and classification in public procurement in Denmark, Norway and Sweden.

Answering to these aim is done through BISI methods. These are described in appendix 1 in section 11.

What is a building information standard?

The aim of building information classification is to standardise use of information by creating similarity, homogeneity and consistency across time, space and participating actors.

Some building information standards cover both build products and building processes. This is for example the case of cuneco classification system (CCS). CCS and other standards can moreover be characterized as "suites" of many related standards, like the Norwegian Standard, (NS) or Swedish BSAB standards. Many standards refer to the ISO standard ISO 12006-2, which is a standard for standards of building information (Ekholm and Häggström 2013, ISO 2015). A list of standards in this case is included in appendix 3.

Building component standards would usually encompass attachment of properties be it physical, functional, aesthical, cost, shape, or time. Several of the contemporary standards are relatively general, because the approach is to maintain the standard structure and handle variety through assignment of properties to the standardized objects.

In the present study, the understanding of classification and standards have on purpose been broad to allow for actors in the project to voice their understandings.

What is innovation?

"An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations." (OECD 2005).

It derives from the definition that innovation can occur in many aspects of a business as well as in a building project studied here. It is thus common to relate newness to the particular context and understand innovation as anything new in the context. Here however it will also be evaluated whether innovations in the project are new in a broader context.

Timeline and terms

Below is indicated the main overall timeline and some of the main processual/phase terms of the project (in section 7 follows a more detailed timeline):

Norwegian concept	English translation	Actual project
Konseptfasen	Programming	2009-2010
Forprosjekt	Outline proposal	2012
Funksjonsprosjekt	Functional Specification	2014-2015
Prosjektering	Design	2014-2015
Detaljprosjektering	Main project	Juni 2015-march 2016
Anbud	Tender	Spring 2015
Utførelse	Construction	August 2015-november 2017
Forvaltning/Drift	Facilities management	January 2018

Building process norm terms translations in column 1 and 2 are taken from NTNU (2015) and Norwegian websites such as Norsk Standard 2017 (https://www.standard.no).

More terms are included in the glossary in the appendix 2, section 11. Many hospital context terms are translated using NHS (UK) reference terms see the glossary, section 11.

Partners in BISI

- Chalmers University of Technology
- Norwegian University of Science and Technology
- K-Jacobsen A/S
- Projectspine A/S
- Central Region Denmark (Region Midtjylland) DNV-Gødstrup
- Helse Nord Øst, Universitetssykehuset i Tromsø
- Landstinget Blekinge, Sjukhuset I Karlskrona

Enjoy!

03 Presentation of the project

The university hospital Northern Norway UNN has its headquarters in Tromsø, but is also placed in several other towns in Northern Norway such has Harsted and Narvik. The UNN employs some 6300 and carry out 400.000 annual patient encounters (patientmøter). The unit in Tromsø employs 4.500. The main body of the buildings of the hospital dates back to 1991 and the regional administration have initiated three major projects recently; The patient hotel, the A-wing and the PET center.

The total project is a 22 000 m² renewal and extension of the existing university hospital. The A wing of 13 000 m² will contain emergency reception with drive in of ambulances, polyclinics, test laboratories, a day surgical department including operating rooms and day care centers, bed sections, intensive care department, rehabilitation department, and clinical-medical laboratories.

As one actor put it "It is not just a wing, but an entire mini hospital. It has the whole package"

("Det er ikke en fløj, men et minisykehus. Det har hele pakken")

Total projected costs are at 1,6 billion NOK. The contract sum for the Design build contract is at 700 mill. NOK, whereof the HVAC subcontract is at 280 mill. NOK.

The designed A-wing has six floors above ground, and 11 floors in total. where the ground floor is reserved for the ambulance and other acute receptions. This reception enables ambulances to enter the building. The 11th floor is reserved for technical installations. Surgery theatres are placed low in the building.

To realise the new A-wing, it was first planned to demolish 8000 m2. This was later extended further. In connection with the construction, a number of renovations are carried out in the adjacent parts of the building, to ensure effective functional relationships between the new building and the existing hospital. In addition, the conditions in the existing emergency reception are improved.

04 The actors in the project

Client (University Hospital Northern Norway UNN)

The hospital organisation is quite extensive and disperse. Attached to top level hospital management is two main elements important for this project:

- The building project organisation
- The facilities management organisation

The hospital organisation has had a long break in major new projects and felt the need for building project expertise. An external consultant was there therefore hired to manage the project.

Architect (Rambøll)

Rambøll is a major Nordic player with extensive hospital design experience. Here it is the Trondheim architectural department which is involved in

- Architectural Design
- Landscape architecture
- BIM coordination

Consulting Engineer (Cowi)

COWI is a major Nordic player with extensive hospital design experience. Here it is the Trondheim engineering department which after the initial programming phase became responsible for design management (detailed design), and progress planning. COWI was from the outlone proposal phase responsible for the following consulting engineering tasks:

- Building (bygg RIB),
- Water and Heating (VVS, RIV),
- Electrical design (elektro RIE),
- Fire (RIBR),
- Acoustics (RIAKU) og
- Environment (RIM).

