INFORMATION STANDARDS - A HINDER OR AN ENABLER FOR INNOVATION?

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The potential of cost reduction by efficient digital communication in building processes in Sweden has been investigated to be 15-25% of the building sum. An important part of this potential is by using building information standards, such as Omniclass and IFC. This research has aimed at evaluating the use of building information standards and its impact on innovation. Standards are understood as classification of information and rules for building processes. Selected literature help reveal the multiple character of relevant standardization in building and the effects on innovation. Ten types of effect are identified. Three national longitudinal case studies of hospital projects in Scandinavia were carried out. Many barriers for innovation when using standards were found. The regional public authorities can decide to adopt standards locally and in two out of three cases they did not. For the companies this is a business consideration: In the Norwegian case, the proactive adoption of the architect, meant benefits for the client and contractor. However, other actors did not follow. In the Swedish case, BIM coordination was hampered by incompatible design systems. In the Danish case, the client demanded use of Cuneco Classification System, a Danish information standard, but the classification was done in a reactive manner at a late stage. The Danish and the Norwegian case were innovative, but the Swedish less so. Nine out of ten types of effects were found in the cases. Standard-enabled innovations were mixed with other innovations. The two most remarkable were the Danish reverse innovation, and the Norwegian shift of structural concept. The information standards and BIM are closely intertwined in practice. A common database of coded objects in the Danish case is a strong innovation enabled by standards. The use of TFM, in the Norwegian architect project and its subsequent use in site BIM is remarkable.

Keywords: information standards, hospitals, BIM, Scandinavia

INTRODUCTION

As the digitalization of building processes progresses, the handling of building information becomes increasingly important, both from a societal and business point of view. One way of improving handling of building information is to employ standards to address interoperability and a less redundant internal structure of building information. Building information standards are understood as classification of information and norms and rules for building processes. However, an equally

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important feature of contemporary building processes is the ability to innovate both in terms of product features and processes. There is thus a need for a coexistence in construction management of standards and innovation. This research has aimed at evaluating the use of building information standards and their impact on innovation.

The core empirical material consists of three longitudinal cases of hospital building projects in Norway, Sweden and Denmark, where a large number of building information standards are in play. This includes Industry Foundation Classes (IFC), Cross disciplinary Marking System (TFM), Building Standard BSAB 96, Program for Technical Standard (PTS), Facilities management Information version 2 (Fi2), Cuneco classification system (CCS). Many of these standards claim to build on ISO 12006-2, The ISO standard for building information standards, yet many variants are present. Selected literature is helpful in revealing the multiple character of relevant standardization in building and the effects on innovation. The paper is structured in a classical way commencing with the theoretical conceptualisation moving on to method, three case studies, analysis, discussion and conclusion.

FRAMEWORK OF UNDERSTANDING

In the practitioners' articulated experience (Scholtenhuis and Doree 2017), and in early literature, standards are a nuisance that hinders local creativity and problem solving and innovation (Farrell and Saloner 1985). It can therefore be perceived as an odd coupling to ask what the impact of standards are on innovation as the answer appears given. However, present studies of standards and innovation provide a series of positive impacts. We understand innovation in the usual OECD manner as "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." Some main occupations of innovation studies in construction cab be identified: Product improvements, (finalised product, sub systems, components), process improvements, business model innovation and delivery innovations (decommissioning/ facility management). According to the international standard organisation, ISO, standards can be defined 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 2009). This definition involves two main understandings of standards, that of systematic ordering of information and that of mechanisms of coordination. ISO (2004) distinguishes the following types of standards: terminology, testing, product, process, service, interface, and data. More in particular, building information standards involving classification and/or rules aim 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 the Danish Cuneco classification system (CCS). CCS and other standards can moreover be characterized as "suites" of many related standards, like the Norwegian NS or Swedish BSAB standards. Many standards refer to the ISO standard ISO 12006-2, which is a standard for standards of building information. Building component standards would usually encompass classification of properties being physical, functional, aesthical, cost, shape or time, and attachment of them to objects. Further classification of objects involves buildings, rooms, systems, resources. Building information standards can also cover the building process, for example through setting rules for information levels in the stages of design and production. Turning to the literature on the relation between standards and innovation, it does encompass studies that find that standardization is a barrier for innovation. The homogenizing effect of standards by prescribing a common set of rules to be followed, contradicts innovative activities that often require breaking existing (standard) rules.. Nevertheless, most studies find positive mechanisms. Abdelkafi and Makhotin (2014) review the academic literature and organize twelve propositions from the academic literature on how standardization enable innovation. Our study found further four links. These have finally been synthesized into following ten links:

