

Public BIM-based model checking solutions: lessons learned from Singapore and Norway

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Abstract

There is an increasing interest for BIM-based model checking in general. The use of public solutions for building permit approval is often highlighted as an example of practical use of BIM. A global spread of these solutions could therefore have been expected. However, implementations in other countries have been limited. This study analyses the Corenet solution in Singapore and the ByggSøk solution in Norway in respect of identifying experiences that can be useful for other countries that intend to develop their own solutions. Use of the Integrated Design and Delivery (IDDS) framework from CIB helps to explain elements with an impact on implementation of the solution. This type of explanation is often missing when presenting or comparing solutions. The impact of this study is increased understanding of knowledge transfer and awareness of which elements can be re-used from others in national implementations.

Keywords: model checking, BIM implementation, maturity, knowledge transfer.

1 Introduction

BIM-based model checking (BMC) is highlighted as one of the most significant benefits for use of building information modelling (BIM) [1]. Use of BMC in the industry is mostly related to coordination of disciplines and clash control. Use of BMC can serve as an indicator of maturity for BIM in projects [2]. The public authority plays an important role as a catalyst to initiate development. National authorities have a special role in implementing BMC [3]. Building permit approval is a mandatory point for every construction project – and in this respect an obvious



candidate for BMC. The number and type of users is directly related to the number of building permit applications – so the number of “customers” of the solution is therefore known in advance. National authorities have resources to develop solutions or adapt existing solutions. Large numbers of implementations in many countries should therefore have been expected due to its role as a mandatory task in all construction projects.

However, this is not the situation – the number of implementations is limited. This raises the question: *“What can be learned from the pioneers?”* and why do we not see the expected numbers of implementations?

National public digital solutions for processing building applications are not common services. Lack of common international terms makes it hard to discover potential solutions in other countries [4]. The Norwegian Building Authority developed the “ByggSøk” (Building Application) solution in 2007 [5, 6]. This is a web-based solution for verification of filled-in application forms related to specific types of applications. They plan to develop a more sophisticated solution called “ByggNett” [7]. The “CORENET” e-Submission System from 1995 in Singapore is well known [8]. These implementations will be used as cases in this paper. Other examples on digital solutions for support of building permit applications can be the “Planning portal” from the UK Government’s online planning and building regulations resource for England and Wales [9]. Korea is developing the Seumter Code Checking System based on research at the Kyung-Hee University [10]. This list is not comprehensive, but indicates a limited number of implementations.

Digital service can be expected to be faster and cheaper than manual processing. Upon closer inspection, this is most important in smaller projects where the fee has a higher ratio compared to design time and project cost. However, maybe the qualitative improvements resulting in a more predictable outcome is the most important impact. The ability to use BMC during the design process can have a significant impact on the design of buildings. Likewise, national building authority can use digitalization during development of new regulations. BMC can be used to explore consequences of new regulations and to identify interactions between different regulations [11].

An international survey by the Norwegian Building Authority [5] pointed out the following benefits of automatic assessment systems:

- Equal requirements for information for all local authorities
- Equal assessment for information for identical types of projects
- Digital information enables reuse for other purposes
- Solutions for pre-check of application in advance of formal submission
- Support for design according to the regulations

Dr. Tan Kee Wee and Cheng Tai Fatt at the Building Construction Authority in Singapore believe that development of an automatic compliance-checking platform will return ten times the investment required [5].

Table 1 presents a Norwegian survey by the Norwegian Building Authority [5] identifying the four most important barriers and drivers for the adoption and implementation of BIM:

Table 1: Important BIM drivers and barriers [5].

<i>BIM – DRIVERS:</i>	<i>BIM – BARRIERS:</i>
- Requirements from public project owners	- Conservative culture
- Requirements from building authorities	- Fragmented industry
- Effective and agile design process	- Lack of competence
- Job satisfaction and recruitment	- Current contractual standards

2 Methodology

This study uses Norway and Singapore as cases for exploring implemented public digital solutions for processing of building permit applications. The traditional perspective has been on technology and exchange of BIM/openBIM files. Technology is an important enabler. However, this approach does not explain or provide understanding for why these implementations have not reached global spread.

