Building Information Standards for Innovation in Public Procurement of buildings

Final report

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Contents

1 Executive Summary

The potential of cost reduction with efficient digital communication in building processes have been investigated to be in the range of 15-25% by Svensk Byggtjänst. An important part of this potential is by using building information standards. The BISI project have studied the use of building information standards and its impact on innovation. Standards are mainly understood as classification of information and rules for building processes. Innovation contribute to adding value beyond cost reduction. The BISI literature study revealed the multiple character of relevant standardization in building. Our conceptualization became building information standards, as the relevant standards did more than ordering of information (classify), they also encompassed standards for other aspects such as processual rules. The literature review also found many enabling links between standards and innovation.

Three national case studies of hospital projects in Denmark, Norway and Sweden was carried out. Many barriers for innovation using standards was found. Apart from demands of IFC, there is not a rigorous legal demand to use information standards. The regional public authorities building hospitals decide adoption locally. In two out of three cases the client did not adopt. The participating companies take a business consideration of whether adoption of new standards is creating sufficient benefits. In the Norwegian case the proactive adoption of the architect meant that the client and contractor achieved benefits from the standardization. But other actors did not follow. In the Swedish case the barriers of innovation also commenced by the position of the client. As six out of eight main design areas used Magicad, BIM coordination was hampered. In the Danish case the client demanded CCS used, but the passivity of some company representatives meant that the training impact decayed, and that the CCS classification was done in a reactive manner at a late stage of the design. In the Swedish and Danish cases the actors had to learn to use the information standards for the first time, which is by itself a barrier. A systematic internal IT-strategy of the companies building up families of objects was in an early stage. The Danish and the Norwegian case were innovative, whereas the Swedish exhibit less innovation. Seven out of the ten links between standards and innovations was found. Standard enabled innovations, expected and unexpected, are mixed with other innovations. The three most remarkable innovations were the reverse innovation in the Danish case, the shift of structural concept for the building in the Norwegian, and the improved daylight access in the Swedish. The information standard enabled innovations were less visible. Moreover, standards and BIM use are closely intertwined in use practices. Spine and a common database of coded objects in the Danish case is a strong innovation enabled by standards. Also, the use of TFM in the Norwegian architect project and its subsequent use to support site BIM is remarkable. Only a few types of information standards, i.e rooms, components and descriptions, is in use compared to the suites of building information standards and many singular standards. Process standardization and component property standardization appear in particular promising next steps.

The reverse innovation in the Danish case is a very important type for the costly and complex hospital buildings. Reverse innovation is innovation related to creating value for the customer under conditions of cost cutting and reduction. The design was reduced with more than 50%. On the national level, the three countries show similarities in the limited, patterned and non-simultaneous use situation. The private and public side is hesitating to adopt standards. Even if some large companies operate across the three countries, they seem unable to use repetition enabled by BIM and information standards. The limited implementation of standards is parallel to the limited uptake of other developmental concepts, such as lean. The widely-implemented concepts are often those pushed by public regulation, such as e-invoicing (DK) and personnel accounts (SE, personalliggare). To help the case companies implement information standards a BISI support structure was set up. It was envisaged to support implementation and use of Spine with CCS. BISI project members, projectspine, Astacus and Jacobsen A/S were in place to help training and implementing the CCS standard and did so in Denmark and Sweden. The BIM project organization received training and use-support. For Sweden a mapping was developed by Projectspine that could translate BSAB 96 to CCS, meaning that users could work with a BSAB interface. The results of this efforts were limited however, primarily because of lacking integration between the engineering CAD systems and Spine.

2 Introduction

This is the final report of the "Building Information Standards for Innovation in Public Procurement of buildings" project – abbreviated BISI. The project has been jointly financed by Nordic Innovation and the participants; companies, universities and hospitals.

2.1.1 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.
- To support the classification of the hospital through the implementation of Spine -software , (Spine is building information management)

Answering to these aim is done through BISI methods. These are described in section 13.

2.1.2 Timeline and work packages

Below is indicated the main timeline and some of the main processual/phase terms of the project

The project consisted of the following work packages: Project organisation and management (establishment of organisation and on), method, literature study, implementation of CCS, empirical study, analysis/reporting and dissemination

The project was planned to run from 1st of January 2014 to 1st of July 2016, but was extended to 1st of July 2016. The work packages are to some extend overlapping in time:

Work package 1: Project organisation and Management: This work package aimed at maintaining the project on its track and ran throughout the projects. Regular skype and physical meeting were held.

Work package 2: Literature Study : Aim: Establishing a state of the art of standards for building information, innovation in public procurement of buildings enabled by building information management and modelling (BIM). It commenced in february 2014 and ended in june 2014

Work package 3: Method: Aim: Developing a method for evaluating use of standards for BIM and innovation. Was executed from june to september2014.

Work package 4: Empirical studies: The joint preparation of empirical studies was done in early autumn 2014.

Work package5: Implementation CCS. Facilitating the implementation of CCS at the public client and the companies was initiated in November 2014 in the Danish Case and in august 2015 in the Swedish case. This continued until june 2016.

Work package 6: Case study Denmark. The case study of a Danish Hospital commenced in November 2014 and continued to july 2016.

Work package 7: Case study Norway. The Norwegian case study commenced October 2015 after several initial meetings. It was ended in the summer of 2017.

Work package 8: Case study Sweden. The case study of a Swedish hospital started January 2015 and ended in October 2016

Work package 9: Analysis and Reporting. Case report were made carrying out analysis of cases, juxtaposing with literature study. Later the final report was made. The analysis and reporting started in October 2016 and ended in September 2017.

Work package 10: Dissemination. The ommunication of the results of the project are planned to be carried out during late 2017.

2.1.3 Partners in BISI

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

2.1.4 Reports in the project

The project is primarily documented in five reports:

- Literature review investigating the use of standards and their impact on innovation
- Case study Sweden- Karlskrona hospital building project
- The design build and operation of the new A-wing of University Hospital North Norway Tromsø
- The design of Phase 3 of New Hospital West Gødstrup
- Building Information Standards for Innovation in Public Procurement of Buildings – Final report (the present)

Secondarily results from the project has been published in six scientific papers entered in section 16.

Many, hopefully all, important concepts are explained in the case reports and in the literature review and therefore not repeated here.

Enjoy!

Christian Koch
Gothenburg 10 0ktober 2017

3 Innovation and building information standards

3.1 Definitions and types of innovation

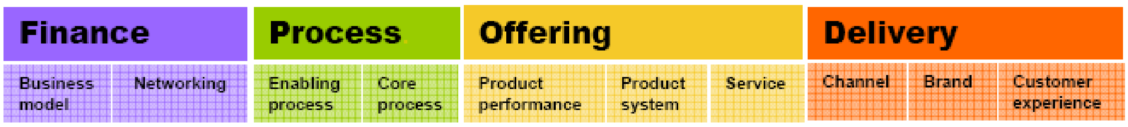
Definition of innovation no 1

A widely used definition of innovation is given by OECD (2005) in the socalled Oslo manual:

"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)

This definition underline that innovation is something implemented in practice, distinguishing it from invention, ie. good ideas. Secondly is the notion of "new" or "significantly improved" which has caused debates. It is common to view this as relative to a particular enterprise context (Tidd and Bessant 2009) as innovation are conceptualized as explanatory for enterprise development. The OECD definition was enlarged over the years from product and process innovation to series of innovation. This is incorporated in the second definition of innovation:

Definition of innovation no 2



(Doblin group, VHA 2006)

Developed by the consultancy group Doblin, this definition covers almost all aspects of a business developing a service or a product from financing to delivery to a customer. In line with this definition the initial BISI innovation focus was

1. Process improvements
2. Product improvements, finalised product, sub systems, components
3. Business model innovation
4. Delivery innovation (decommissioning/ facility management)

But as it will be shown below this understanding became further enlarged during the literature study and during the case studies.

3.2 What is a standard

ISO defines standards as

…documented agreements containing technical specifications or other precise criteria

to be used consistently as rules, guidelines, or definitions of characteristics, to

ensure that materials, products, processes and services are fit for their purpose'. (Blind 2006)

this definition brings together at least two main understandings of standards, that of systematic ordering of information and that of mechanisms of coordination.

ISO (2004) points to the following types of standards:

- terminology standard

- testing standard
- product standard
- process standard
- service standard
- interface standard
- standard on data to be provided

3.3 What is a building information standard?

The aim of building information standards involving classification and/or rules is to standardise use of information by creating similarity, homogeneity and consistency across time, space and participating actors in the building sector.

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 NS or 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).

Building component standards would usually encompass attachment of properties be it physical, functional, aesthical, cost, shape, or time. It would involve classification of objects - Buildings, components, rooms, systems, resources…. A Property data classification and standards for meausuring volumes etc of entities, i.e. metrics

But building information standard can also involve standardization of the building process for example through setting rules for information level in the stages of design and production.

3.4 Types of standards in NO, SE and DK

3.4.1 Building information Standards in Norway

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 first of all the Industry Foundation Classes (IFC). Secondly other openBIM standards. The IFC 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 is basing their strategy on Building Smarts openBIM standards as the foundation for exchange (export, import), storage and process of the Building Information Model. They require IFC used by their suppliers. Statsbygg has also 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.

Buildingsmart Norway has a portfolio of process tools to offer:

- P01 – Koordineringsmodell og byggeplanlegging

- P02 – Romprogrammering
- P03 – Kostnadsanalyse/Livsløpskostnadsanalyse
- P04 – Objektmerking – FDV (couples direct to TFM)
- P05 – Georeferering
- P06– Energianalyse
- P07 – Overdragelse til entreprenør
- P08. Byggeteknisk prosjektering
- P09 – Brann prosjektering
- P10 – Akustisk prosjektering
- P11 - Elektroteknisk prosjektering
- P12– Universell Utforming

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. The series consist of the following standards (the date refer to when those that are finished were in place):

- 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 the NS standards are used in Norwegian Building industry, other not and others again are still under development.

The local hospital variants of standards are often variants of TFM. An emerging National Norwegian ambition of enabling benchmarking between hospital units might unify this landscape more in the future (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.

3.4.2 Building information standards in Sweden

There are two main standardization bodies active in Sweden and important in standardization issues generally in the building and real estate sectors; Svensk Byggtjänst and BIM alliance. With regards to the hospital area, the Jönköping len (region of Jönköping) is hosting the PTS standard and further standards specific for this area and occasionally used by one regional authority is also important.

The BIM alliance host Building Smart and IFC in Sweden (see further description above). IFC component coding is widely used in Sweden for example when carrying out collision control between models. The BIM alliance also host fi2, The BIM alliance is a non governmental association with membership of 180 players from all parts of the Swedish Building and Real estate sector. It has grown from 140 members in 2014.