After the design build tender COWI was contracted by Bravida (contracted by Consto and in turn the UNN client. In this phase COWI was responsible for design for water and heating (VVS), including sanitæranlegg, varmeanlegg, sprinkleranlegg, kjøleanlegg, gassanlegg og ventilasjon)-prosjektering and electrical design.

Design build contractor (Consto)

Consto is originally a northern Norway regional design build contractor (abbreviated DB contractor). They have relatively recently become national. They are involved in

- Project management, site management
- Design management steel, prefab, facades
- Carpenters work

Consto are also involved in the other two UNN projects, the patient hotel and the PET center.

Technical installation contractor (Bravida)

Bravida is a major Nordic and European player with extensive hospital design experience. Here it is the Tromsø department which is involved in

- HVAC Plumbing, cabling, ventilation, sprinklers
- Electrical construction
- Automatic installations.

Bravida Tromsø have only recently become the comprehensive technical installation contractor, that is Bravidas corporate strategy.

Other contractors: around 20, examples

Painters

Tile setters (flislegger)

Specialist's suppliers, many, examples:

Olympic operation surgery equipment

Schneider, Electrical equipment supplier

ABB, Electrical equipment supplier

Siemens, Electrical equipment supplier

Ruukki (Finnish) steel supplier

Arcon (Finnish) supplier of Steel structural engineering

Prestressed hollowcore floors supplier (Hulldekk)

Staticus Norwegian/Letvian supplier of Façades

05 Organisation

The project has been organized differently over time, according to the development of tasks, but also the change of contract form.

The first design organisation 2009-2015 consisted of the clients project manager and representatives from the architect and consulting engineers.

The second organisation featured more or less the same as above but a rigorous process of collecting user demands from hospital employees. Managers and FM- people commenced participating. A series of user groups were active during specification 2012-2014.

The shift to a design built organisation from 2015 and on, also implied tuning the organisation to the production tasks. The DB contractors project manager and design manager became central persons.

New design was commenced in collaboration with the client, yet with the architects and consulting engineers in a less central role. Once production commenced, a production organisation using lean management became central and building workers, specialists suppliers and a series of subcontractors became central. Intensive coordination work is carried out on site.

IT- organisation

BIM coordinator is placed at the Architect. The coordinator have been active throughout the design and detailed design phase and also presently (summer 2017) during construction.

When the project reached the detail design phase at the design build contractor, 12 BIM models were in use. The coordination of these was done at regular 14 days meetings.

The common model was used for inspection and clashtesting, (size 133 Mb).

06 The IT architecture

Client

dRofus, room programming software, including a Technical Information Database called TIDA prepared for transfer of data to a FM system.

Interaxo, project web

Plania, Facilities management system (FM).

Architect (Rambøll)

ArchiCad, Design software

Revit

DRofus

Gprog

Consulting Engineer (Cowi) piping, ventilation, fire protection, and electric.

dRofus

Revit

Autocad, design software

Magicad (ØE 2016) design software

Further engineering profession specific applications

Excel, Microsoft office spreadsheet

Gprog, software for descriptions

Design build contractor (Consto)

During the detailed design of structural elements, steel, prefab and façade; Tekla, Revit and Autocad.

BIM models (architectural plus structural engineering) (JS&EM 2016)

Tekla, BIM software for structural engineering (EM 2016)

Microsoft project – planning software

Excel was used for planning

Unisite developed for follow up and monitoring of progress on site

BIMX for visual inspection of architectural BIM model on a smartphone

A BIM hut (BIM Kiosk) on the building site to support the DB contractors employees in using the BIM model as tool in the work (as supplement to the provided 2D drawings).

HVAC contractor

BIM models in Revit and Solibri model checker.

The table below collects the models in use at the time of production. The models were regularly run together in one common model for inspection and clashtesting, this common model is at 133 Mb.

There is however also examples of interoperability that did not work. Transfer from a BIM Revit model to Gprog should in principle be possible using IFC. However neither the Architect nor the consulting engineer used an automatic transfer. The contractor did no attempt to transfer BIM data into Microsoft project.

It can be noted that the clients FM organisation does not directly use or plan to use BIM- models. The FM system will Plania should be used more in the future planning of FM activities. The interpretation is that Plania does not make any barriers towards BIM and that the loss of not operating a BIM model is minor as the more important part is to be able to import data into Plania.

The main gain using Plania is that all the information needed is located in one system. In the old system we had quite detailed information.

The preparation of as built data is also somewhat troublesome. Excel is used to collect data, to process the data and enter them into TIDA (Technical Information Database, part of Plania). To day this is not a seamless process.