This study introduces a wider approach than technology and looks into missing perspectives. In this respect, the Integrated Design and Delivery (IDDS) framework from International council for research and innovation in building and construction (CIB) has been used to explain elements with an impact on implementation of solutions. This type of explanation is often missing when presenting or comparing solutions. IDDS is a priority theme in CIB, initiated in 2006. The IDDS is comprehensive presented in CIB Publication 370 [12] in 2013, with summary in CIB Publication 373. The first version presented was CIB Publication 328 in 2009. The IDDS framework is based on three core perspectives; People, Process and Technology – expressed as: Collaborating people, Integrated process and Interoperable technology [12]. This perspective is clarified by the three imperatives: Building Information Modelling, Knowledge management and Integrated project delivery as presented in Figure 1.

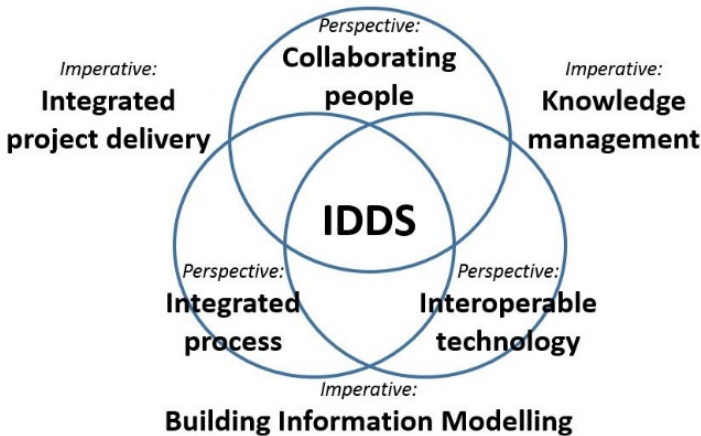


Figure 1: The three perspectives and the three imperatives in IDDS [12].



In this study are the three perspectives interpreted with a focus on digital processing of building applications:

Integrated process:

Processes and requirements related to preparing, this includes both the applicant and the building authority.

Collaborating people:

Focuses on the background assumption for people's actions. BIM maturity, competence and tacit knowledge is a part of this perspective.

Interoperable technology:

Include presentations of the technical solutions and exchange of information.

There is a connection, direct or indirect, between all three perspectives. The importance of focus on the relationships in the IDDS framework can be illustrated by using one perspective to obtain effect on components in one or both or the other perspectives [13]. This approach can contribute to enable change in design of solution and realization of change in practice. The success of development should therefore be measured by its capacity to create change. Focus should therefore not be on the deliverables from the project, but the impact of practical use [14]. The importance of focusing on collaborative BIM use has also been pointed out in reviews [15].

These perspectives; Collaborating people, Integrated process and Interoperable technology [12] are used to structure the cases from Norway and Singapore. The status of these three perspectives is based on literature reviews.

3 Case: Norway

3.1 Integrated process

Building permit application process in Norway is presented in Figure 2 [5, 16]. This process has direct and indirect influence on a long range of elements and is therefore a good introduction for understanding of all components and relations.