Svensk Byggtjänst is a shareholder company owned by some 30 associations in the Swedish building sector. Svensk Byggtjänst host a series of standards; BSAB- series, AMA, and CoClass.

The BSAB 96-series has been in use for a long time. It has the following substandards:

- Infrastrukturella enheter
- Byggnadsverk
- Utrymmen
- Byggdelar Byggdelstyper total
- Produktionsresultat total

”Allmän Material- och Arbetsbeskrivning” (AMA); General material and workmanship descriptions, is a collection of design and construction strandards. It is a dominant standard for generating descriptions and builds on BSAB 96. AMA consists of the following standards:

- AF (administrative procedures)
- Anläggning
- hus
- VVS och kyl
- EL

fi2, real estate administration (hosted by the Bim- alliance) is a standard for the real estate area established by a group of public and private real estate bodies in 2002. The standard is open to access and additions and its classlist consist of 61 list uploaded by six different bodies, whereof BIM alliance have produced 25 and SABO (the association for public housing) have uploaded 16. The Classes are overlapping and represent local appropriation. Product also includes the XML language fi2XML and three APIs. The standard is mostly used by large real estate administrators.

Program for Technical Standard (PTS). This standard builds on experiences from earlier hospital building projects and aims at assuring that best practices and experiences are taken into account in following projects. It is hosted by Regionfastigheter Jönköpings län and is used widely in souther and mid Sweden. The standards set demands guidelines for the designers to follow, such as standard rooms. Here the PTS contains demands for interior equipment, functional requirements, and visualisation of the rooms, classification of rooms, interface to the FM system Landlord (PTSforum, 2016). Consequently, the PTS also creates a certain level of similarity between the different hospital projects. PTS is joined by 13 regions and used in neighborouring regions such as Blekinge, Skåne (Scania) and Småland. The tools avaible in PTS project are:

- Lokalprogram
- RFP (rumfunktionsprogram)
- Inköpsplanering
- Hållbarhet
- Illustration (app för Ipad)
- Process
- Lokalkategorier (funktion)
- Connect (plattform)

The new standard Coclass was launched in autumn 2016. This is an ambitious attempt to substiture the BSAB series and other standard and create standard suitable for BIM and IT architectures. It is still early to evaluate whether it will gain any foothold in the sector. At present large players such as the transport authority (Trafikverket) have announced that they will implement Coclass. Coclass is thus in limited use, but but carry future potential.

The Building Information Properties (BIP) standard is hosted by a group of large companies, including ÅF and Skanska. The Building Information Properties (BIP) standard was originally developed to support the Karolinska project in the technical installation areas. BIP is intending to standardize how BIM object properties should be coded when using IFC import and export, enabling a software independent information. A series of companies is part of the alliance from the beginning; Sweco, WSP, ÅF, Tyréns och Skanska and others have followed suit; Peab, NCC, Veidekke, konstruktörer från WSP, Ramböll, White, Link and Locum. The broader use of BIP is not statistically investigated, but many clients demands use of BIP and the major technical installation players are capable of using it.

3.4.3 Building information Standards in Denmark

There are three main standardization bodies active in Denmark, important in standardization issues generally in the building and real estate sectors; BIM7AA, Molio and Landsbyggefonden.

Bips/Molio hosts and develops a series of standards including CCS. Molio is an self owned fund with an aim of collecting and spreading knowledge for the Danish Building sector. Molio consist of Byggecentrum and bips that merged in 2016. Bips has for long issued standards for the building sector, including DBK and CCS.

Landsbyggefonden (national fund for public housing) is responsible for the standard "Forvaltningsklassifikation" Classification for administration, that cover the social housing sector.

BIM7AA established in 2014 host a building component classification tool and two other standards. It is a joint venture of a group of influential architect firm, also using their membership in the association of Danish Industry as platform.

IFC is in widespread use in the Danish building sector. A Building smart chapter is organized as part of Molio – see above.

SfB is also in widespread use in the Danish building sector. There is not body supporting this. Also SfB forms the basis of many company and internal department specific standards (bips 2015).

The BIM7AA is explicitly close to SfB to ease the use. A manual for coding of building component was launched in 2014 and quickly became influential. Two more standards has been released since then. A present three standards are issues:

- Typecoding
- Detailing and Responsibility (BDR)
- BIM7AA BIM Project and Parameters (BPP)

BIM7AA have a stronghold among architects firm and mediumsize consulting engineering companies.

The "forvaltningsklassifikation" currently consist of the following standards. A central feature of this standard suite is it close correlation with the accounting standard for public housing in Denmark. The standards are:

- Ressourcer og processer
- Form og anvendelse
- Metode til styring af vedligehold
- Bygningsdelstavle
- Egenskabsdata
- Mappingtabel, bygningsdele
- Kontoplan, konto 115 og 116
- Begrebskatalog

The public/ social housing sector is a large sector and relatively well organized. The standards have been updated regularly since they were first launched in 2009.

CCS is a suite of standards also complemented with mapping tables to other standards. The following standards are in place:

CCS classification:

- Bygningsdele
- Rumanvendelse
- Bygværksanvendelse
- Materiel

Other tools:

- Classes of properties (Klasser af egenskaber)
- CCS Identification
- CCS Information levels
- Håndtering af rum
- CCS Strukturering af egenskaber
- CCS Måleregler, Basis
- CCS Måleregler, Bygningsdelsoversigt
- CCS Måleregler, Bygningsdele
- CCS Prissætningsregler, Basis
- CCS Prissætningsregler, Bygningsdelsoversigt
- CCS Prissætningsregler, Bygningsdele

- CCS Tilbudsliste
- CCS Purpose
- Standard for designing object libraries

Mapping tables

- Forvaltningsklassifikation (FVK) og CCS
- SfB og CCS
- DBK og CCS
- CCS Rumanvendelse (R0) og CCS Rumanvendelse (R1)
- KASER SfB-bygningsdele og CCS

CCS was implemented with EU support in 11 enterprises and organisations in 2015, 2016. This created documentation of implementation that was subsequently communicated to the sector. However, after this very few have officially joined the group of implementing companies. This does not exclude a number of more discrete implementations in projects and companies.

There are no common standards for hospital building in Denmark. Some coordination between projects is carried out by the regions and ministry of health.

The Cobie standard, (Cobie stands for Construction Operation Building information exchange) has recently been recommended in Denmark in operation of public buildings (Asmussen & Lyck 2016). Similarly there are several proposed standards for information levels and information delivery manuals (IDM) in circulation (Olsen et al 2016).

3.5 Crosscutting characteristics of standards in DK SE and NO

The standards are both complementary and overlapping. There is a fragmented set of responsible bodies, which coordinate the standards and their efforts more over less.

All countries have suites of standards in place for covering the building sectors need. These suites are however more or less embedded in practices of the sector, i.e. they are only partially implemented as the literature review indicated is recurrent.

Especially standards for the process of design and it information level, design/detail levels seems not to be in place, albeit in different clothing in the three countries.

4 Summary of literature review

The literature review found two main types of understandings of standards; standards as systematic ordering of information and standards as mechanisms of coordination through rules. This understanding implies that standards overlaps with an encompasses information classification, which falls into the first.

The literature of standards is vast and it is therefore surprising to find relatively little on portfolios of standards. For example, taking up issues of strong coordination and dependence between standards in a portfolio, i.e. orchestrated standards which might combine process, product, people and other aspects of a domain, versus loosely juxtaposed portfolios where the standards are largely independent of each other.

In some areas of standards and standards research, it is well described that diffusion and adoption of a standard meets barriers. Standards are often only partially in use in practice. This can be viewed as a purposeful way of using standards by appropriating it to local conditions or as a less efficient way of utilizing the potential of a standard, as deviation from the full use can be viewed as hampering transfer and comparisons.

Standards are often mixed and overlapping in a domain. Few domains using standards exhibit the complete coverage of one standard. Several studies find their domain of studies covered by multiple intersecting standards.

The sociomaterial approach to standards and innovation appear attractive as theoretical frame for the study. The existence of different ideals and understanding of the structuring of information standards highlight seeing standard creation and standard dynamics as political processes. Collaboration and competition based on understanding and interests characterises standard creation and use.

The literature encompasses studies that find that standardization is a barrier for innovation. The homogenizing effect of standards by prescribing a common set of rules to follow, contradicts innovative activities that often require breaking existing (standardized) rules. Standards are well suited for routine activities, however for non-routine activities as innovation they may be rigid and too stiff. Successful technical standards may “over support” a technology making it difficult to change or improve. Because a standard fixes the boundaries of an object, this restricts positioning new innovations outside of these boundaries. This occurs both on micro scale of single products as well as for macro situations when a network of standards is in place, causing incompatibility to the whole system, for example at sector level.

The literature thus encompasses studies that find standards are a barrier for innovation. But most focus is on positive mechanisms. The study finds a set of positive links between standards and innovation, the literature review synthesized a list of 10 links between standards and innovation:

1. link: standards might indirectly make resources for innovation.
2. link: Standards can enhance repetitive elements in products enabling single customer innovation
3. link: Process standardisation stabilizes work activities that create product innovation
4. link: Improved interoperability and interfaces between subsystems enable product innovation.
5. link: Standardisation creates larger markets for products.
6. link: Standardization of product data might provide innovation in customer relations.

7. link: A sector standard can trigger system innovation

8. link: Standards might enable Business model innovation

9. link: Standardisation might trigger paradigmatic innovation

10. link: Standardization of one technology induces new related innovative technologies.

However, the study also shows that the positive impacts on innovation of standards are not fully explored in the literature, there are more imaginable links that might be important. Open innovation and open standards as well as financial and organizational innovation are examples of that.

5 Case projects – short presentation of project and results

5.1 New Hospital West at Gødstrup in Denmark

This case is Phase 3 of a greenfield hospital project in total at 140.000 $m^{2.}$ Phase 3 contains two main parts, roughly two buildings: The Somatics department including Cancer, Neurology, Day surgery. This is a multi story rectangular building at 22.000 m^2. The Service Center containing service functions for the hospital such as kitchen and laundry. This is mainly a two story building at 7200 m^2.

The overall timeline for phase 3 is shown below

Phases in Danish	**Phases in English**	**Actual project**	**Followed by BISI**
Dispositionsforslag	Outline proposal	TR3 Nov 2014-	X
Projektforslag	Project proposal	TR3 Several jan 2015- maj 2016	X
Forprojekt (myndighedsprojekt)	Preliminary project (regulatory project)	TR3 Spring 2016	X
Hovedprojekt	Main project	TR3 Somatics aug 2016- okt 2016	X
Udbud	Tender	TR3 service center feb-july 2016	X
Udførelse	Construction	TR3 Service center August 2016-	

The project proposal phase took over a year due to overrun of estimated cost. Therefore, several project proposals were elaborated.