Table: BIM models in use

Actor	Number	Focus of model	Software
Client			
Architect	3	Structural Façade Landscape Interior	Archicad Archicad
Engineers	6	Electricity 1 Electricity 2 Electricity 3 Heating Ventilation Sprinkler	Revit Revit Revit
Design Built Contractor	2	Structural Steel Prefab	Tekla Tekla Tekla
HVAC Contractor	6	Electricity Heating Ventilation	Revit Revit Revit
Total number in use	12		

Design build contractor/ during construction

Solibri model checker in design of prefab, structural engineering and facades (JS and EM 2016)

Excel and Microsoft project for scheduling of site work (not integrated with BIM software, “interface” printed drawings)

Solibri model checker to enable use of the BIM model in the planning and scheduling meetings

A BIM hut (BIM kiosk) on site with a possibility for Consto’s construction workers to check the model.

BIM+ app for smartphones (content provided by Architects BIM coordinator)

Unisite for progress monitoring.

SW for health and safety auditing.

07 timeline

Below some main events in the project is pinpointed. Many of them are further explained and discussed later in the report.

2009

The concept project initiated and developed

The client appoints a project manager, externally recruited, to run the project as the clients representative.

2012

A competition for the design is won by COWI (engineering) and Rambøll (architecture). The task was to do a functional specification project of the Awing. This involved specification of rooms. The tenders demand for BIM solutions was moderate. The architects developed the BIM manual for the project.

2014

Architectural design and engineering design. The latter was organized according to contracts for each technical specialism, preparing for a similar contractor structure.

The clients shifts project manager and contract strategy, to design build contracting. At this time the consulting engineer interpreted that the design was about 90% ready. At later stages tensions occurred on the degree of finalization.

Prequalification of the later DB contractor and HVAC contractor that teamed up for offering a bid.

Detailed design ongoing at Architect and Engineering consultant. Engineering consult arrives at have 6 different BIM models, 90 detail project and models for each floor of the building.

A functional specification is developed to support the tender for a design built contract. This is also internally in the hospital sold as an important freezing of demands. Hospital management underlines the importance of the process done, of the joint scrutiny (gjennomgang) which has been done as well as that the specification has been signed by group leaders in the organisation. Moreover it is guaranteed that no changes is made without internal approval. The functional specification contains drawings on several levels and describes rooms and equipment (Hanssen 2015)

2015

April contract negotiation Consto - UNN

June Design built contract signed

Consto receives a very detailed architectural BIM model and extensive material from Rambøll. Consto, especially their project manager for design, choose to rely on the material and commence by making samples here and there in the model and the material. Consto takes over the risk in a Design Built contract on that basis (JS 2016).

Yet Constos propose a new built approach which leads to roughly three quarters of a year design of the steel structure (EM 2016).

August building site activities commence. Demolition of the existing A-wing.

October construction of Steel skeleton and concrete element assembly commences.

2016

January February Construction of Steel skeleton and concrete element assembly continues.

January -September Architect and Engineers develop work drawings for HVAC . This process involves the Design build contractor and the technical installation contractor. Draft work drawings were sent as pdfs to the contractors, which audited them and sent them back marked up with request for changes and improvements.

March; the first façade elements are mounted.

June July; the inside of the building is sufficiently dry to commence mounting inner walls.

15 of august deadline for the contractors to deliver a "tight building".

August When the HVAC contractor started working with larger crews (20 people in total), they discovered that many of the work drawing remained unchanged, with previously identified errors remaining.

August December; Installation works and other contractors worked their downwards in the building commencing with the 10th floor. The complex technical installations of the surgery theatre was carried out in parallel.

An external HVAC expert was hired to audit the HVAC design. A number of issues were found.

September; the design formally finished.

Construction and installations construction work their way downwards in the building.

2017

January; construction continue to work its way downwards in the building. The takt planning means that carpenters are followed by technical installators (plumbers and electricians). Later comes tile setter and painters.

February, wall building, technical installation and other works reach the 5th floor. Meanwhile at floor 10 walls are painted, floor mounted and inner ceilings under construction.

April test commences gradually

May. A gradual handover for the Facilities Management organisation began. The first step out of three. These steps mean that the contractor provides as built data structures/classified according to UNNs classification system.

August; test planned to continue, production planned to be largely finished.

November: functional tests planned to be finalized, and testing operation can commence

December: planned organizational changes in the hospital.

2018

January Clinical operation planned to commence.

08 Analysis

This section contains the analysis of the Tromsø A-wing project. The structure of this chapter is the following: a. the project in general, b. the classifications in use, and c. the innovations. Where a. are relatively short, b. contains the many different standards in use in the project and c. contains a number of themes; different innovations, expected and non expected.

08a The project in general

The project is a new wing fitted into an existing university hospital. However at a time this new wing contains many functions that make its design and construction almost as complicated as a small new hospital. The budget and time schedule in principle enable concerns of innovation.