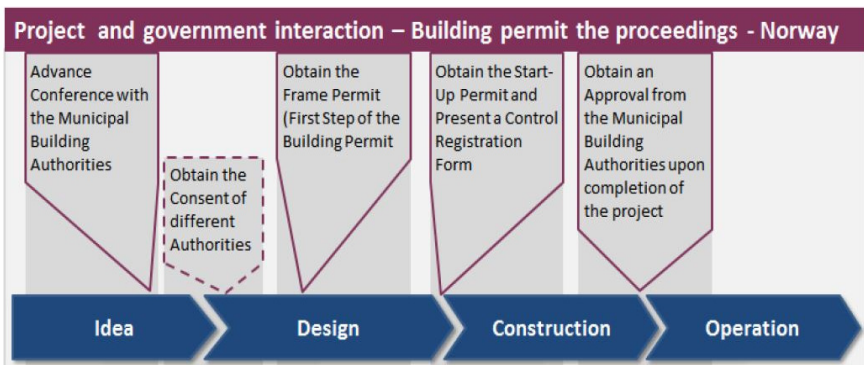


Figure 2: Building application and permit process in Norway [5, 16].

In 2012 there were approximately 110,000 applications submitted to the local building authority. Approximately 37% were submitted as paper-based forms (completed manually on paper, or as print-outs of PDF forms completed manually on the computer). ByggSøk was used as a tool for completing approx. 70,000 (63% of total) applications. Figure 3 shows the distribution of ByggSøk services from 2005 to 2012 [4].

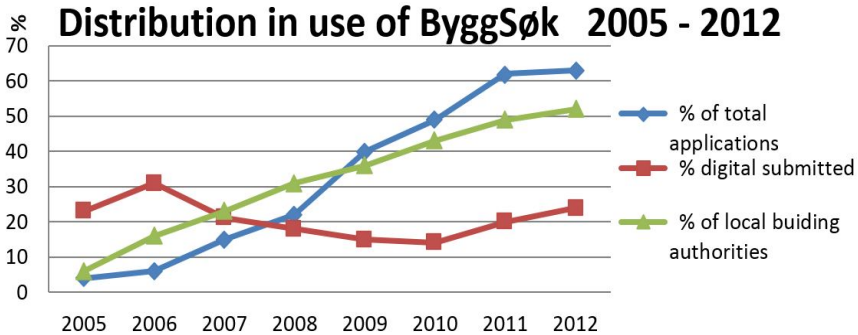


Figure 3: Distribution in use of ByggSøk 2005–2012 [4].

The processing of all applications submitted by ByggSøk is processed at one of the approximately 330 local building authorities in the same way as traditional applications using paper forms. The total number of building officers in Norway is approximately 1500 employees, varying from one part-time up to 440 in the capital.

The building permit application from ByggSøk can be submitted as:

- Printout on paper, sent by ordinary mail/delivered manually to local building authority office. This enables the supplement of paper drawings and other documents.
- Digital files over the internet. The application forms as one single PDF file, in addition to an XML structured file. Supplementary documents and drawings must be attached as PDF files. There is an option for submitting additional documents/drawings by mail. The processing does not start until the local building authority receives this.

Figure 3 illustrates an increase in use of ByggSøk as a tool for preparing the application. However, the percentage of digital submission has not increased. The Norwegian Building Authority points out two perspectives as possible explanations:

- Applicant: A large number of documents from many sources must be digitized. ByggSøk is only used to ensure that all relevant forms are filled in. There are no added benefits (reduced fee, shorter processing time) for 100% digital applications. ByggSøk is used as an advanced “application writer” with input validation of fields in the form (but no validation of content).
- Local building authority: Lack of system to process the applications in a digitized way (XML-import and use of digital attachment). Received applications are printed out and processed manually [6].

The climate and population set some constraints for the construction industry. Norway's climate has very large variations, both during the year and from north to south. This constraint influences both the buildings and their construction, in addition to working conditions and need for local adaptation of the buildings. The building authorities do not check technical specification, but the legislation requires that the design and construction is performed by qualified companies [17].

3.2 Collaborating people

The AEC industry is the second largest sector in Norway in terms of revenue and number of employees. The Norwegian AEC industry included 54,982 companies, 219,598 employees and €48.1 billion in turnover in 2013. The turnover has increased by 40% since 2009 [18]. The revenue for the hundred largest companies is approximately 30% of the total revenue for the AEC industry in Norway. This is the result of an industry that is fragmented, consisting of numerous small companies. 95% have 5 or fewer employees, 1% of companies have more than 50 employees, and 90.9% have under 10 employees [18]. The Norwegian population is 5.1 million on an area of 385.178 km², resulting in 15 people/km². This influenced the size of buildings and what the society give priority [17].