The use of BIM models in the project in shown in the table:

Actor	Number	Focus of model	Software
Architect	3	Façade Outfitting (Aptering) Landscape	Revit Revit Autocad
Engineers	4	Structural Electricity Heating Ventilation	Revit Revit Revit Revit
Total	7		

Innovation overall

- Reverse innovation – substantial reduction in function of the envisioned hospital product (Product improvements)

- CCS standard require innovation backwards through the Facilities Management (Product improvements).
- Establishment of the company Projectspine (Business model innovation).

Classification overall

- CCS-classification in a reactive manner (classification just before delivery -not during design)
- Hidden classification was done in a proactive manner – (use of Revit object structure)

The table shows the use of classification and standards in the case project:

Project	Phase	System in use	Classifications in use
TR1	Design build main body	Revit dRofus Sigma/Estimate	SfB, CCS v.1 rooms, components
TR3	Brief expansion	Revit dRofus	BIM 7AA CCS v 1 rooms CCS information levels Revit
TR3	Brief reduction	Revit dRofus	BIM 7AA CCS v2 (rooms) CCD v2 (building components) Revit
TR3 Sub Project Service Center	Design Service center	Revit dRofus	CCD v2 (building components) Revit BIM 7AA
TR3 Sub Project Service Center	Tender and bid service center	Revit Estimate	CCS v 2 (building components metrics (måleregler), information levels,)

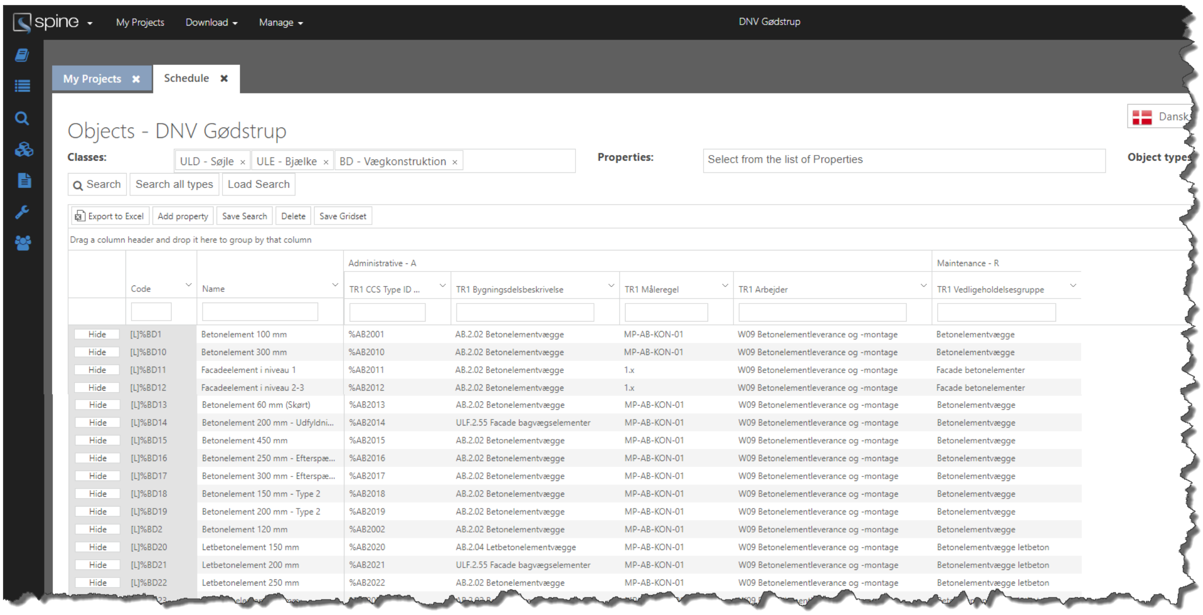


Figure: Screen from the Spine database in the Danish Hospital project with entered rows of classified concrete columns

5.2 Karlskrona Hospital in Sweden

The Swedish case studies an extension of the Blekinge hospital in Karlskrona. The building extension is at 11.000m2. The hospital in Karlskrona is one of two hospitals to serve the Blekinge region and its population of 156.000 inhabitants (Blekinge, 2016). The new hospital building labelled 02 46 consists of seven floors, including one underground floor. The building is planned and designed to host a nephrology centre, a breast centre, pathology-, cytology- and microbiology laboratories, a morgue, an autopsy department, training facilities and a series of technical facilities (UULAS 2015).

The overall timeline for the project:

Phases in Swedish	**Phases in English**	**Actual process of the project**	**Followed by BISI**
1. Behovsanalys 2. Förstudie 3. Program 4. Systemhandling 5. Projektering 6. Förfrågningsgrundlag 7. Utlysning/Upphandling 8. ByggProduktion 9. Överlämning 10. Förvaltning	1. Analysis of needs 2. Pre-study 3. Programming 4. System design 5. Detailed design 6. Tender preparation 7. Tender 8. Construction 9. Handover 10. Operations	 Maj-June 2015 May –June 2015 August- December 2015 January 2016 – (ongoing june 2017) Expected January 2018 Expected 2018-2019 Expected 2020 Expected 2020	 X X X

The project became delayed during detailed design an tender preparation, mainly because the client needed more time to decide to commence the project.

Table: BIM models in use

Actor	Number	Focus of model	Software
Architect	2	Façade, indoor layout	Revit
Engineers	7	Structural Electricity 1 Electricity 2 Heating Ventilation	Revit Magicad Magicad Magicad Magicad

		VVS Sprinkler	Magicad Magicad
total	9		

Innovation overall

- Few examples of innovation; use of object library in Magicad and strengthening of a innovation system/network around PTS – other innovation was not related to classification

Classification overall

- Blekinge Landsting room classification, fi2, BSAB96 (AMA), IFC

The table compiles the classifications and standards used:

Phase	**Systems in use**	**Classification in use**
Outline proposal	-	Rooms Blekinge classification
Design and Main project	Revit, Autocad, Magicad, Solibri Spine	BSAB96 fi2 IFC Standards embedded in software CCS (embedded)
Tender	Revit, Autocad, Magicad, Archicad, Solibri, Excel, Spine	AMA/BSAB 96 for descriptions Standards embedded in software CCS (embedded)

5.3 University Hospital North Norway - new A wing

The university hospital Northern Norway UNN has its headquarters in Tromsø. The UNN employs some 6300 and carry out 400.000 annual patient encounters. The unit in Tromsø employs 4.500. The main body of the buildings of the hospital dates back to 1991.

The total A-wing 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.

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. The ground floor is allocated for the ambulance and other acute receptions. 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.

Below is a timeline for the project:

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

The project changes contract form when moving from main project to tender. It was then change from design tender build into a design built contract, which meant restarting some of the design work.

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	Revit Revit

		Electricity 3 Heating Ventilation Sprinkler	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		

Innovations overall

- Modification of TFM for work drawings. Simplification of components standards to enable craftsmen work on site
- app for reading the architectural BIM model
- Some innovation where it is not possible to discern BIM use and information standardization
- Some remarkable non IT or standardization related innovations:
  - conceptual change of the building demolishing
  - changing steel, prefab and façade
  - lean management and huddles an dtakt planning
  - BIM hut on site for DB-contractor
  - Work environment inspection tool on a app

Classifications in use

Note that two variants of TFM was in use ,one for architectural design and another for Facilities management

Phase	**Systems in use**	**Classification in use**
Outline proposal	dRofus ArchiCad	Rooms UNN classification Helsebygg classification Rooms Sintef classification
Design	Archicad, Revit, Autocad, Magicad, Solibri	TFM – components TFM – components , modified IFC

		Standards embedded in software
Main project	Revit, Autocad, Magicad, Archicad Solibri	TFM and TFM modified Steel design Revit inbuilt IFC Standards embedded in software
Tender	Revit, Autocad, Magicad, Archicad, Solibri, Excel, Gprog	NS 3420 for descriptions Standards embedded in software
Construction	Revit, solibri	All types
Operation	Plania, Excel, TIDA	The UNN classification based on NS3451 and close to TFM.

6 Results: Standards impact on innovation in the following ways.

Below the case study findings from the three hospital cases is discussed. It commences with barriers and continue with standards enabling innovation aspects following the ten links identified in the

6.1 Barriers for innovation with standards found

Overall the project found more performing barriers than enablers. The cases are rich in examples of barriers and some of these efficiently kept information standardization aside the design and building processes.

It is common for the three countries studied that there is not a public demand (legally) to use information standards apart from the data exchange standard IFC, which is demanded in Denmark and Norway (Statsbygg 2013). To implement and use information standards is therefore up to the public clients, which in all three cases are regional public authorities. The representatives thus have to consider adoption more on the basis on the assumed cost reduction and societal value creation. This in turn correspond to the participating companies that are left with a business consideration as to whether it is creating a sensible business benefit to adopt a particular information standard. On the basis of our three cases it is thus not possible to say whether a public regulation, i.e. an order making information standards obligatory would have made any difference.

As two out of three public clients in the project decided not the demand a particular standard it was left for the company representatives in the two projects to decide. In the Norwegian case the proactive adoption meant that the client and contractor achieved benefits from the standardization. However the technical installation engineer and contractor did not follow suit. The main barriers identified in the Norwegian case for the lack of innovations related to standards and classification was a combination of

- Lack of involvement and demands regarding use of BIM and classification from the client
- The architect did a lot of component classification in the design phase, but this work was not followed up to the same degree from the other consultants, contractors and the client.
- 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.

In the Swedish case the barriers of innovation was exerbated through the client's low priority of IT demands in contracting and low priority of strategic management as well as project management of BIM. No IT agreement was accorded upon. Adding to this large parts of the consultancy team in the design operated under a low level of BIM integration. In six out of eight main design areas the use of Magicad made the coordination suboptimal and in these areas it did not appear to be very effective in allowing actors to organise their interaction. To some degree this is due to the inexperience of actors with the integration software. The Swedish case reached a higher level of BIM integration than the Norwegian and lower level than the Danish. It should also be noted that the expected barrier of the hospital PTS standard did not occur. Experiences from other hospital building projects was initially used to portray the PTS standard as stiff and observing that when clients decided to strictly follow the standard, it would be a barrier for innovation. However, this experience did not map to the Blekinge project, where there did not occur need for deviations nor collisions with prescriptions of PTS.

In the Danish case where the client demanded a building information standard used, the passivity of some company representatives meant that the training effort adopted to enable the use of CCS decayed, and that the CCS classification was done in an reactive manner at a late stage of the design, as part of preparing for tendering the contractors.

In the Swedish case time and effort to support the use of information standards in room programming and component identification was carried by the architects BIM coordinator and the BISI consultants and led to efforts that were not really used in the project. Again a type of passive and open resistance from engineering consultancy representatives and the clients was explanatory.