1. link: Standards might indirectly make resources for innovation. In the context of product and process development, there are often resource demanding side activities to the innovation that tend to occupy resources. Standardization of such side activities and sub products lead to reduction of the use of resources and thereby indirectly provides resources for innovation (Sandholtz, 2012).

2. link: Standards can enhance repetitive elements in products that enabled single customer innovation. Standardization can nurture efficient repetition of sub products based on and aimed for recurrent needs of many costumers and simultaneously enable the creation of innovation for single customers (i.e. a mass customisation strategy of product development, (Piller and Tseng, 2010).

3. link: Process standardization stabilizes work activities that create product innovation. In project based environments, design and engineering processes tend to be volatile and difficult to maintain on course. The standardisation of work processes stabilizes work progression and thereby support the creation of an innovative final product as result of these stabilized processes.

4. link: Improved interoperability and interfaces between subsystems enable product innovation. Complex products consist of many sub systems. Product development and product innovation would often encompass embedding new components and subsystems in an existing constellation or structure. Interoperability and interfaces are critical for this. Standards for the interfaces and interoperability can improve and enhance product innovation (Clark and Baldwin, 2000).

5. link: Standardization creates larger markets for products. Standardization of products would overcome use barriers in local markets and thereby create larger markets for products (Schilling, 2008).

6. link: Standardization of product data might provide innovation in customer relations. Complex products are often delivered with a digital product data model, that when standardized can enhance customer related innovation. Standardized data on a building can support process innovation in facility management (Volk, 2014).

7. link: A sector standard can trigger system innovation. A standard that embrace a sector might trigger Innovation system innovation or institutional innovation i.e changes in relations between central actors such as leading companies, educational institutions etc. and thereby innovation in the system itself.

8. link: Standards might enable business model innovation. Standards might enable development of new products and processes that create the basis for business development, i.e. new sold goods, new channels to customer, new revenue. Or in other terms business model innovation (author reference)

9. link: Standardization might trigger paradigmatic innovation. For example from linear to iterative design.

10. link: Standardization of one technology induces new related innovative technologies. Standardization of one (key) technology induces the development of new related technologies

Even if the above list is extensive, it is not comprehensive. Financial innovation and open innovation are not found in standards studies.

Summarizing. The literature of standards and innovation is vast. Many links between standards and innovation are found, but the study also shows that the positive impacts on innovation of standards are not fully explored. There are more imaginable links that might be important. Open innovation and open standards as well as financial and organizational innovation are examples. It is also 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. 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.

METHOD

The literature study behind this paper was done in two rounds, one early in the research project and one at a later stage. The case reports from Denmark Norway and Sweden are part of the Building Information Standards and Innovation project financed by Nordic Innovation and the participants. The selection of the three cases was done for mundane reasons using the authors contact net in the three countries. Several candidates were approached before succeeding with the three studies. The empirical method is a combination of interviews and documents study complemented with minor on site interaction, participation in meetings etc. The *Danish* case is part of 140.000 m² design of a new regional university hospital, Gødstrup hospital, covering a design of two buildings. The budget is approximately a half billion Euro. The overall design and construction are divided in several overlapping subprojects made by different design teams and companies. 43 interviews were done, 42 over 2016-2017, one in the spring of 2018. The project contains a somatic department, including cancer, neurology and day surgery, a multi-story rectangular building and service functions for the hospital. The *Norwegian* case study is a 22.000 m² transformation and extension of the existing University Hospital, Northern Norway (UNN) in Tromsø, finished January 2018. Total budgeted costs are 170 million Euro. In total 16 interviews are conducted. The A-wing contains polyclinics, test laboratories, day surgical department including operating rooms and day care centres, intensive care department, rehabilitation department, and clinical-medical laboratories. 8.000 m² were demolished and a number of renovations are made in the adjacent parts of the building. The *Swedish* case covers the design of a new building on the Karlskrona campus hospital in Blekinge Landsting (county council). The process followed over 2½ years through 12 interviews. Detailed design is still ongoing, preparing for tendering of contractors. The new building will add 11.000 m² to the hospital complex. A pre-study showed that the renovation required for a necessary relocation of medicine technology, microbiology and other departments within the existing building structure was costly. The option of a new built extension to the existing hospital buildings gained preference. It consists of seven floors. The building is planned to host a nephrology centre, a breast centre, microbiology and other laboratories, a morgue, an autopsy department, training facilities and technical facilities. The research project has been limited in resources in studying these three building processes.