Adoption of BIM in the Norwegian AEC industry has come a long way in a relatively short period of time. BIM is today in use in most large construction projects. Especially public project owners have awareness and are requiring architects, engineers and contractors to use BIM. Architects and engineers have adopted BIM to a greater extent than contractors and Facility management (FM) professionals. Furthermore, the building construction sector seems to be more mature than the infrastructure sector, which to a greater extent is reliant on proprietary solutions. In addition to traditional design tasks, BIM is used for collision control, energy analysis and extraction of quantity for cost calculation.

The last five to ten years, the adaptation of BIM has increased greatly in Norway. Architects are the primary adopters, followed by engineers and contractors. Most large construction projects are currently designed using BIM. In addition to traditional design tasks, BIM is used for collision control in the design phase and the production of quantity-related data for cost calculation. During on-site construction, BIM is used to a small extent. The same goes for BIM use in the building operation phase [5].

3.3 Interoperable technology

ByggSøk is the Norwegian solution for electronic communication in building application processing. The first version was launched on July 1, 2003. The development lasted for three years and the cost was about 2 million Euro (2003 rate). With ByggSøk, the builder can fill out the application and send it via the internet. The current version (Version 3.2) was launched on January 7, 2013. The technical specification of ByggSøk was drawn up internally by the Norwegian Building Authority [6]. The application is based on EXPRESS Data Manager™ (EDM) from Jotne EDM Technology in Norway. The system is an object database with tools to manage complex product data models. EDM can resolve data



interoperability issues like exchange, sharing, integration, quality and archival. HTML, PDF, FTP and XML files can be exported. ByggSøk has a three-layer architecture: database, server application and user interface. The system uses a primary SQL database with transaction support. Any data exchange is done using the XML format [5].

ByggNett is a new strategy for digitalization of the entire construction related industry. This include public sector. Further development of ByggSøk with extended services for processing of building permit applications will be an important part of the new ByggNett strategy. The level of service and complexity is illustrated in Figure 4 [4].

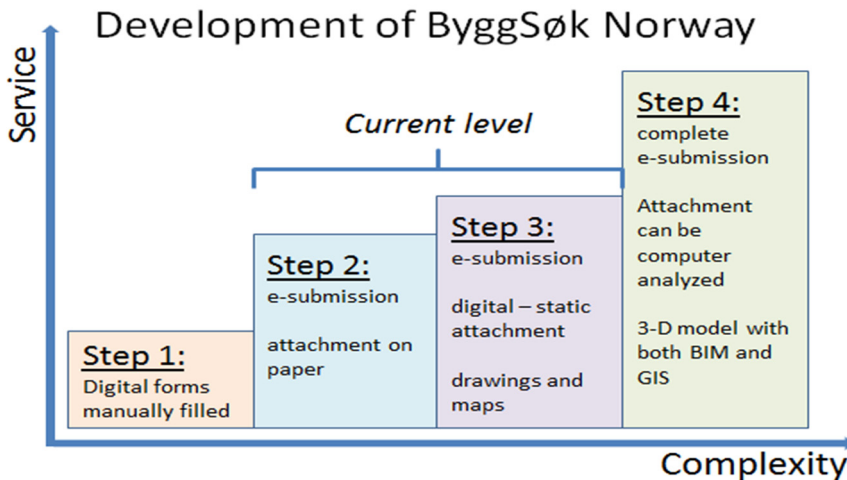


Figure 4: Development progress of the Norwegian solution [4].