It is common for the Swedish and Danish cases that the actors had to learn, understand and use the information standards for the first time. This by itself created a barrier and let to proneness of using previous more know standards wherever possible.

When using CCS in the Danish case architects, engineers and other employees frequently voiced criticism of the naming of CCS claimed to be counterintuitive. This can be understood a a typical first time user experience. When a information standard is firmly embedded in IT systems and used over and over again the perception of counterintuitive elements are likely to decay.

The companies in the project was of various sizes. Nevertheless it appears that a systematic internal IT-strategy of building up families of object was only at is beginning. One company did have a common base of hospital design object that could be and was used. But most companies still were doing the objects from Revit or the like families.

6.2 Enabling links found for standards enabling innovation

6.2.1 Standardisation indirectly provides resources for innovation

Standardisation can be of products or processes and further aspect of the business processes. By standardized routinized elements, these will require less resources and thereby indirectly release potential resources for innovation. For example this can be classification that orders components in a tender, enabling Contractors to give bids at a lower cost, enabling the client to restructure economy and open for innovation

6.2.2 Standardisation can nurture efficient repetition *and* innovation for single customers

Efficient repetition is for example exploited in platform strategies where generic product features are identified. At a time, this provides, in a mass customisation strategy, systematic space for innovation aimed directly at the single customer. Examples:

- In one hospital project the room programming became more structured because all standard and special rooms entered the same structure enabling a move towards more standard rooms. Thereby the room programming became more efficient than usual for such large and complex building, here handling about 4000 rooms, whereof 80% became classified as standard rooms. The hospital project involves a large amount of repeated components, building elements up to entire blocks of beds. Room programming using CCS reduced the number of special rooms and increased the standard room to 80% of the 4000 rooms.

- The design could concentrate more on the last 20%, that could not be standardardized as they were unique special rooms.

6.2.3 Standardisation stabilises processes in a volatile project based environment

For example at the Danish hospital project, CCS has first supported a systematic detailed planning of the design process, digital architecture and work method. This planning created stability as it afterwards had to be followed. Moreover and second CCS supported ”data discipline”.. Also the enabled later reuse of the CCS elements supported stabilisation. An important prerequisite for this was a systematic training effort of the members of the design team, especially those involved with Building Information Modelling (BIM).

6.2.4 Improved interoperability between subsystems enable product innovation

If interoperability and interfaces between subsystems in a product structure is well defined innovation efforts can focus on these subsystem, which is an advantage especially in large complex product systems like building and hospital buildings. For example, at the Danish hospital project, CCS, enables handling of many types of digital objects, such as documents, BIMs, spreadsheets, data sets (in databases) and drawings. The classification codes enable automatic identification by distinguishing between the items. It is common and necessary in large complex buildings project to use considerable resources for coordination of the design activities, which is located in the many participating companies at numerous places and usually involving many different IT –systems and data structuring approaches. Here CCS supports interoperability also by standardising the interfaces between these systems.

6.2.5 Standardisation creates larger markets for products.

For example IT suppliers participating in the hospital project have used their experiences with CCS to incorporate the classification in their IT-systems. They are currently marketing that in the Nordic and Baltic region. More in general there is a large global market for hospital design providers, where experiences of CCS can be transformed into design service offerings globally. Here it is likely however that competing standards will create future market conditions (Fomin, 2012)

6.2.6 Standardization of product data might provide innovation in customer relations.

For example, facility data models created from as built BIM models might enhance the client/customers use of these data and enable the possibility of new services for the customer such as external supply of cleaning, benchmarking, space management, systematic maintenance and other service agreements.

6.2.7 Business model innovation

For example, Betech was provided with the opportunity to develop the software tool SPINE, which later led to that the company Spine became a spin off of Betech.

6.2.8 System innovation

For example the Swedish hospital standard PTS was taken up by Blekinge. This means Blekinge joined the network of regions building hospitals that were using PTS. This community also further develop PTS and carry out common development projects with for example Chalmers.

6.2.9 Paradigmatic innovation

For example a thoroughgoing standardization of product data and process data in the building life cycle might first change approaches to design. For example from linear to iterative design. Second a new interaction and collaboration would be enabled within contract forms such as partnering and design built, with far more iterative and interaction design and construction. A final example would be a feed back of experiences of buildings to designer for future design.

6.2.10 One technology lead to another

For example standardization of one (key) technology, such as information levels induces the development of new related methods of delivery.

Link	**DNV-Gødstrup**	**UNN-Tromsø**	**Karlskrona Hospital**
1. Standardisation of product and process elements indirectly provides resources for innovation as the standardised elements require less resources (Sandholtz 2012)	Early gains were swallowed by redesign activities Lower bids from all contractors after design, gave gains that are still open to use	-	Collision control enabled through IFC, help avoid losses in future construction
2. Standardisation can nurture efficient repetition and the engineering of innovation for single customers (i.e. a mass customisation strategy of product development, (Piller, F.T. and Tseng 2010).	Reduction of rooms and building components- as they reused objects library from Phase 1. Projectspine: structure and CCS-reorganized in object library and object properties.	Consultant optimize digital design by using classification	Used software object structure for classification
3. Standardisation stabilises processes in a volatile project based environment (Jacobsen 2013)	The reuse of the CCS structured Revit Object library from phase 1. Minimize number of component variants and ensure better quality control	dRofus and TFM have created a certain stability	MagiCad have standard object library - effective bill of quantities

4. Improved interoperability and interfaces between subsystems enable product innovation (Clark and Baldwin 2000)	From design models to FM-systems (require data structured by a classification system) mostly a process innovation however	Use of TFM support use of a site hand held BIM system, BIMx. Mostly a process innovation however	
5. Standardisation creates larger markets for products (Schilling 2008).	Diffusion occur through firms working on several hospital projects	Diffusion occur through firms working on several hospital projects Commencing national coordination	Diffusion occur through firms working on several hospital projects
6. Standardizarion of product data might provide innovation in customer relations	-	-	-
7. Business model innovation	Project Spine	-	Project Spine
8. System innovation (institutional innovation)	-	A national organisation, Sykehusbygg, is emerging	PTS and the network of regions building hospitals is strengthened
9. Paradigmatic innovation (from linear to iterative design)	-	-	-
10. Standardization of one technology induces new related innovative technologies	-	-	-

The analysis showed at a time some correspondence with the literature reviews expectations of innovations enabled by information standards, but also innovation not triggered by standards and the absence of some expected innovations. The three project experiences a set of barriers for use of standards and innovation triggered from this.

Some of the expected yet absent innovations were: In the Danish case, several aspects of process innovation were absent. First it was expected obtain improved coordination enabling the handling of higher complexity. However, the design project was carried out by four companies operating from different addresses using video conferences to do sufficient, timely yet complex coordination. On top of this, coordination was under pressure when the project underwent a long phase of reduction economically and functionally. Secondly it was expected to create stability through using standards. As one year was spent to reduce the project, there has been some instability. But even in the more stable periods this did not emerge. One important – and absent- tool for creating stability is the CCS standard of information levels. This standard is intended to help project participants jointly negotiate the information deliveries during the project

The Swedish case is probably the least innovative of the three and therefore exhibit the absence of many of the expected innovations (type 1, 4, 6, 9 and 10). Beyond those related to standards also sustainable innovation and full BIM use was voiced by the project members as absent.

In the Norwegian case the type 1, 3, 9 and 10 were absent. However other aspect of the case demonstrate innovative activities. For example, when it comes to unexpected innovations, the Norwegian case exhibited three unexpected innovations. First the architects simplified the TFM coding to a five number digit to enable craftsmen onsite an easier identification. Second an app able to show the current BIM models was implemented. Third a production progression monitoring app was implemented. All three innovations utilized the classified design material/BIM models.

Probably the most important unexpected innovation was that of reverse innovation occurring in the Danish case. Reverse innovation is innovation related to creating value for customer under conditions of cost cutting (Koch 2017). The design team reduced the cost of their design more than 50%. This type of innovation in hospital design and building are very important. Hospitals are public investment financed through tax payments of the citizens. Project budget overruns such as Karolinska is problematic (Wunderlich 2017). Several other overruns occurred while this project was. ongoing. The project team and the client together found acceptable reductions, maintaining patient oriented functionality. The process commenced during the brief phase. In one step of this process the client demanded an estimate of the cost. This estimation was made using the Revit models and objects and also using BIM 7AA and CCS. The result of this estimation was an overprize of 65%. The client therefore demanded a substantial cost reduction, without harming the functional demands. It was decided to reduce "evenly" across the entire intended design. The process was carried out stepwise, producing a number of proposals in intervals of one month. Each brief included a calculation of the cost. This involved "take off" of material quantities of the architectural BIM models and engineers using experience based square meter prizes. Thus, the relation between functionality and cost were kept in strict synchronization. This effort came to include an in depth reduction of all aspect of the design:

- Ground plan
- Number of stories
- Facades
- Balconies
- Internal Roofs
- Floors
- Panels
- Indoor equipment
- Installations (Ventilation etc)

The initial 33.000 m^2 design was reduced to 22.000. One story was removed, and fewer square meters per floor was allocated. The façade concept was redesigned to one that look similar to the earlier phase, but with of other and fewer elements at a lower cost. Through dialogue with the health and safety authority it was made possible to reduce the number of bathrooms at the personnel facilities with 50. At the water and heating supply design a change of radiators and shift of toilet, from a wall mounted to a floor mounted model was done. Two surgery studios came to share one ventilation system Adding to these there are also examples of functions that are "parked" in a manner making it possible to take them out at a later stage. This goes for example for an exercise gym, which is placed in a corner of a building.

These revisions became enabled by the use of building information models. The architects remade their facade model, but could maintain the outfitting and fixtures model relatively intact. During this process most companies used the structure and classification provided by their Revit software. CCS did not come into systematic use. In the process of reduction, the client used the room programming entered in dRofus as reference for aiming at maintaining patient oriented functionality. As the overall calculated future needs of number of treated patients also fell, there was a possibility to remove three surgery studios and some bed rooms.

The client eventually approved to the realized reduction and also viewed it as the design organization really had been creative, possibly derived from the cost pressure. At a time, it should be noted that the architects and engineer were payed (extra) to do the reduction exercise.

Such reverse innovation effort appears to have high relevance for public procurement of buildings.

7 Impact of building information classification on innovation

This section commences with considering findings of that building information standards in use have be a barrier for innovation. Then follows a discussion of the nine found types of links between standards and innovation, adding to the above mentioned unexpected.