CASE HOSPITAL DENMARK.

The design of somatic department and service centre commenced with a design brief in January 2014. The construction of the service centre started summer 2016. The design went through a long process of reduction after an early brief estimated cost overrun. The service centre is in operation and the somatic department will be in operation at the beginning of 2020. The client project manager stated from early beginning of the project, that the value of all digital information created during the entire building project should be structured and consistently organized. Furthermore, that the key to a future productive and cost-effective operation and maintenance was the possibility to transmit the data into a Computer-aided Facilities Management (CAFM)-system during the design and construction process for later use of the O&M department. In order to succeed, a common data structure for the entire building project was required and a lot of involvement from the involved teams of the different sub-projects. The client chose one common classification system, CCS, which was able to support classification of all types of design and construction objects. The hospital was the first building project that used CCS aiming to structure all type of information - from drawings, documents and folders to BIM objects and quantities in the tender list etc. The design team of the first and largest sub-project build up a generic object library of Revit objects (rooms and building system and components) structured in accordance to the CCS-systems. The object library contains property information of each type of object and what types of information the contractor should deliver when the building ready to be delivered. The owner purchased a “traditional” CAFM-system, which was able to import the CCS structured BIM data during the design. However, when the O&M-department representative tested the import of the two design team’s CCS-structured BIM data, it was quite clear that the classification was uneven. The cause for this difference was mainly that the teams had different interpretation of CCS, object naming, and information needed in design, tender and construction phases. The client had to invest a common project BIM object library. All later sub-project’s design and construction teams are to use this object library afterwards.

CASE HOSPITAL NORWAY.

The process started in 2009. The outline proposal of the new A-wing was done in 2012 followed by the functional specifications including specification of rooms and design in 2014-2015. The tendering was done in spring 2015. However, the client shifted project manager and contract strategy, moving from the main design project to a design-build contract, mainly to mitigate perceived risks in the project. At that time, the consulting engineer interpreted the design to be about 90% ready. A design-built-contract was signed changing the concept to a double length building and another facade. The design-built contractor received a very detailed material from the architects and engineers, but calculation of material costs still elevated the price, a cost increase at around 36 million Euros. A new approach to the building shell leads to roughly 9 months’ new design. The building site activities commenced in the autumn 2015 and continued in 2016 and 2017. The Lean based TAKT planning means that carpenters, plumbers, electricians, tile setter and painters follow each other. The project was on schedule until it was finished by January 2018 and inaugurated June 2018. dRofus and the module for room classification and unique numbering of rooms is used in the programming. This is a commercial standard room programming tool used by the national and many regional health authorities. For the outline project, the architects decided to build up a classified BIM model on their own initiative. This was not from start a requirement from the client, which was uninterested in digitalization issues. For the design of the project, different software programs like Archicad, Revit and Autocad were used, put together in a portfolio of building information models managed by a BIM coordinator from the architects. The BIM coordinator did a lot regarding classification for the architectural design on building elements and components. The engineering consultants did not to the same degree, but used the standard of their BIM systems (such as Revit) for classification. For them, use of classification is a change of practice from marking building components on drawings. The client did not express a particularly strong focus on digitalisation during design and construction neither, but focused on the content of the hospital. After the change to a design-build contract, the focus was on the construction. The project did not want to use extra resources on an advanced BIM model. The architects did a modification and simplification of the classification for work drawings and components standards to enable craftsmen's work on site. The BIM model was developed, just to meet the contractors' basic needs without any further attention to the operation and maintenance of the building in use. Two variants of TFM (Cross disciplinary Marking System) was in use, one for architectural design and another for Facilities management.