The overall vision for the ByggNett strategy is simple, effective and predictable services throughout the life cycle of the built environment. The strategy indicates development of an integrated, complete solution for processing of building applications. This includes services for both the local public building authority office processing the application and for the applicant, professional or private, submitting the building permit application. There is an increased gap between Step 3 and 4 in Figure 4 to illustrate this step is demanding. Step 4 can be related to Level 3 in the UK strategy for digitalisation of the entire construction industry [19, 20].

The activities and measures in the ByggNett strategy [7] are based on three basic guidelines:

- User orientation
- Do-It-Yourself service
- Collaboration

The strategy will ensure the best possible relationship between different initiatives and achieve their goals in both the short and long term. The strategy describes five priority areas for development of:

- Relationships with industry and other authorities
- Processes and methodologies that support digitization
- Competency
- Regulations applicable for digitalisation, and
- Services and tools, applications and registry for storing, processing, sharing and presentation of information.

Implementation of this strategy is challenging because it affects many “players”. Due to this complexity, will implantation of the strategy focus on a series of small projects, instead of one large project or one comprehensive software solution [7].

4 Case: Singapore

4.1 Integrated process

Building permit application process in Singapore is presented in Figure 5 [5, 21]. This process have direct and indirect influence on a long range of elements and is therefore a good introduction for understanding of all components and relations.

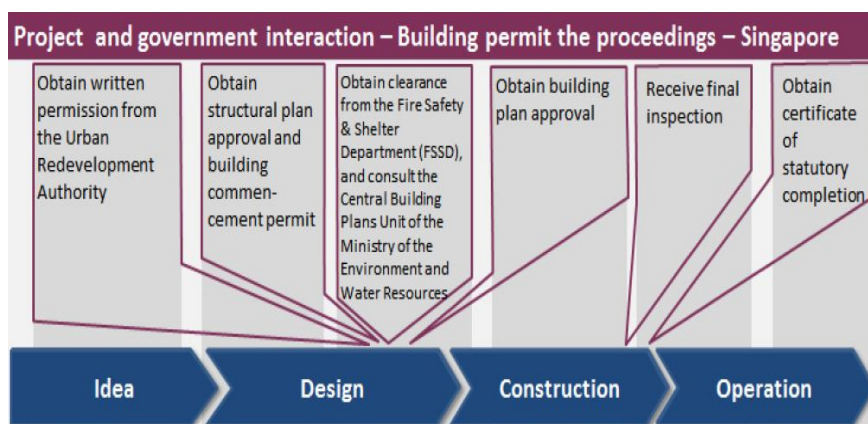


Figure 5: Building application and permit process in Singapore [5, 21].

e-Submission is mandatory: In Singapore, almost 100% of planning applications are now performed on the e-Submission System. With a customer base of over 2,500 companies, it is used widely by architects, engineers, surveyors, plumbers, electricians and other professionals. In an industry survey, 89% of the respondents indicated they had experienced cost and time savings related to printing of plans, transportation/dispatch services and increased staff productivity. Adoption of the e-Information System is similarly widespread, with a user base of over 12,000 industry professionals, resulting in the gradual phasing-out of printed copies of circulars and correspondence by the participating regulatory departments [5]. An overview of approved plans in 2014 [22] is listed in Table 2.

Table 2: Listing of approved plans in 2014 [22].

Type or application/approval	Number
Approved Building Plans	4,402
Approved CD Shelter Plans	2,917
Approved Structural Plans	16,614
Permits to Commence Structural Works Issued	6,381

Temporary Occupation Permits (TOP) Issued and Certificates of Statutory Completion (CSC) are part of the Norwegian building application in reporting finalized projects. These numbers are not relevant in relation to the Norwegian process.