The case material shows only one minor example of a standard in use creating a barrier for innovation. The modified TFM code used in the Norwegian case probably made interpretation easier during the building phase yet it collided with the other varian of TFM used for the facility management system. The barrier was handled indirectly by the hospital hiring an external consultant to prepare as built data for entry into the FM system. This resource thus levered the barrier. In principle if both parts of the chain had followed the same TFM system data from the architectural BIM models could easier have been transferred to the FM system and provided space for improvements with operations.

It should however be noted that both the Danish and Swedish case shows barrier for innovation related to the implementation effort of bringing a new standard into operation. Such efforts are change work and sometimes are allowed to halt before a stable implementation is in place.

Below the nine enabling links is discussed one by one:

1. link: standards might indirectly make resources for innovation.

In the Danish case the use of standards did create cost cutting and potentially avaible resources. However during design this effect where outweighed entirely by the needed cost cutting. When it came to contractors bidding, the offers were actually lower than expected, which created a new buffer, whose use was an open question when the BISI project study period ended in summer 2016.

In the Swedish case a benefit of the use of IFC was it enabled collision control during parts of the design phase, reducing the amount of collisions that emerge during the build phase, when solving the problems is more expensive. This better interoperability between different modelling software's would lead to indirect efficiency gains. This despite the collision control was relative simple and only allowed for ocular control as the models lacked more precise information.

The Norwegian case had more limited benefits of its use of IFC and collision control, because of the changes in contract form.

2. link: Standards can enhance repetitive elements in products enabling single customer innovation

The client in the Danish case created a repetition of coding used from phase 1 of the project. This was provided as a database and supported by the tool spine. This even creates an option for the client to used this structured library for later projects.

3. link: Process standardisation stabilizes work activities that create product innovation

In the Norwegian case 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.

4. link: Improved interoperability and interfaces between subsystems enable product innovation.

The original content of this link focus on subsystems in large complex products. Modularity and standardized interfaces would enable product innovation, both within sub systems and across them. Hospitals buildings are such complex products with many intersecting subsystems.

The Danish case had such an interface between two complex system, namely the phase 1 building system and the phase 3 building system (the present case). The client aimed at a common standard of building information through using the same coding in CCS in both, but also a host of technical installations directly interfaced between the two systems (such as piping, electrical cabling and ventilation). This standardization first meant reductions in the development of descriptions for the somatic building and contributed on the information handling side. However direct product innovation enabled by the standardization was not found. A transfer from design models to FM-systems (require data structured by a classification system) did occur and can be thought of as mostly a process innovation.

In a similar process manner, the use of TFM in the Norwegian case support use of an app BIM system, BIMx, which provided updated BIM models for the site managers and workers. Again this should be considered mostly a process innovation.

5. link: Standardisation creates larger markets for products.

In all three cases the participating architects, consulting engineers and contractors to varying degree participated in several hospital projects in parallel to the one studied in the BISI project. As well as before and after. One architect company did develop an object library for use across hospital project. The content mainly illustration of inventory; equipment, furniture etc.

The use of PTS and the related competences would similarly tend to favour building companies which are skilled in using PTS. At least in one case a Danish architect hired a Swedish single architect to act as consultant of PTS for the Danish company contracted to design a hospital in Sweden.

The common use of TFM for facilities management in Norwegian hospital appear to create larger markets for FM systems and FM consultants. More recently (2016) a stronger common national organisation has been built in Norway, Sykehusbygg, (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).

6. link: Standardization of product data might provide innovation in customer relations.

For architect BIM was used for visualization purposes in their interaction with clients/customers. Early visualization are often changed many times and its probably instrumental for their use that they are not laden with classification codes. Later as previously mentioned in all three case the delivery of information to the future operations and facility management played a role. In neither cases we found innovations in customer relations.

7. link: A sector standard can trigger system innovation

In the Swedish case the client Blekinge Landsting adopted fi2 and PTS. Fi2 was used for room classification and Blekinge Landsting shared their developed room classification. PTS PTS is a technical standard for hospital projects and was here followed during the design, which was a smooth process. Both examples have the potential of contributing to the further development of the health innovation system in Sweden and the community innovation around fi2/BIM alliance.

In the Norwegian case the use of TFM by UNN and other 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.

Also the recent establishment of Sykehusbygg in Norway as a national organisation promises future system innovations The new strategy of Sykehusbygg (2017) represents a possible stronger common development of standards in the future.

In Denmark, there were limited links between the participating companies and the building sector innovation system.

8. link: Standards might enable Business model innovation

In all three cases standardization enabled small software companies to developed their, product, services and business model. In the Danish case this include Projectspine, dRofus, Sigma and Likan.

Projectspine developed as a company as a result of a spinoff from Betech data. So while developing the classification support tool Spine, people from Betech became aware of an opportunity to create a new company. The company were able to purchase licenses of Spine to the project companies and the client Region Midtjylland. Later other Danish hospital project also purchased the software.The other companies dRofus, Sigma and Likan similarly developed software and services that can be used in future building project.

Projectspine had a platform in the Swedish project for developing its product for the Swedish market, the limited use of Spine in the case prevented however it to develop into a genuine reference case, but at least the Projectspine organisation gained important experience.

In the Norwegian Case, Unizite got an opportunity to expand to a second reference customer for their system for onsite monitoring of progress.

9. link: Standardisation might trigger paradigmatic innovation

The potential for this effect is definitely there, yet many elements including design and engineering processes in the three case projects stayed relatively mainstream. The BIM use was on a par with the respective sectors. There was therefore no sign of paradigmatic shifts.

10. link: Standardization of one technology induces new related innovative technologies.

This type was not found in the cases.

Overall standard enabled innovations, expected and unexpected, are mixed with other innovations in the three projects. Compared to the three most remarkable innovations; the reverse innovation in the Danish case, the shift of structural concept for the building in the Norwegian and the change of daylight access in the Swedish case, the information standard enabled innovation are more discrete and to a degree invisible (Bowker and Star1999). The innovation moreover occur in a manner where standards and BIM use are closely intertwined. One can point to the use of spine and a common database of coded in objects in the Danish case as a strong innovation enabled by standards. Also the use of TFM in the Norwegian architect project and its subsequent use to support site BIM is remarkable.

8 Changes in innovative direction in public procurement of buildings enabled by Classification

The focus here is on hospital buildings, a particular, yet important part of public procurement of buildings. The healthcare sector represents an important part of the Scandinavian welfare states (WHO 2009) and these countries invest the most in Europe (OECD 2013). And in these years we witness an unprecedented wave of investment in renewal and extension of this infrastructure. Norway thus invested an estimated 10 billion Euro in new hospitals from 2000 to 2011 and a number of projects on its way, such as the (Håhøy 2013, Sykehusbygg 2017, see the table below), and Denmark has announced future investment at 5, 5 billion Euro (Danske Regioner 2011). Sweden's regions will invest 5,86 billion Euro in large projects from 2014-2020, excluding Karolinska, which by itself cost more than 6 billion Euro (SKL 2014).

projects	NOK Billions
Bergen	5,4
Drammen	8,2
Aker	3,3
Hammerfest	2,2
Nordmøre	4,1
Førde	1,5
Stavanger	7
total	31,7

Table: examples of upcoming Norwegian projects

A part of this development is the emergence of large business suppliers of services for building and operating these hospital services in architectural, engineering, contracting and real estate industries (STD 2016). Companies like White, Arkitema (architects), Bravida, Imtech, Caverion (technical installations), Sweco, Cowi (engineers), Skanska, Veidekke (contractors) all contribute to the renewal of the Scandinavian hospitals and do it in a multinational manner across the Scandinavian area.

At a time Sweden and Denmark are counted amongst the most innovative countries in Europe, and Norway is an innovation follower (Eurostat 2015). In all three countries there is considerable attention to innovation in the hospital and health area. For example Karolinska, probably the most heavy R&D hospital unit in Scandinavia, published its innovation strategy recently (Karolinska 2017).

The hospital projects studied in Norway and Denmark appear to be innovative in aspects independent of the information standards. In Tromsø the A wing structural solution was proposed changed by the contractor, that also used a variant of lean for the first time. In Denmark a series of innovations was developed and tested at the "innovation stable" next to the hospital site. The innovative activities was less outspoken in the Swedish case. It is thus not a general passivity or even resistance towards change that can explain why information standards created relatively limited results as mapped out above (section 5)

The organisation of PTS in Sweden, with user groups and continuous updating, make it a systematic tool for continuous innovation. The standard is in principle voluntary, but there are examples of regions that choose to follow PTS strictly. The standard is detailed and can be used initially to support a process of specification of user demands, to support design and to support facilities management. The organisation, PTS forum also carry out R&D projects.

A more recent initiative from Swedish municipalities and regions, SKL (2017) is a strategy for use of BIM in regional hospital projects. The strategy is relatively cautious when it comes to BIM and information standards. It accept mixed use of BIM and 2D Cad and expect IFC to be an important standard, whereas Coclass, the new Swedish standard is barely mentioned.

The Norwegian Sykehusbygg strategy is a strategy for use of BIM and digitalization in hospital projects (Sykehusbygg 2017). The strategy was formed by both a central expert group and input from the regions in Norway. It manages to go across considerable local differences. There is a belief in open standards such as IFC and also a policy of striving for one common information standard. The TFM standard should be homogenized across regions according to the strategy.

In Denmark the present portfolio of hospital projects comes from a 2007 government decision to create a quality fund for hospital projects. The portfolio encompasses 16 project, five new hospitals and 11 retrofit projects. In total an investment envisioned to be at 41,4 billion Danish kroner.

One should expect such a concerted portfolio would enable common standardization and thereby reduction of costs. The government and regions did organize a common expert panel and experience and information exchange on a web site for good hospital building ("godt sygehusbyggeri"). And a systematic consideration on standardized solutions was carried out. However, by 2011-2012 the position of the authorities became that the project was too different, that architectonic and logistical concerns as well as a long term tradition for employee involvement would mean that standardization was not advisable.

In the process a number of coordinated actions were taken, whereof only a smaller part referred to the building process and most to the content of the future hospitals. The two main initiative "best practice of the building process" and "the exchange of room design" did not lead to any concrete initiatives.

As the design of the projects was unfolding their differences even in areas of design where they could have been standardized raised media attention. Debate and critique of differing design for the same functional demands was raised, leading main decision makers to repeat the position mentioned above.

With respect to building information standards, the projects designed in parallel to the one studied here, mostly opted for BIM7AA as standard and to a lesser degree to CCS. The BISI case study of Gødstrup thus became an exception rather than an early mover.

Evaluated the innovation occurring in the three cases compared to the general status of the hospital projects in the three countries, the status look like this:

- The Danish project involves BIM and IT infrastructure broadly in line with or a bit ahead of contemporary solutions on the Danish building market, because of the use of the new standard CCS and relatively intense BIM model coordination. The project group consist mostly of companies who have been doing Danish hospitals for a long time. The project is also exhibits innovation of processes, products, organisation and business models. However, most innovations do not surpass what would be common on the Danish market or the Scandinavian market.