The fitting of a new building into an existing building gives special interfacing challenges as the adjacent older buildings operate another floor height, than contemporary hospital buildings do. The floor height is viewed as a key element of long term flexibility of the building. This complication triggered the proposal of demolishing more of the existing.

The use of BIM and digitalization tools has until the tender stage been driven by one architect also appointed as BIM coordinator. His understanding also implied early proactive classification of building components and rooms using dRofus for rooms and the multidisciplinary marking system, TFM in a modified form for components. This was accepted by the client, yet not directly required.

The client carried out an important change when shifting from design bid build of a portfolio of contracts to a design build contract tendered on the basis of a functional specification, yet after most of the detailed design had been carried out. This assured a transfer of risk to the design build contractor and created some discontent by the consultants. The transfer of design materials (BIM models and documents) from the designers to the design build contractor was very extensive and in essence incomparable with other contract forms, representing an "in between" form (Hansen 2013). Subsequently redesign was carried out of for example the façade and the use of glass wall internally

The project is characterised by a mixed IT and manual work practices. Some integration between IT systems and BIM models between companies and client are carried out. But this integration coexists with certain other work tools that remains paper based. One example was generation of bill of materials, which was done in each system separately and checked on paper. Another example is work drawings, which are pdf based when delivered by architects and engineers. The Design Build contractor benefit from this paper based work form in their planning and operation, yet also appear prepared for a digitally based interaction. The HVAC contractor is still not ready for digitally based interaction, when it comes to work drawings.

Another challenge of fitting the new building into the existing occurred during construction, where an existing concrete wall had to be enforced.

08b The classifications in use

During the functional design in the project proposal phase room programming was a central activity. At the outset the Sintefs classification was used, implemented in dRofus. The hospital/clients use their own room classification system. There is even elements of the national Helsebygg system in play.

The architects classified elements such as doors, furniture, hospital equipment for the rooms in the A-wing using the coding that dRofus offered. There were large amounts of special furniture, but also more common elements such as meeting tables. This started during functional specification and continued during design. Even if dRofus has a built-in standard for classification, it appears that the systematic can differ from project to project depending on the input and who is doing the work. Some of the information is stored several places in dRofus. Challenges thus occur regarding how the classification and coding in dRofus is organized, and how the different software design software and the architects and engineers traditional way of coding is done.

The Architect’s BIM coordinator developed a variant of the TFM coding, by reducing the code with one digit. This modified system was used to classify early, proactively and thoroughly in the architects model. The architects and consulting engineers platform for design were relatively dependent, despite 14 days regular coordination and collision control where interoperability appears relatively unproblematic (interview).

The consulting engineer initially used running numbers in geographical areas for rooms. The entering into dRofus was following an end-user dialogue. At a later stage TFM was suggested for components classification and when the engineering commenced a handing over to the contractor, a demand for a detailed and further numbering from the contractor was surfacing. This reveals that the engineering was classified in a relatively reactive manner, i.e. not being entered if not absolutely necessary, which is viewed as more efficient (interview). The engineer did not use generic and classified objects from their own company libraries.

As more design types entered more BIM models were developed based on different design software; ArchiCad, Revit, Autocad. In number BIM models grew from 1 to 8-9. The BIM models were coordinated using IFC.

Once the technical design was ready for tendering descriptions, exerpts was exported from ArchiCad, Revit, AutoCAD and Magicad BIM models and transferred to Excel and further to Gprog, a software tool to make descriptions, which embodies an implementation of NS 3420 (Norsk Standard 1999). It was attempted by the architects to transfer directly to Gprog from Archicad without success.

The HVAC contractor followed what the client wanted, which was the specific UNN classification (also called “the classification system”/klassifikasjonssystemet). The HVAC contractor viewed this as a kind of combination of TFM with local demands.

The clients facilities management organisation invested in a FM system, Plania. It was demanded that (as built) data should be prepared for being feed I this system. And is was demanded that UNN classification system was used. There is a dRofus-module designed for Facilities Management handover, TIDA (Technical Information Database) where contractors have access to upload all FM documentation related to "their" systems and components. TIDA was actively used by both contractors and the clients FM organisation, predominantly using the UNN classification system.

Phase	**Systems in use**	**Classification in use**
Outline proposal	dRofus ArchiCad	UNN classification Helsebygg classification Sintef classification
Design	Archicad, Revit, Autocad, Magicad, Solibri	TFM – components TFM – components , modified IFC
Main project	Revit, Autocad, Magicad, Archicad Solibri	TFM and TFM modified Steel design Revit inbuilt IFC
Tender	Revit, Autocad, Magicad, Solibri, Excel, Gprog	NS 3420 descriptions
Construction	Revit, solibri	All types
Operation	Plania, Excel, TIDA	The UNN classification based on NS3451 and close to TFM.