SWEDISH HOSPITAL CASE

The hospital client first tendered an architect firm to do a program for the building. Then a design organisation consisting of another architect firm and several engineering firms. Further participants were room planners of the client, quality control responsible and work environment responsible. At this design stage, the most important innovations occurred as the architects reconceptualised the outer shape of the building and the light access throughout the building envelope. A returning early theme is the distribution, function and organisation of the rooms. The client demands communicates his demands mainly through the 'room function program' (RFP) developed during summer 2015. The RFP gives prescriptive guidelines for which components should be in each room. The systems design of the architects floor plans were carried out, and the classifying of rooms through running numbers and functional naming. As the architectural design gradually emerged, the structural engineer commenced making concepts for the structure. The distribution of the rooms influenced structural design only at heavy equipment, dangerous chemical or explosive activities. The structural engineer needed to balance the demands from the architect, the electricity and the HVAC. An example of a conflicting demand was observed at the placement of the rooms vis a vis bearing pillars. The RFP, and the design of rooms was almost finished by May 2016. However, further changes demanded by client, impacted on RFP and the design. From the end of the conceptual system design phase, an increase in IT based review and coordination work occurred, using IFC and Solibri. Collision control continued through the detailed design phase and towards the end it obtained more time, as tendering for construction was postponed. The constellation of IT systems was three different CAD systems; MagiCad, Revit, and Autocad. In addition a document system, "byggnett". The way of working is a mixed IT/paper method where also several less interoperable IT systems have been involved. To transform 3D BIM models to 2D pdfs has involved considerable extra work

ANALYSIS

The Danish case showed that a classification system is not enough to ensure well-structured and consistent data across different sub-projects. One common BIM object library is necessary for fulfilling the project managers statement that data created in early design and construction should be an applicable and productive foundation for the future operation and maintenance of the hospital. The different design teams tend to define and structure BIM objects differently, even if they structure the objects in accordance to a comprehensive classification system, like CCS. The designer's interpretation of needed types of objects was clearly reflected in the use of design phase and the needed level of information. The owner invested in a common project object library for the whole hospital project to ensure that the CAFM-system did not contain redundant objects definition. The benefit of a common project object library will probably give the O&M-department a consistent tool for managing their future operation and maintenance work, as the digital content represent the real physical components and technical systems, even though the components and technical systems where designed and constructed by different teams in different sub-projects. Another benefit is the re-use of object definitions. In the following sub-projects, the design and construction teams had to use the predefined project object library. In the *Norwegian case*, we see a need for a much stronger involvement and commitment from the client to lead the process and define the relevant level of standardization and classification. The client organization and the engineers in the building project is relatively passive in the digitalization issues. The BIM coordinator from the architect company is here the driver behind digitalization initiatives such as proactive use of building information standards and BIM. However, this does not cover the building projects fully. The new strategy of Sykehusbygg represents a possible stronger common development of standards in the future. However, the regional public authorities that build hospitals still decide adoption locally. The proactive adoption of the architect in the design phase meant that the client and contractor actually achieved benefits from the standardization. There are several national systems for standardization and classification partly used. The use of TFM supports use of an app BIM system, BIMx, which provided updated BIM models for the site managers and workers. 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. The use of TFM by UNN and other hospital organisations in Norway is a possible platform for a common standardisation support new built and facilities management. The practice is, however, limited to local variants of TFM. The recent investment in a FM system is not directly integrated or communicating with the other systems due to a lack of unified interfaces. In the *Swedish* process, several standards have been used: The client's room classification, Fi2, BSAB 96 (AMA), PTS and IFC standards. Also, the CCS building component standard have been offered yet less visible. It supports a BSAB coding that can be entered in Revit models. However, in six out of eight main design areas the use of Magicad made the CCS function suboptimal as they are not interoperable unless IFC is used. There are few examples of actual innovation not related to the use of classification standards. The redesign of the daylight access to the building is the most important. Here the architects did benefit by their BIM systems and the embedded standards. However, this was not directly experienced as such by the architects. The use of the PTS and Fi2 standards enables the diffusion of innovations among hospital projects. The limited use of BIM and limited attempts to integrate the IT architecture have multiple explanations. The constellation of IT systems and way of working in the Karlskrona project use three different CAD systems, where integration between Magicad and Revit was a particular barrier. However, it is central that the clients do not demand integrated BIM design. This is exhibited by a low priority of IT demands in contracting, low priority of BIM by strategic management and project management. No IT agreement has been accorded upon. Adding to this, large parts of the design consultancy team operated a low level of BIM integration. This in turn created barriers for integration of classifications and standardisations beyond the above-mentioned standards (Blekinge Landsting-s room classification, Fi2, and AMA). To assure occasional, monthly, coordination of models, during detailed design, IFC was used.