- The Swedish project involves BIM and IT infrastructure broadly a bit below contemporary solutions on the Swedish building market, despite the participation of large national players. The project is also exhibits relatively little innovation. This probably places the project a little below what would be common on the Swedish market or the Scandinavian market.

- The Norwegian 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.

Apart from the Swedish PTS example the public initiatives creating innovation through building information standards is thus not impressive. One can therefore turn to focus on the private side:

Many Nordic architects, consulting engineers, contractors (AEC) and even real estate firms operate across the Nordic countries rather than in just one of them (STD 2016). This is even more strong in the hospital building sector than in other parts of building. This creates a larger basis for using common tools, standards and work methods. Moreover, public clients demand of design, production and use of state-of-the-art sustainable buildings similarly requires a set of calculation, design and monitoring tools, which in content converge, yet today remains national in their character in contrast. There are cases and anecdotical evidence that the companies at present do not manage to exploit the potential of the common Nordic market for hospital building beyond managing to tender and win contracts and participate in the project, without following it up with business strategies of common objects, families, process models etc.

Innovation in procurement in building of hospitals thus still holds a large potential and many barriers both on the public and the private side to be overcome.

9 Comparing the use of standards and classification in DK, NO and SE.

The status of IT investments in Swedish construction industry is probably on a par with the UK. This means that around 70% of the companies are able to, with software and competent professionals, participate in collaborative BIM projects (NBS 2017). The comparison and drawing a parallel to UK is done because of the lack of solid quantitative material of the status in Sweden. Earlier investigations (Samuellson & Björk 2014) showed that Swedish architects use went to 45% of them using 3D in 2011 and the Swedish consultants moved to 53 % in 2011. This is equal to the UK statistics. Numerous single company cases support an assertion that BIM investment are moving on amongst architects and consulting engineers. With regards to the contractors the ten largest have quite advanced BIM installations on the path of 4D and 5D installations. A recent investigation of mediumsized contractors (Bosch et al 2016) showed that around half of the responding companies had used BIM in projects. The companies commonly referred to a lack of competence of BIM and described the use as being within visualization in design and for the client's user. Secondly more than half used BIM for collision control. It is clear that the companies at present does not use BIM for production planning issues such as scheduling, manning, purchasing. In facilities management use of BIM is still early days (Volk et al 2014). There is overall a non-simultaneity in the BIM and IT status of the industry.

The use of information standards is a side-wagon to the BIM development and follow similar non-simultaneity. The differentiation shown above for mid-size contractors indicates a similar use of standards such as SfB, BSAB, AMA, and fi2 (the Swedish standard landscape was decipted in section 3). And in the hospital area PTS is a voluntary standard used very differently by different regions of Sweden. A recent study of possibilities of cost reduction through more efficient communication shows that widespread agreement appears to exist to the potential of savings is around 15-25% of administration cost of communication (Svensk Byggtjänst 2016).

The recent formation of the non governmental association the "BIM-alliance" is very important for creating a more conserted action for the use of information standards. This goes in tandem with the recent launch of "Coclass" a new standard meant to substitute previous BSAB standards. Coclass even covers civil engineering and facilities management. BIM-alliance hosts several of the Swedish standards currently in use, such and fi2.

There is at present no common public legislation for using standards and BIM. In 2014 however five large public clients (Specialfastigheter, Akademiska hus, Riksdagsförvaltningen, Statens Fastighetsverk and Fortifikationsverket) together published a strategy similar to the UK BIM ladder and pointing to future new standardisation as a common interest with the BIM- alliance.

For the hospital area, the PTS standard collaboration is important. Originally issues by the region of Jönköping it is now widely used by regional authorities building hospitals. An organisation for continual update is in place.

The status of IT investments in the Danish construction industry is probably on a par with the UK as the Swedish. This means that around 70% of the companies are able to, with software and competent professionals, participate in collaborative BIM projects (NBS 2017). A recent investigation of BIM use (bips 2015) showed that 50% of the respondents, judged to be among the leading Danish companies, were using BIM on a majority of their projects or all their projects. The use of the BIM-models included collision control, take off of volumes of materials, using the models for analysis, in collaboration with external partners. Numerous single company testimonies support an assertion that BIM investment are moving on amongst architects and consulting engineers. With regards to the contractors the three largest have quite advanced BIM installations on the path of 4D and 5D installations, but experience "holes" in their integration of systems. However most other companies, larger and mediumsized contractors, have less use in place. This means that only few contractor companies at present use BIM for production planning issues such as scheduling, manning, purchasing. In facilities management use of BIM is still early days (Volk et al 2014). There is overall a non-simultaneity in the BIM and IT status of the industry.

The Bips investigation of the use of standards 2014-2015, showed seven different standards in use in Denmark. The two most prominent was SfB and self developed systems. Shortly after the data collection of the investigation a new standard was launched; BIM7AA type coding of building components. Judged from multiple interactions with Danish companies in 2015-2017, the BIM7AA coding is probably used most in DK by 2017 with CCS, SfB and self developed codes as second. Moreover, simply following the default coding suggestions by the commercial software in use in probably common in some phases of design.

In Denmark, the development of CCS became a process that led to a split in two communities of standards, one around BIM7AA and another smaller around CCS. Both are embedded in influential fractions of the Danish national associations and institutional set up.

There is at present no common public legislation for using standards and BIM. A socalled IKT-order presently in place recommend the use of standards, without authorizing one particular standard. This order is presently under consideration of government of cancellation. The large public clients does not follow a common strategy similar to the UK BIM ladder or the like.

For the hospital area, a common national organisation is in place, yet it is not having a common strategy or policy on the issue of BIM or information standards. The present status is that hospital projects running in parallel and even made by the same companies ues different standards, predominantly BIM7AA and CCS.

The status of IT investments in the Norwegian construction industry is probably on a par with the UK as the Swedish and Danish. This means that around 70% of the companies are able to, with software and competent professionals, participate in collaborative BIM projects (NBS 2017). The evaluation is done because of lack of statistical material covering Norway.

Several bodies have been active over a long period for developing and implementing information standards. In particular, Building Smart, Norway with their engagement in IFC and Statsbygg through their elaborated client strategy and praxis (Statsbygg 2013). The recent Sykehusbygg strategy (sykehusbyg 2017) appear to be a strong move towards a future more coordinated strategy of digitalization and information standardization.

The limited, patterned and non simultaneous situation appear to be common in the three sectors. Both on the private and public side there is hesitation when it comes to use of standards. As openly expressed by the Danish regions; the hospital projects are too different to be strongly standardized. It is interesting to note that by 2017 a host of companies operate across the three countries covered by the BISI study and one should think that this size of companies would be able to exploit repetition through BIM and information standards use. This does not seem to be the case

The limited implementation of standards should maybe also be put into the context of the uptake of other types of developmental concepts, such as lean, knowledge management etc. Here one can note that many concepts are partially implemented in the three countries. This goes for partnering, lean, knowledge management, quality concepts etc. There are counter examples of widely implemented concepts, probably due to the public regulation in place. This goes for e-fakturering (DK) , personalliggare (SE) and passive houses (NO).

10 The support structure and experiences implementing building information standards

In this section a status is made over the support given by the BISI-project to the three hospitals projects and their participants:

Overall the BISI project member together with project managers from the hospitals carried out the following activities

o Dialogue with the ICT organisation members on the value of classification and planning of the practical implementation of building information standards in the building projects.
o Carried out training of ICT/BIM employees concerning the use of classification systems.
o Carried out training of the Danish and Swedish projects architects and engineers in classification systems.
o Carried out training of the Spine software to support a more ”automatic” classification of BIM-objects in Revit.

10.1 Denmark – implementation effort

The building information standard CCS was a client requirement at the hospital project. The consultants agreed to an ICT-contract with the client demanding all digital material handed over should be CCS-classified including building components and rooms. Also all digital material, that is handed over at the decommissioning should be classified in CCS. However, the agreement was vague when it comes to information level or design levels during the process, which led to temporary deviation from the overall demand of classification.

To give an understanding of the classification system CCS can create value two meetings was held with the 5 parties' ICT-organisation members in November 2014 and February 2015. At these meetings, the ICT-organisation members was receiving information in the CCS-classification system. There was agreement that if all project members classified continously in the process, it would be possible to use the classification system to structure material volumes, so that it was possible continuously to use these specifications to calculate more precise volumes and costs estimations. This was a new improved element in the process levered at the meetings.

At each party at the project K-Jacobsen trained all project ICT/BIM-employees and engineers/architects in CCS-classification system. Both building components and rooms.

The company Projectspine made their software Spine freely avaible for the hospital project from 2014-july 2016. Enabling an automatised CCS-identification and coding of building components and rooms in Revit. This makes the modelling process and structuration of volume of materials (take off) remarkable more efficient. Projectspine trained all parties in the projects in the use of Spine, carried out on demand support for the Spine users and carried out quality control of BIM models classification level and correctness.

Projectspine and K-Jacobsen also gave continuous support to the projects ICT-leaders about the use of Projectspine CCS.

10.2 Sweden implementation effort

As mentioned there was no client requirement of use of ICT or classification systems at the hospital-project in Karlskrona. And a weak back up from higher level management.

Two meetings were held with the ICT organisation and project organisation members as well as project managers from the different parties at the project. Here the value of classification for innovation presented and discussed. One meeting was in august 2015- another in february 2016. At the meeting in august there was a certain agreement about using Revit and classification for design at project management level of the participating companies. However, this had decayed at the februar meeting where parts of the engineering design now was to be done in Magicad.

Astacus had a series of meetings with the ICT coordinators of the client and the design management (Tengbom) throughout autumn 2015 and spring 2016 dealing with which standards to use and how. And even in which way the client could require classification. Covering both rooms and building components. The client decided not to directly require classification, but to make it voluntary. Moreover a ICT agreement was not made.

Two training sessions were held for the parties ICT/BIM organisation members about implementation of the Swedish standards (BSAB and Fi2) and the use of Spine to support this. Project spine made a mapping between BSAB96 and CCS enabling Spine to operate in CCS and supporting BSAB 96.

The BIM model coordination commenced in February 2016 and continued regularly throughout the spring. This had to be done using Solibri and IFC meaning the collision control was almost only visual.

It was attempted by BISI to provide a workable solution for classifying with Magicad as Spine does not support Magicad. The proposed work arround did not come to work in practice.

10.3 Norway implementation effort

Two initial meetings with the UNN project manager, the contractor and the architect, was used to introduce the service offerings of the BISI project. An introduction to Norwegian standards was made by NTNU. The project was offered a Spine implementation, a mapping to TFM and training. The project decided to decline because of the already realized progression of the project. The project was in the construction phase already.