4.2 Collaborating people

Construction contracts for the built environment sector are expected to reach between €19.7 billion to €23.8 billion in 2015, given a sustained pipeline of public sector projects. This follows an exceptionally strong performance in 2014 where the total construction demand set a new record of €24.8 billion, fuelled by a higher volume of institutional and civil engineering construction contracts [23]. The AEC industry in Singapore consists primarily of labour migrants in terms of building workers. Overall, 300,000 work permits were granted for migrant workers in the construction industry in June 2013. The high proportion of labour means that the industry is slowing, taking productivity into account. The government has initiated a program for productivity improvement [24]. The population is 5.5 million on an area of 718 km², resulting in 7,615 people/km² [25]. Tall buildings are dominating – enabling professional roles in the design and application process. Singapore has a tropical rainforest climate with no distinctive seasons, uniform temperature and pressure, high humidity, and abundant rainfall. Temperatures usually range from 22 to 35°C [25].

The adoption of BIM in Singapore is estimated at 65%. Most of the AEC industry players are using AutoDesk solutions. The Singapore Building Construction Authority's approach to industry adoption of BIM is based on a top-down philosophy. According to Dr. Evelyn Teo at the University of Singapore, the driving forces behind the implementation and adoption of BIM in Singapore are strong economic incentives and education. The technology is mature and available; it is the soft human aspects of organization, culture and adoption of the technology that are the real challenges. In 2010 the Building and Construction Authority (BCA) in Singapore launched the BIM roadmap. This is intended to increase productivity and the level of integration among the various stakeholders in the AEC industry. The goal is that 80% of the AEC industry should be using BIM by 2015. Singapore is currently focusing on open BIM. Though progress is moving slowly, supporters believe that non-proprietary solutions represent the only way to resolve interoperability issues [5].

4.3 Technology

The idea of an artificial intelligence planning checking system was first conceived of in Singapore as early as 1982. In 1995 the Ministry of National Development of Singapore, with the Building and Construction Authority as implementing agency, initiated CORENET (Construction and Real Estate Network) [26]. In 2002 CORENET was upgraded and the 2D BP Expert System replaced with the 3D IFC data model. The application is based on FORNAX™ from novaCITYNETS. Fornax is an IFC viewer developed for the ePlanCheck project in the CORENET program. FORNAX™ was developed specifically to perform automated checks on electronic drawings against building and land regulations for design compliance and to generate compliance reports. It extends the IFC models and builds additional intelligence to enable the implementation of checking functions. The FORNAX™ software platform was developed by novaCITYNETS. At the base of the FORNAX™ software are [5]:

- a) database technology from EPM Technology A/S;
- b) an ACIS library from Spatial Corp;
- c) Open Cascade technology from Open Cascade; and, most importantly,
- d) Industry Foundation Classes (IFC) Release 2x2 from BuildingSMART IAI International.

CORENET currently has three services: e-Submission, e-PlanCheck and e-Info.

The e-Submission System has been up and running as an electronic service since early 2002. Involving the 16 regulatory authorities across eight government ministries that regulate the construction and real estate industry, it facilitates collaboration among the various regulatory authorities. By allowing industry professionals to submit and monitor the progress of planning applications over the Internet, e-submission serves as a single government counter, available non-stop on a 24x7 basis. Industry professionals today do not need to make hard copy prints of building plans or take physical trips to the authorities. Transparency has also been improved, as all stakeholders can monitor the status and progress of planning applications online. As part of the project, government processes have been streamlined to improve efficiency and customer experience. e-Submission is based on PAVOTM, a suite of the J2EE application, which enables submission logic-handling and rules validation. It provides built-in business intelligence and secure transmissibility [5].