CROSSCUTTING ANALYSIS OF INNOVATIONS

Below the enabling links between standards and innovation are discussed one by one. However, no. 10, was not found, and therefore only nine of ten are discussed here:

1. link: standards might indirectly make resources for innovation. In the Danish case the use of standards did create cost cutting and potentially available resources, but this effect was outweighed by a needed cost cutting during the design phase. When it came to contractors bidding, the offers were lower than expected, which created a new buffer. In the Swedish case, use of IFC saved resources through proactive collision control. In addition, the interoperability between different modelling software's would lead to indirect efficiency gains. The Norwegian case had more limited benefits of the use of IFC and collision control, due to 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, provided as a database and supported by the tool Spine. This created an option for the client to use this structured library later.

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. Hospital buildings are complex products with many intersecting subsystems. The Danish case had an interface between two complex system, the phase 1 building system and the phase 3 building system (the present case). The client aimed for coding in CCS in both, including technical installations directly interfaced between the two systems. This standardization first meant reductions in the development of descriptions for the somatic building and better information handling.

5. link: Standardisation creates larger markets for products. In all three cases the participating architects, consulting engineers and contractors participated in several hospital projects before, in parallel or after. One architect company did develop an object library for use across hospital projects containing illustrations of equipment,

furniture etc. The use of PTS and the related competences would similarly tend to favour building companies which are skilled in using it. The common hospital use of TFM in Norway for facilities management appear to create larger markets for FM.

6. link: Standardization of product data might provide innovation in customer relations. Architects used BIM for visualization purposes in their interaction with clients/customers. In early phases, visualization is often changed and it is probably instrumental for their use that they are not classified. Later, the delivery of information to the future operations and facility management played a role in all three cases. We did not 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 the client shared their developed room classification. 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 signifies a possible common platform. In Denmark, there were weak links between the case 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 develop their product, services and business model. In Denmark this include Project-spine, dRofus, Sigma and Likan. Projectspine had a platform in the Swedish project for developing its product for the Swedish market. However, the limited use of Spine prevented it to develop into a genuine reference case, but at least the Project-spine 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.

DISCUSSION AND CONCLUSION

The aim here has been to evaluate the use of building information standards and their impact on innovation. Through selected literature, a framework of understanding was established on possible positive impact of standards on innovation. In the empirical work, many barriers for innovation using standards are found. Apart from demands of IFC, there is not a rigorous legal demand for standards, so the regional public clients decide. Two out of three clients did not adopt standards. The participating companies have a business approach to standards. The proactive adoption of the Norwegian architect meant that the client and contractor achieved benefits, but other actors did not follow. In the Swedish case, the barriers of innovation also include the position of the client. As six out of eight design areas used MagiCAD, BIM coordination were hampered. In the Danish case the client demanded CCS, but the CCS classification was done at a late stage of the design and was therefore not influential on the most important innovation, the reverse innovation. 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, the Swedish less so. Seven out of the ten links between standards and innovations were found, but they are mixed with other innovations. The three most remarkable were the Danish CAFM database innovation, the Norwegian shift of structural concept, and the Swedish improved daylight access. Only a few types of information standards, i.e. rooms, components and descriptions, is in use, compared to the portfolio of building information standards available. The standards used internally in the cases are both complementary and overlapping. This mirrors a fragmented set of national level responsible institutions/bodies, which coordinate and develop suites of standards. But these are only partially implemented corresponding to the literature review finding. Especially standards for the process of design and its information levels, or design/detail levels and the production process is not in use. Several standard studies find domains covered by multiple intersecting standards. This has implications for managing building information with standards. A given standard will develop in versions and only be relevant for some time. The implementation barriers found here, thus risk to reflect a condition of constant transition of one set of standards to another.

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