The BISI Project contributed to an increased emphasis on the operational phase, which supported UNNs priorities of BIM during operation. BISI interviewed the Real estate and operation function (eiendom og drift). This implied a focus on issues around data transfer between BIM models and the clients newly purchased FM-system.

10.4 Evaluation of experiences of implementation

The implementation support of BISI had four main components. First to influence the public client to demand use of building information standards. Second to provide a software tool to support the integration of the classification between the parties. Third to offer training to project members and managers. Fourth to provide support to project members, face to face and over phone/skype.

There was a “high noon” approach to classification. It was understood as only needed in the very last instance before transfer to other parties. This approach fitted poorly with the support given early in the project.

The training effort became more focused on ICT-responsible members of organization in the particular projects rather than other employees and managers in the participating companies.

The “translation” software for the Swedish and Norwegian case were a very important offer. Yet BISI did not manage to convince the project players to adopt it (as it was done in Denmark).

11 Perspectives

On the basis of the developed results, the BISI project raises the following six perspectives:

1. From single standards to coexistence of multiple standards

Building information standards are one example of standardization in industry and society. It should be expected that building information standards follow roughly the same trends as other standards, such as short time of operation, frequent updates, more generic and flexible and multiple standards in the same domain (Koch & Beemsterboer 2017). There are observers that appear to think that the AEC sector is special. World Economic Forum (2016) and Boston Consulting group for example appeals for creating mutual consent to standards and calling for a robust standard body/association. Such calls appear to disregard the long term experience of Buildingsmart and the many national initiatives taken the later years. In a similar manner EU appear to talk with several tongues, on the one hand advocating a common EU strategy on standards, yet at a time leaving the issue of a common standard open in the recent EU BIM handbook (EU 2017). The handbook proposes to avoid making new national standards, yet shy away from taking position in terms of the many new BIM standards that various European countries have made. The Swedish regions comments this through appreciating that the handbook does not take position (SKL 2017). This occurs in parallel with the findings here where all three countries studied exhibit several standard communities developing each their standard, many of them claiming to be open, non proprietarian and compliant with the international ISO standard for building information standards.

Appreciating the presence of many, complementing standards, the joint efforts should possibly be more directed towards mapping and translation of different standard enabling the coexistence, complementing pushing internal development of each standard.

2. From the all mighty global standards monopoly to a federal coexistence of standardisation

Generally it is well established that markets develops de facto standards, once one or two product come into a dominant position (like Microsoft). BGC (2016) notes that also BIM suppliers fight to establish standards and capture market share in AEC markets. And Autodesk, Bentley systems and other do participate in such battles even if their engagement in standard development has be increasing the later years (SKL 2017). But the battle also extends to competing non commercial bodies. This other aspect of multiple standards in a domain is thus the competition between the communities each carrying a singular standard or a suite of standards.

These bodies, communities, associations and organisations tend to develop internally oriented mechanisms of protection of their particular approach to building information standard or what The Swedish Transport Authority labels a “BIM centric community” (EU 2017, p 41).

Rather than a continued red ocean competition, the energy should be used to find and construct a federal order of coexistence, i.e. doing joint mappings between standards, joint development projects, continual dialogue and possibly coordination.

3.From implementing one finished standard to continuously implementing suites of standards under continual transformation

An often raised criticism of standards is that they are either unfinished or outdated. In the contemporary economy with shortlived horizons for products and continuous change, the idea of stability through standardizing is but temporal. Standards are but transitory. they should be thought of a instrumental in a window of time before new changes are to be expected. So the time gap from “unfinished” to “outdated” is closing in. The capacity of IT systems to handle several structures of ordering should be exploited far more a long with company procedures for implementation of standards when it is properly timed with the organisations other activities.

4. Big data technologies accelerates use of standards or substitute them

The use of big data technologies in construction is emerging (Bilal et al 2016). One can envisage two major impact on the use of building information standards. First the use of machine learning to automate classification has been tested in document classification, but could be extended to classification of rooms, building component, human and physical resources, translation from one standard to another and more aspects. This capacity would accelerate the coding and classification and ease of use of especially classification standards. Second big data analytics provide algorithms that can order heterogenous and unstructured data (Koch & Beemsterboer 2017) and thereby generate order and insights from the huge data pools created both during design, construction projects and operations. This second trend would tend to substitute information standards for a far more agile digital tool able to order data according to demand.

It is likely that operating big data technologies and analytics will be instrumental for ordering and reusing data more than earlier. And it is likely that such effort will reveal that even complex new building involve large amount of repetition in the use of data, meaning less need for power ordering of heterogenous and unstructured data. Which implies that the first trend above, accelerating the ordering inbuilt in existing standards is a likely development, also linking in with mass customization and platform strategies of building design and production.

5. organizational choice; specialists or general competences

The effort of using building information standard was to some degree placed with the BIM organisations in the followed case projects, with designers and others as users of the standardized information. The CCS and Spine training effort in the Danish case especially was directed to the BIM organisation, whereas in Sweden the trained group was broader. Both in the Danish and Norwegian cases specialists were hired to enable the transfer of coded data into the Facility management systems. The use of the standard afterwards was similarly characteristically different. This difference raises the issue whether ordering of data when coding according to the standard should be a specialist task or whether the entire design, construction and operation organisations should be trained in used the coding.

Ultimately this organizational choice should be taken consciously by company and clients organisations as well as project organisations. It is however likely that broad training would lever some of the barriers experienced in the Danish and Swedish project. Knowledge *of* the standard is probably instrumental over *know how of using* the standards.

In a longer perspective, basic knowledge of the standard will be useful when handling the inbuilt coding in software systems which in the future probable will be more prevalent, also referring to the above perspective of big data.

6. From macro saving to single business competitive advantage

The macro level savings of interoperability and use of standards has been established a few times. In 2016 Svensk Bygggtjänst asked players in Swedish industry what the cost saving potential would be of optimal functioning of descriptions and other project information (Svensk Bygggtjänst 2016). For public publics the estimation was in 15-25%. The present United Kingdom “Construction 2025” strategy for lifecycle savings is at 33%. Boston consulting group estimation of savings of digitalization is set to save 15-20% over the period 2017-2027 (BCG 2016).

Such macro estimations are valuable and the savings can probably only be realised through cross sectorial collaboration. Nevertheless, as it was found in the BISI project, such general savings does not establish a business case neither for the public clients, nor the private companies. There are very few testimonials, single firm result communication or scientific investigation that evaluate the cost and benefits at single enterprise level. In Denmark for example 10-11 organisations that uses CCS for example have been supported to implement CCS in 2015 (socalled START projects). However, evaluations made as statistics across companies and no clear business case was therefore presented (Deloitte & Bips 2015). If one think broader, a few studies has tried to establish the economic benefits of BIM (Azhar 2011, Sen 2012, Westergård et al 2012) and Gerundino and Weissinger (2011) contains one short case study of a construction company about the economic benefits of a quality standard from the company perspective. But these studies does not cover building information standards directly.

The companies have a legitimate business concern and their employees often work in projects that is having its own economy and cost structure. If both these groups should endeavor in implementing new building information standards as proposed in Denmark and Sweden presently, they are in need of much stronger business case arguments than what is presently available. A more profound and long term embedding of standards in the company needs to be supported by leadership that links standards to competitive advantage. Paradoxically public bodies and sector associations can be instrumental in providing the evidence for the business case. Another possibility would be that small BIM consultants profiled their consultancy through providing the business cases.

12 Recommendations

1. Given the barriers found in the case studies, in projects carried out by large public clients, it is recommended that the three national building sectors in Denmark, Norway and Sweden put far more emphasis in joint efforts for the adoption of building information standard. The benefits for a common use are substantial, but it appears that viewed from the single firm or project these benefits are not enough to create a transformation relying on a single project to many project dynamic.

2. In a similar manner, at present the three states are not demanding use of particular information standards. The importance lack of this coordinated push is not studied directly here, however a public order on an obligatory standard would undoubtedly create implementation and thereby enable innovation in the respective building sector.

3. Both Sweden and Denmark have relatively new standards developed. For both countries the big challenge now is to enhance implementation. In both countries it is but a handful of companies who have implemented the new comprehensive classifications, whereas a new narrow and competing classification is advancing in Denmark, leading to an restated patterned use. Implementation efforts can be run by non governmental organisations like Buildingsmart, BIM-alliance, BIM 7AA and Molio, but would be far stronger if led by the nation states.

4. In such national effort trailblazing success implementation in leading companies that demonstrated the positive effect has high importance. In the communication of such success company experiences it is however important not to slide into marketing and to be sure to communicate benefits along with the needed investment.

5. There is a need for establishing a business case for information standardization at company level. Svensk Byggtjänst (2016) establishes that improved communication in administrative processes of building can lead to reduced costs in the area of 15-25%. This is evaluated through single company representatives, yet is only specified on a very general level.

6. To implement a new building information standard in a company is a long process. It need to be supported by leadership, training, nurturing project successes, investment in software, continual updating and enhancing of internal families/object libraries.

7. An implementation of a building information standard in a project should be supported by an ICT agreement. Such an agreement should specify which standards should be used when. Including classification and information deliveries. The ICT agreement is moreover an important tool to clarify the clients role and demands.

8. Both in a project and an enterprise implementation training is important. All relevant employees and managers should be involved in this. It is not enough to focus on BIM or ICT employees.

9.The companies operating in the three national markets, or in several of them or beyond will need to operate several information standards. Already the national situations are patterned, and the situation is even more patterned when operating internationally. This implies operating internal matchning and translation between standards and the use of properties that refer to multiple standards in internal objects. In general, the companies need an element of their IT strategy that prepare for multiple standards in use.

10. Our cases come to focus on only a few types of information standards, i.e rooms, components and descriptions. In all three countries suites of building information standards are available. Especially process standardization through use of level of detail/design appears attractive. It is

possible for firms to implement suites of standards stepwise and obtain good results on the way. It should not be expected however that suites of standards represent a longer term stability. A company's standard portfolio has to be managed and renewed regularly if not continuously.

13 Conclusion

The BISI project has four aims

- To map and analyze the impact of building information classification on innovation processes in the building sector in Denmark, Norway and Sweden.
- To map and analyze changes in innovative direction in public procurement of buildings enabled by building information classification in Denmark, Norway and Sweden.
- To compare the use of standards and classification in public procurement in Denmark, Norway and Sweden.
- To support the classification of the hospital through the implementation of SPINE -software , (SPINE is Standard Project Information Network Exchange)

Early in the project, the multiple character of relevant standardization in building became clear. Our conceptualization thus enlarged from classification to building information standards, as the relavent standards did more than ordering of information (classify), they also encompassed standards for other aspects such as processual rules, level of detail, practices etc.