In this project, at least two versions of TFM is in use. The version the client use (because TFM is viewed as being to detailed) and the version the architect develops during the design (using one digit less). It is observed by the actors that often TFM is believed to have the functionality to provide a homogenous and uniform classification, yet interpretations and variant tends to flourish at the Norwegian building market. TFM are interpreted by the various public clients, but also in building companies, and vary down to offices, persons and users (interview). It is a change of practice from classifying and coding of building systems and components related to drawings, to a situation that all this must be done digitally for example in dRofus, Revit and Plania. It is hard for experienced practitioners to adjust to this, and some do not really see the added value and/or consequences. It is another systematization than they traditionally have been using.

There are opposing interpretations of the level of detail in TFM, two actors find it too detailed and one too little detailed to encompass all necessary components. The FM organisation risk to get too much data, which combined with the usability of the system being suboptimal is at risk of not being used. Several actors posit that "*We want to deliver as little as possible, make it simple and easy to navigate. A very simple manual for O&M with basic information".* Yet this leads to too little detail to encompass all necessary components for a TFM classification.

The changed use of TFM and its variants also resonates with an emerging National Norwegian ambition of enabling benchmarking between hospital units (Sykehusbygg 2017). In this perspective, a common more uniform classification becomes important, yet is at odds with long term existing practices in the different regions.

The Architects BIM coordinator has been a central driver for the implementation of classification and the client and the design build contractor have benefitted from that. The client has chosen not to drive this issue, which created a room for different interpretation and use of classifications

It is likely that the "as built" information has/will have a structure close to TFM, yet slightly different and that this will lead to extra modification when fed into the facilities management system.

There has not been any standard for phases of detailing of information in play. The participating companies instead relied on agreements for deliveries for the Norwegian building sector (REF)

08 c the Standards impact on innovation -expected and realized

In this section the impact of standards on innovation is analysed. We do this by first briefly outlining what our literature review established would be the expected innovations – and we then turn to what are the realized.

Innovation benefits identified in the literature study of the BISI project (Beemsterboer & Koch, 2016). In with the literature review, innovation is seen as a process of implementing something new or significantly improved. This section is firstly organised in line with the seven innovation benefits of standards as described in Table 1. Afterwards other innovations is discussed that was found in the case study.

Table 1: Possible innovation benefits due to standardisation

Standards may enable innovations through:
1. Improved coordination enables higher complexity 2. Standards enable process stability 3. Quicker diffusion of innovations 4. Direct efficiency gains enable exploitation of new ideas 5. Indirect efficiency gains give resources to do something new 6. Standard adoption requires organisations to innovate 7. Standard development increases capacity and network of participants 8. Standards enable business model innovation

Source: (Beemsterboer & Koch, 2016)

Improved coordination enables higher complexity

The project experienced in shift in contract form, that put its coordination mechanisms under pressure. In the early design organisation the consulting engineer was charged with an entire package of disciplines, except architecture and structural design (RIB). The Design Built contractor chosen by the client opted for new solution of fitting the building into the existing, of steel, facades. The impact of building information standards should be viewed in this context.

The coordinated BIM models did contribute to enabling this substitution of design parties. The impact of a well standardised material cannot be discerned from more generally the BIM models and the documentation, but in this embedded manner the standards also contributed to handle the coordination challenges.

There appears to have been two strongly coordinated parallel tracks which was then looser coordinated: one stronger coordination occurred from Architect to structural engineering and construction of steel, concrete, facades and inner walls. Another occurred from HVAC engineering to HVAC construction works. The shift in contract form resulted in a weaker relation and coordination between the engineers and the architect and the BIM coordinator in the later phase of the project because the HVAC consultant had a contract with the HVAC contractor and any changes had to be cleared with them, the Design- Build and the client building organisation and the clients user representatives (in that four step order). Nevertheless, the later organisation did manage to handle changes in the architecture, RIB and HVAC.

Standards enable process stability

Standards for processes in use have been the agreements on the Norwegian building market on design services and design build services (REF). These standards does not directly accommodate use of BIM or classification. A level of design or level of development standard have not been used.

It can be argued that even product oriented classification can contribute to process stability. In this perspective a series of standards contribution to stability could be analysed. For example The use of dRofus and TFM with standardisation of room categories, numbering of rooms and functions and components have given a certain process stability in the basis for the design and construction. However, the potential for a stronger and more consistent information capturing and flow throughout the whole process has not been fully utilized.

Quicker diffusion of innovations

The hospital projects in Norway has for long represented an important arena and community for developing standards and innovation. In a long period, however the regional clients organisations worked with each their standards and also developed their own innovations together with their consultants and collaboration partners. In this period, much of the diffusion of innovation would occur through companies working on more hospital projects either in parallel or in sequence. But it has throughout the last renewal wave been a widespread activity to visit and and learn from each other. Something that the client also has practiced in this project.