The e-PlanCheck initiative is the most ambitious part of CORENET. The process allows designs for new buildings to be digitally checked against building codes, using automated procedures, rather than manual paper-based processes. Involving eight regulatory authorities from five government ministries, the project will be rolled out in phases, starting with architectural works and building services. e-PlanCheck has been implemented on top of FORNAX™, a software platform developed by novaCITYNETS, which extends the IFC models and builds additional intelligence to enable the implementation of checking functions. As the name suggests, checking functions are the core functionality of the e-PlanCheck system. At the base of the FORNAX™ software are: (a) database technology from

EPM Technology A/S; (b) an ACIS library from Spatial Corp; (c) Open Cascade technology from Open Cascade; and, most importantly, (d) Industry Foundation Classes (IFC) Release 2x2 from BuildingSMART International. With IFC 2x2 as a base, a layer of FORNAX™ objects were built. These FORNAX™ objects are enhancements to the IFC 2x2 model. These objects provide richer information, which is required for the implementation of checking functions in the system. In order for the system to perform checks successfully, qualified persons submitting plans need to use CAD software that has been certified as capable of producing the IFC 2x2 model data expected by the system. This data is complemented by client-side functions that capture the additional information required by the checking functions. UK consultancy company AEC3 provided model development assistance to the Singapore government [5].

The e-Info System, available since 2002, provides a comprehensive central repository for building and construction-related information in Singapore, presented in a single format via a single portal on the Internet. The integrated information channel provides a quick and easy source of reference, doing away with the need for industry professionals to maintain hard-copy reference materials. Email broadcasts are also available to alert users to new information and updates on the portal. Supported by 13 regulatory organizations across seven government ministries, e-Info offers information on codes, regulations, guidelines, standards, product catalogues, contractors' performance and Singapore standards. By leveraging the XML technologies, e-Info stores and describes information in a machine-interpretable format that can be processed and understood easily by different IT applications. Apart from allowing seamless communication, the content can be used by different Internet-based e-business applications. At the same time, the removal of machine dependency means the life and value of information in e-Info can be better preserved and extended. During earlier development, CORENET (BP Expert System) experienced problems related to lack of 3D CAD customized to Singapore's data format and the consequent high cost of sustaining local customization efforts. Building and Construction Authority has decided that full development will be based on the IFC standard [5].

5 Exploring Norway and Singapore by the IDDS framework

Table 3 gives an overview of the situation in Norway and Singapore in terms of the IDDS framework. It is the relations between the three perspectives; Integrated processes, Collaborating people, and Interoperable technology, that are relevant.

Table 3 represent overview of components from the Norwegian and the Singapore solution for digital processing of building permit applications. The overview illustrates both similarities and differences between Norwegian and Singapore solutions, but it does not identify any components that alone explain the success of both solutions. Even if both solutions use model server technology, this is implemented very differently. The overview does not identify whether if the connection between the components are direct, indirect or absent.

The IDDS framework indicates that the success of both solutions can be explained by based on the balance between the perspectives and adaptation of



Table 3: Exploring Norway and Singapore through the IDDS framework.

IDDS	Norway	Singapore
Integrated processes		
Number of application processed pro year	High Approx. 110,000	Low Approx. 4,500
States of involvements	Start early in the application process – Idea phase	Limited – End of design phase
Demand for BIM	Large public projects	For building applications
Validation of technical solutions	Not checked by the authority	Checked as part of the application
Role of “drawings”/ models	Limited, External aspects; heights, area, and distance to other buildings, infrastructure	Important to check technical requirements, fire safety. Flexible view of section in model is important
Scope of content/ perspective in application Technical	No checking technical solution – Requirements addressed to responsible company Only focus on process	Comprehensive checking of technical requirements Fire, Technical solutions
Legislation	Comprehensive	Comprehensive
Legislation type, Act, Code, Guidance level	Function based, with some prescriptive guidelines	Prescriptive based (mostly), some function based requirements
Size of project in the application	Variation, mostly small private projects	Large professional projects dominate
Number of offices processing the application	Many, approx. 330 local building offices (in most municipalities)	One central office
Size of building authority approving applications	High variation; 1500 people total in Norway, from 1 part time employee to 440 employees in the capital.	Large, one central office
Collaborating people		
Structure of industry	Fragmented, small companies under 10 employees dominate	Large companies, large commercial projects
Application produced by	Private applications dominate in numbers	Commercial companies
Role definitions Responsible applicant	No professional requirements, role only as contact person	Certified operator, profession role
Importance of construction industry for national economy	High	High / medium



Table 3: Continued.