The main answer to the first two aims/research questions was elaborated through three national case studies of hospital projects in Denmark, Norway and Sweden, appreciating that innovation should be studied in context.

The three cases exhibit many examples of barriers and more barriers than enablers were found. There is not a rigorous public demand (legally) to use information standards in the three countries, even in the Danish and Norwegian states does pose demands for IFC and classification. The regional public authorities have to consider adoption more on the basis on the assumed cost reduction and societal value creation. In two out of three cases the client did not see this as necessary. The participating companies take a business consideration of whether adoption of new standards is creating sufficient benefits. Whether a public regulation would have changed the limited adoption is difficult to evaluated within this research. In the Norwegian case the proactive adoption of the architect meant that the client and contractor achieved benefits from the standardization. However other actors did not follow suit. The main barriers identified in the Norwegian case for the lack of innovations related to standards and classification was a combination of a series of issues, where a shift in contracting strategy by the client, leading to more focus on economy, time schedules and buildability is probably the most important. In the Swedish case the barriers of innovation also commenced by the position of the client. Adding six out of eight main design areas used Magicad, that made the BIM coordination suboptimal. To some degree inexperience of actors with the integration software also played a role. In the Danish case where the client demanded a building information standard used, the passivity of some company representatives meant that the training effort adopted to enable the use of CCS decayed, and that the CCS classification was done in a reactive manner at a late stage of the design, as part of preparing for tendering the contractors. It is common for the Swedish and Danish cases that the actors had to learn to use the information standards for the first time, which is by itself a barrier. It appears that a systematic internal IT-strategy of the companies building up families of object was only at is beginning.

Overall two of the three cases, the Danish and the Norwegian appears innovative, whereas the Swedish exhibit less innovation. The analysis of the ten links between standards and innovations, showed that seven of them were present, whereas innovation in customer relations, paradigmatic innovation and one technology lead to another weren't present. Standard enabled innovations, expected and unexpected, are mixed with other innovations in the three projects. Compared to the three most remarkable innovations; the reverse innovation in the Danish case, the shift of structural concept for the building in the Norwegian and the change of daylight access in the Swedish case, the information standard enabled innovation are more discrete and somewhat invisible. The innovation moreover occurs in a manner where standards and BIM use are closely intertwined in use practices. One can point to the use of Spine and a common database of coded in objects in the Danish case as a strong innovation enabled by standards. Also, the use of TFM in the Norwegian architect project and its subsequent use to support site BIM is remarkable.

Our cases come to focus on only a few types of information standards, i.e rooms, components and descriptions, which is limited compared to the suites of building information standards and even more fragmented singular standard of various types. Process standardization and property standardization appear in particular promising next steps.

The most important unexpected innovation was as mentioned that of reverse innovation in the Danish case. Reverse innovation is innovation related to creating value for customer under conditions of cost cutting. The design team reduced the cost of their design more than 50%. This type of innovation in hospital design and buildings are very important for public procurement of buildings.

The comparison (aim/research question 3) of the use of standards and its triggering innovation in the three countries show many similarities between the three countries. The limited, patterned and non simultaneous situation are common. The private and public side is hesitating when it comes to use of standards. It can be observed that a host of large companies operate across the three countries, but they seem unable to exploit repetition through BIM and information standards use.

The limited implementation of standards should maybe also be put into the context of the uptake of other types of developmental concepts, such as lean. Also many other concepts, than standards are actually partially implemented in the three countries. This goes for partnering, lean, knowledge management, quality concepts etc. There are counter examples of widely implemented concepts, probably due to the public regulation in place. This goes for e-invoicing (DK), personel accounts (SE) and passive houses (NO).

To respond to the fourth aim/research question, a support structure was set up. It was envisaged to support implementation and use of Spine with CCS as core engine in each of the three hospital cases. BISI project members, in particular Betech (later Projectspine), but also Astacus and Jacobsen A/S were meant to help training and implementing the CCS standard. This support structure came into use in Denmark and Sweden. In the Danish case the BIM project organization received training and use-support. At a later occasion Projectspine was hired by the client to organize a database of objects coded in CCS for the future FM system and to support design of phase 3. In the Swedish case a mapping was developed by Projectspine that could translate BSAB 96 to CCS, meaning that users could work with a BSAB interface, while the SPINE engine would translate it into CCS. The results of this efforts were limited however. In the Norwegian case it was posited by the client and the design build contactor early on that the project was in too late a stage to commence changing standards and the BISI support did not come in use.

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15 Method

The research design and method was done according to the four main research questions of the project:

1.To map and analyze the impact of building information classification on innovation processes in the building sector in Denmark, Norway and Sweden.

2.To map and analyze changes in innovative direction in public procurement of buildings enabled by building information classification in Denmark, Norway and Sweden.

3.To compare the use of standards and classification in public procurement in Denmark, Norway and Sweden.

4. To support the classification of the hospital through the implementation of SPINE -software , (SPINE is Standard Project Information Network Exchange)

The overall research orientation of the study is a sociomaterial view (Orlikowski and Scott 2008). This implies understanding building information standards and their use as socially constructed and with an role of the material such the building and the IT . The position is further elaborated in the literature review. The research practice is moreover that of abduction; iterating from theory to the empirical and back again (Alvesson & Sköldberg 2009).

The literature study was predominantly designed to support answering the first research question developing an understanding of innovation, standards and the relation between them. The literature study was carried out a several iterations. One in the beginning of the project, one in the middle while carrying out case studies.

Identification of relevant standards and classification to respond to research question 1,2 and 3 was done in a combined top down bottom up manner. The research group has been present in the three national building communities for a long time and have been close to standardization bodies at the national level. This gives a top down view of standard present, avaible and under development. Yet this might be quite far from actual use in the companies. Therefore, an emphasis is put into standards found in the case studies and in investigations of company use.

The choice of the method of case studies was initially based on the expectation that innovation is contextual (Tidd and Bessant 2009). Moreover, our literature study underlined that standards were often implemented partially and even in variants in different organisations. It therefore purposeful to study the effect firstly at project and company level.

Selection of case studies became a long process also characterized by making necessary compromises. Several candidates in Norway and Sweden was under consideration and contacts established. But the candidates chose to decline. The Danish case was selected on the basis of previous collaboration. Initially there was a strong emphasis on possibly implementing CCS, which was eventually cancelled in the Norwegian case, which instead studied the use of the national Norwegian standards. The three cases ended becoming relatively comparable in size (22.000+7.200 m^2, 11.000 and 13 000 m^2. Appreciating the long length of hospital building projects, it was originally not aimed at directly comparable case, therefore, the Danish project was intended to focus on design and preparation for tendering of a greenfield hospital, but only following one out the several main phases, the Swedish on early design and the main design project and the Norwegian construction on site and preparation for operation of the facilities. As the processes unfolded, and became prolonged more activities than planned became covered. Yet still the needed for closing the empirical field work did make limitations to our results.

The Swedish case study was focused on the design phase and in time from January 2015 until October 2016. This means that the programming phase, and the construction and operations phase is not covered. The case study is based upon a combination of document analysis, informal dialogues, interviews, and observations as to the activities ongoing on the project platform. The document analysis covers material uploaded on the common project web (byggnet), publically accessible material from the web and document given to the researchers by actors in the project.

In total twelve interview was made. In November 2015 four interviews with the architects and the structural engineering company was done. In November 2016 two telephone interviews were done with the client and the structural engineer. In May 2016, 6 semi-structured interviews were conducted with Engineering consultants. Nine of the 12 interviews were conducted face to face and three as telephone interview. The interviews lasted between 40 and 90 minutes each and were taped with permission of the interviewees, with exception of two telephone interviews, where notes were used. Consequently, the tapes were transcribed into text.

The identification of innovation and innovation triggered by standards was initially carried out during the interviews. This was done in an open manner searcher for more examples and types as the literature review had encouraged to look for more types. After the interview a selection of sub-sections in the transcription was done. In doing so, it was attempted to account for the diversity in perspectives and contributions made by the interviewees.

The Danish case study was mainly carried out in the period November 2014-July 2016. This implies that the project had been followed from outline proposal to commencement of construction of one of the two buildings involved. In the following period summer 2016-summer 2017 the project has been followed in a more distant manner. The case study builds on interviews, literature studies , document analysis, self reporting and presence at joint meetings.

In total 42 interviews, whereof 6 has been on telephone was carried out. Face to face interviews have taped and transcribed. Three Telephone interviews were done with selected contractors during and after the tendering process. Document analysis has been done on materials provided by project participants. It includes project plans, and public information of the project. There have not been access to the joint project web. Participation in joint meetings encompassed four meetings.

The analysis was carried out in a similar manner as described under the Swedish case.

The Norwegian project was studied from October 2015 to February 2017. The project was 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 distant manner. 16 Interviews was carried out. Both direct interviews face to face and telephone interviews, semi-structured following a prepared template. The document analysis carried out encompassed project plans and public information of the project. The researchers participated in two joint meetings.

The analysis was carried out in a similar manner as described under the Swedish case.

To respond to research question 2 and 3 literature and other documentation was collected that describes and analyze the national situations of building information standards and the development of the hospital sector

To respond to the fourth research question a support structure was set up for the three cases where BISI project members, in particular Betech (later Projectspine), were meant to help training and implementing the CCS standard. This support structure came into use in Denmark and Sweden. In the Danish case the BIM project organization received training and use support. In the Swedish case a mapping was developed that could translate BSAB 96 to CCS, meaning that users could work with a BSAB interface, while the SPINE engine would translate it into CCS. In the Norwegian case it was posited that the project was in too late a stage to commence changing standards and the support did not come in use.

The final analysis carried out through developing the final report led to revisions in types of links between innovation and standards, leading to that the analysis uses different categories that the foregrounding case reports. Which is another iteration in the abductive approach reflecting the partial mismatch between the expected and actual innovation forms.

Limitations

The resources of the BISI- project have been small compared to the long high resource efforts of the three cases and to the needed implementation support for working with new information standards. For example the Norwegian A-wing project was located in four main organisations and a client organisation in four addresses. It has been necessary to focus the data collection in the cases 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.

The principal investigator in the project has also been member of the board of bips and later Molio, while doing this project, In Denmark all interviewees has been informed about this potential conflict of interest. At a time however this position also enable further insight in the Danish work with the standard CCS.

The BISI support structure for implementation of building information standards had limited human resources. It would have been useful in the Danish case to retrain project members when the main projects started, whereas the training resources was used early to enable proactive coding. In the Swedish case much time and effort was used to lever the coding, with limited use in the project.

16 Published scientific papers

Koch, C., & Jacobsen, K. (2014). Computerized Information Standards Enabling Innovation in Public Procurement of Buildings Human Interface and the Management of Information. Information and Knowledge Design and Evaluation (pp. 373-383). Springer.

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