More recently (2016) a stronger common national organisation has been built (Sykehusbygg 2017). This might imply a more common and coordinated standardisation and common development of innovations. However it appears that the regional organisations will keep their present version of TFM at least for some time into the future (Sykehusbygg 2017).

The consultants, architects and engineers are part of several other hospitalprojects and distinguish between which are more or less innovative also with respect to standard use and digitalisation. The present project have in this context acted more as a receiver of standards and innovation than acting as diffusor of new innovation.

Direct efficiency gains enable exploitation of new ideas

Using IFC enabled regular and intensive collision control during detailed design between a number of BIM models. Such improved and active collision control improve the quality of design, preparing it better for the construction. Joint inspections using for Solibri also enables finding issues and problems that can initiate innovative solutions.

As mentioned previously the contract form was changed when the design was under detailing. Most actors refer to this as having generated extra costs in terms of man hours spent. However, the shift to a design -built contractor also generated a major conceptual change in the building. This shift can be interpreted as a major cost reduction gain, but also involves other types of gains, such as a better fitting to the other adjacent buildings. It is ascribed to the design build contractor to having proposed and realised this conceptual shift. It can be seen as enabled by extensive use of BIM engineering and indirectly drawing on classification standards inbuilt in Thekla and Revit. It is however not possible to discern BIM use from classification use.

Indirect efficiency gains open up resources to do something new

There are several examples of cost reductions carried out in the project. A shift of façade concept and a price check of valves are two. In a similar sense as with the direct efficiency gains it is not possible to discern BIM use from classification use.

There has not in general been a systematic search for cost reduction in the project and the focus has more been on avoiding that costs would grow too much.

Standard adoption requires organisations to innovate

The BIM coordinator of the architect took the opportunity to adopt a rigorous use of classification of the architectural design, once it was clear that the client wouldn't drive the issue and stayed passive. The rigorous classification did collide with concerns of building workers ability to interpret the long code names of TFM. The BIM coordinator therefore innovated a new and shorter version of TFM used on the work drawings.

The FM organisation of the client prepared itself to receive the structured as build material by hiring a consultant to aid in transferring the data in the FM-system. Internal on the job learning of the FM system and its classification was also carried on. Mostly the classification used was the existing UNN classification system however. The HVAC designers and contractors used the UNN classification system rather than the TFM.

Standard development increases capacity and network of participants

The widespread use of TFM by hospital organisations in Norway signifies a possible common platform for a common standardisation support new built and facilities management. So far however the practice appear to be limited to developing local variants of TFM.

The new strategy of Sykehusbygg (2017) represents a possible stronger common development of standards in the future.

Standards enable business model innovation

There are not found examples of direct business model innovation as consequence of use of building information standards. The software supplier Unizite already had established their business model of providing tailormade software and apps before entering a collaboration with Consto. The other software supplier are mostly relatively distant in the project, including the supplier of Plania the FM system.

The surgery theatre supplier Olympics was asked to design their surgery theaters in a more BIM based manner than they apparently was used to and appear to have realised that even it there were collision issues with the ventilation design. This innovation create new business opportunities for Olympics in future hospital project. It is not possible to discern a BIM contribution to this from a standard contribution.

Realized Innovations – other than expected

In the following we consider innovations (and non innovations) found during the case study.

Modification of TFM

A modification of the TFM coding to accommodate this particular project (ArchitectEH interview). This was done to support reability of the 2D work drawings.

In doing the simplication the architects did run out of code when classifying on the work drawings.

The Architect modification of the TFM code.

A TFM building component code normally looks like this

+AAA=NNN.nnn-BBnnn

+AAA is the resulting lokaliseringskode
NNN.nnn is a system code
-BBnnn is a compont code

For the Awing project the right hand side elements have been modified to

nn.nnn

Where nn is a two letter component code
And nnn is numbering

For example and indoor wall was coded AV.123 (indoorwall number 123).
In some occasions a code for further specification was developed. Thus
”AV S12” means and indoor end wall, number 12. (S for Skjødt – end)

The modification enabled 2D drawings use on the buildings site of craftsmen and building workers, which appear to have received this modification well. The impression of the building workers of the DB contractor is that they are well prepared for future digitalization. The HVAC contractors employees and hired-in people still need 2D drawing to do their work.

BIM model on app

In collaboration between the architects BIM coordinator and the DB contractor opdated BIM models (on the architectural side) were provided on at smart phone app call BIMX. This software interfaced with the Archicad BIM model through using IFC.

Monitoring production progression on an app

A software company (unizite) developed at a smartphone tool for follow up and monitoring of progress on site. The system is designed in collaboration with the site manager and reflects an emphasis on follow up regularly on takt and zones in a manner where areas are left finished and cleaned. The system draws on the architectural model and its classification to provide overview of the large number of zones and activities running in parallel. This system is extracting data from the remainder of the IT-architecture, but operates on 2D drawing models (plantegninger) and is not creating feedback to other systems.