IDDS	Norway	Singapore
Collaborating people continued.		
Importance of public projects for construction industry	Very important	Important
BIM maturity/technology awareness	High, and with focus on openBIM/IFC-format	High, but with focus on use of Autodesk software
Interoperable technology		
Type of technology	Model server	Model server
Input – specification of file format	Text informs Files as attachment; PDF (preferred), doc and jpg	File based –view of building models
Processing	Input of text in forms	Input of text in forms
Validation (checking/control)	Validation of correct filled-in forms No check of attached file - manual operation	Validation of correct filled-in forms Support for check of attached files of building models - semi-manual operation
Presentation	Not included Read PDF/jpg files of drawings	Use of Fornax viewer for presentation of model. Enable free choice of sections.
Integration with other registry:		
- cadastre	Not included	Included
- business registry	Included	Included
- other public authorities	Not included	Included
BIM implementation in industry	High	High
OpenBIM implementation	High	Limited

components. An impact of this will be that lessons learned must be funded on understanding of *why* they have chosen to do, then on copying *what* done for national use.

6 Discussion

The intention with this study was to identify lessons learned from successful solutions.

It is not a comparative study trying to identify the best solutions from each country – and then recommend combining these into the “best” solution – be we “copied” for national implementation. The construction industry – and related research has traditionally been done with focus on technology by use of defined criteria. Other “soft components” has often been more randomly examined. The

challenge is to find applicable framework for the entire construction industry, and in this respect was the CIB Priority theme IDDS framework selected as a framework in this study. Other theories within innovation, transfer of technology, institutionalising, maturity etc. can contribute to better understanding of elements involved. Whether use of IDDS, or IDDS alone without support from other theories give the complete picture can be discussed. On the other hand has use of theoretical framework contributed to give counterweight to the dominating focus on technology.

7 Conclusion

This study identify similarities and differences in components included in the Norwegian and the Singapore solution for digital processing of building permit applications. Both solutions has been in practical use for over ten years and undergone several revision to be update to current needs. Both solutions are based on model server technology. All countries have approval of building permit as mandatory part of a project. Global use of digital solutions should therefor been expected, and this study should have identified the most important components. However, this is not the situation. Use of the IDDS framework has identified that it is the balance between the three perspectives; Integrated process, Collaborating people and Interoperable technology, which have contributed to the success of these two solutions. Lessons learned are that increased understanding of the balance between these perspectives is the much more important criteria for success, than initiatives to copy the “best” solution, or component for another country. There is no, or limited, indication that Norway and Singapore have copied directly each other’s solutions. They have been aware of each other, an in this respect can transfer of knowledge be regarded as an important contribution. Implementation must be founded on adaptations to national situation and constraints. Solutions in Norway and Singapore have undergone several revision to be update to technology, regulation and digital maturity. Continues development must be included as part of introducing digital solutions processing of building permit applications. Experiences from use of the IDDS framework recommend this used for developing increased understanding. Traditionally has countries introducing new technology based solutions been regarded as pioneers. However, technology alone do not contribute to transfer of solutions of public BIM-based model checking solutions. Future pioneer will be countries that balance different perspectives to enable solutions for with positive cost/benefit for the life cycle of the solution.

8 Further research/studies

Experiences from this study indicate need for a more integrated research approach for analysing of multiple components and their relationships. Further studies will focus on the relation between the three *perspectives* (Integrated process, Collaborating people and Interoperable technology) and the three *imperatives* (Building Information Modelling, Knowledge management and Integrated project



delivery) to understand *how* increased transfer can be supported. Further studies will focus on identifying; *Drivers for change, Enablers, Barriers and Opportunities*. This study can include all countries planning to develop solutions. The important approach in future research will give priority to explore impact of change and their direct, indirect, derived and potential effects.

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