Innovations not connected to use of building information standards

The HVAC Engineers have designed ventilation using innovative ventilation principles, including displacement ventilation (fortrængningsventilation) and stirring ventilation (omrøringsventilation), including prescribing an exhausting valve on the roof.

The DB contractor’s representatives proposed another conceptual approach the new A wing. By demolishing the existing A2 and A3 building it is possible to design a steel and concrete structure that is evaluated to be more efficient that accommodating the existing, which use non standar height to the ceiling. (JS 2016)

The DB contractor and The HVAC contractor is using Lean management for the first time in the Tromsø department of the DB contractor and The HVAC contractor on this project. For The DB contractor this involve identifying “good areas” (zones) and accompanying takt-controlling of the installation work as well as The DB contractors own building workers. One floor has for example the following five zones: atrium west, corridor west, middle, corridor east and rooms east. The DB contractor evaluated the experiences as very good.

The DB contractor used a Finnish steel supplier (Ruukki) for the first time in Norway. This can be considered a business model innovation.

The HVAC contractor participated and contributed to the planning and zoning and also after a years use of the system felt that the experiences were good. However, they also experienced that for piping and electricity the zoning was done suboptimal, certain cablings and pressure test of the piping had to be done in a “zone-crossing” manner. In the piping system, extra valves would have done a difference. This would have required that the design of the piping was done in accordance with the use of zones in the production planning. However, the consulting engineers did not have the information at the time of design.

Also, the HVAC contractor have only recently integrated all three installation areas in their business: Piping, ventilation and electricity. The A-wing represent a new organisation of management is the DB contractor demanded a single point of reference and the HVAC contractor attempted to accommodate this and maintaining sufficient technical competent management for each sub area. Thus balancing internal and external demands of the organisation (organizational innovation)

In a similar manner to the systems using apps mentioned above, another app for supporting safety auditing rounds had also been developed. This was also tailormade for the DB contractor. This system was not connected to the remainder of the IT-architecture.

09 Conclusion

The main aim of this report was to map and analyse innovations enabled by building information standards in the A-wing Hospital project of UNN in Tromsø.

The main result of this study is that it has not been possible to document direct effects from the use of building information standards. However, as information standards are embedded in software systems the effect of using BIM and other IT tools on innovation can be understood of a result of a hybrid of three elements; standards, IT and human efforts. And this hybrid combination leads to innovations.

The project is characterised by a mixed IT and manual work practices. Some integration between IT systems and BIM models between companies and client have been realised. Once entering the construction phase 12 BIM models was used in a coordinated fashion. But this IT-integration coexist with certain other work tools that remains paper based. The design build contractor benefit from this paper based work form in their planning and operation, yet also appear prepared for a digitally based interaction. The HVAC contractor is still not ready for digitally based interaction, when it comes to work drawings.

Not *one* building information standard, but many are in used. This include IFC for data transfer, room classification based on a Sintef system. NS 3240 for descriptions, Tverrfaglig merkesystem, TFM and several other building component classifications systems. No process information standards have been in use.

The Architects BIM coordinator has been a central “fiery soul” (eldsjel) for the development of classification and the client and the design build contractor have benefitted from that. The client has chosen not to drive this issue.

There appear to be many variant of TFM is in use in Norway. In this project two variants are involved: The version the client use, and the version the architect develops during the design. It appears that TFM in a sense carry a false promise, as it is believed to have the functionality and authority to provide a homogenous and uniform classification, yet interpretations and variant tends to flourish. TFM are interpreted by the various public clients, but also building companies, and even inside them (i.e different offices, and persons).

The two most important innovations that had some relation to the classification was a modification of TFM for work drawings and a app for reading the architectural BIM model. Many other innovations in the project did not have direct link to the use of building information standards. The most important was the conceptual change of the building demolishing more and changing steel, prefab and façade. Other examples include the use of lean management including daily huddles and takt planning is an important innovation, a BIM hut on site for DB-contractor worker to read BIM models, a Work Environment inspection tool on a app, and the innovative ventilation principles used by the HVAC engineers.

The main reasons for the lack of innovations related to standards and classification in this project seems to be a combination of;

- Lack of involvement and demands regarding use of BIM and classification from the client
- The architect did a lot of classification in the design phase, but this work was not followed up to the same degree from the other consultants and players.
- The use of the different standards and classification systems where not consistent and the existing potential not fully utilized
- A shift in contracting strategy due to a changed understanding of the financial situation, leading to more focus on economy, time schedules and buildability.
- The shift in contracting strategy led to more suboptimization for the different consultants and contractors involved because of different contractual frameworks
- The systems used in the design and construction phase are not fully aligned to the FM system used in the hospital.

The project involves BIM and IT infrastructure broadly in line with contemporary solutions on the Norwegian building market, assured by the involvement by major players doing Norwegian hospitals. The project is also exhibits innovation of processes, products, organisation and business models. However, most innovations does not surpass what would be common on a Norwegian market or the Scandinavian market.

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11 Appendix 1 Method

The main period of study has been October 2015-February 2017. This implies that the project had mainly been followed from early construction to medium finished construction. In the preceding and following periods march 2015- October 2015 and February 2016-summer 2017 the project has been followed in a more lax manner.

The method builds on interviews, literature studies, document analysis, and presence at joint meetings.

Interviews

Both direct interviews face to face and telephone interviews, semistructured following a prepared template.

16 Interviews carried out with:

Clients project manager: 2 (april 2016 and February 2017)

Clients facility manager: 2 (april 2016 and february 2017)

Clients facility management employee 1 group interview (april 2016)

Architect and BIM coordinator project: 2 (marts 2015, april 2016)

Architects, Rambøll: informal dialogues with two further representatives or Rambøll, joint inspection of a work drawing, beemer based demonstration of architectural BIM model

Consulting Engineers COWI: 2 (april 2016, februar 2017)

Design Built Contractor Consto 4 (april 2016, februar 2017)

Site and building under construction visit (februar 2017)

HVAC Contractor Bravida 2(april, februar 2017)

Software developer Unizite (may 2017)

Document analysis

Project plans, public information of the project

Participation in joint meetings

Meeting with architect spring 2015, client representative, contractors autumn 2015

Site visits

One visit at site hut april 2016

One half hour walk through of building under construction in February 2017

Limitations

The resources of the BISI- project have been small compared to the long high resource efforts of the A-wing project located in four main organisations and a client organisation in four addresses. It has been nessessary to focus the data collection to a few occasions, working with a lot of "expost" information, information that is built on how actors interprete something that happened in the past.

11 Appendix 2 Glossary

Below the used translations from Norwegian is listed. Translation is made using sector documents and website. National Health Service (NHS) UK documents and websites

Arbejdstegninger = Work Drawings

Beskrivelser= Descriptions

Flislegger= tile setter

Fløya = Wing (i.e A-fløya= A-wing)

Fortrængningsventilation = Displacement ventilation

Hulldekk= prestressed hollowcore floors

Omrøringsventilation = Stirring ventilation

Operationsstuer = Surgery room (NHS), or Surgery theatre

RIB, Rådgivende ingeniør bygg = Consulting Engineer Building

Appendix 3 Relevant standards

There are three main standardization bodies active in Norway and important in standardization issues; Building Smart, Statsbygg and Norsk standard. With regards to the hospital area further standards specific for this area and occasionally used by one regional authority is also important (as for example a room classification systems originally developed by SINTEF).

Building Smart is an international association, which is developing and maintaining the Industry Foundation Class. The standard has reached version 4 add2. IFC4 Add2 is the second addendum of IFC4. It was released in July 2016 as buildingSMART Final Standard. The previous version of IFC was IFC2x3 TC1 (Buildingsmart 2017). IFC is widely used in Norway for example when carrying out collision control between models.

Statsbygg is a public authority responsible for public institutions buildings. Statsbygg has developed and recommends the ”Interdisciplinary label system” Tverrfaglig merkesystem (TFM). The system is developed to support public clients in managing design projects (Statsbygg 2011). TFM is widely used in public building projects.

Standard Norge/ Norsk Standard er del af ISO systemet og udvikler og vedligeholder en lang række standarder:

- NS 3451 *Bygningsdelstabell* (Norsk Standard 2017) According to NS widely in used in Norwegian construction, often without players knows about (NS 2017)
- NS 3455 *Bygningsfunksjonstabell*.
- NS 3420 *Beskrivelsestekster for bygg, anlegg og installasjoner*,
- NS 3450 *Prosjektdokumenter for bygg og anlegg – Redigering og innhold av konkurransegrunnlag*
- NS 3940 *Areal- og volumberegninger av bygninger.*

- NS 3456 *Dokumentasjon for forvaltning, drift, vedlikehold og utvikling (FDVU) for byggverk*
- NS 8405 - Norwegian building and civil engineering contract
- NS 8360 *BIM objekter – Navngivning og egenskaper for BIM objekter og objektbiblioteker for byggverk.* Approved 2015.

NS3457-series.

This series is under development and is envisioned to be a united set of standards. Builds on ISO 12006-2 Building construction – Organization of information about construction works – Part 2: Framework for classification of information.

- NS 3457-1 Metoder og prinsipper for organisering av informasjon (2008)
- NS 3457-2 Byggverkskomplekser
- NS 3457-3 Bygningstyper (2013)
- NS 3457-4 Romfunksjoner (2015)
- NS 3457-5 Anleggstyper og anleggsdeler
- NS 3457-6 Sonetyper
- NS 3457-7 Systemtyper
- NS 3457-8 Komponenttyper

Some of these standards are used in Norwegian Building industry, other not and others again are still under development.