ByggNett

Status survey of solutions and issues relevant to the development of ByggNett

DIREKTORATET FOR BYGGKVALITET

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PREFACE

On assignment from the Norwegian building authority (DiBK), Holte Consulting has conducted a status survey of solutions and issues relevant to the development of ByggNett. The assignment has been carried out according to Holte Consulting's proposal dated June 3, 2013. The status survey is conducted in close cooperation with the client through the fall and winter of 2013.

Holte Consulting appreciates being part of an exciting project and a positive collaboration.

Oslo, January 31, 2014
Holte Consulting AS

Rune Refvik
Project Manager

Magnus Skallerud
AEC industry professional

Paal André Slette
AEC industry professional

Aleksander Bjaaland
Information technology professional

ABSTRACT

BACKGROUND

The Norwegian building authority (DiBK) has been commissioned to formulate a strategy for developing an online collaboration platform for the AEC sector. The project is called ByggNett.

SCOPE AND PARAMETERS

Holte Consulting has been assigned the project to conduct a status survey of solutions and issues relevant to the development of ByggNett. This survey includes topics such as technology, standards, regulation and legislation. Three topics are central to the survey:

- Existing automated and digital solutions for the building application and permission processes;
- Overview of initiatives to develop solutions for model checking and digitalization of building application and permission processes;
- Use of BIM based on open international standards within the AEC industry and government agencies.

This survey includes only the section of the Norwegian Planning and Building Act relating to building applications and permits. The survey reviews only that part of the interaction between a building project and authorities that relates to the building application and permission process. The project on business models for the development and implementation of ByggNett covers the economic and commercial aspects. The concept survey shows the big picture and puts ByggNett in a wider context.

METHODOLOGY

Information is obtained by means of literature survey and interviews. Obtained information is systematized, analyzed and compiled. It forms part of qualitative methodology.

MAIN FINDINGS

BIM

- The terms Building Information Model (product) and Building Information Modeling (process) are being used interchangeably. People have a conception of the meaning they attach to the term. This may cause significant communication challenges.
- Change in human behavior is the greatest challenge regardless of profession, project role or geographic location.
- The software for BIM-based design, construction and operation is mature and available.
- Maturity and adoption of BIM-based work processes diminish from best practice in the design phase to hardly being present in the operation phase.
- Open BIM (IFC) has a stronger position in Europe than in the rest of the world.
- There is an inconclusive debate whether one data format for all purposes (IFC) is the right solution for data exchange between involved parties.
- A consensual solution for unique identification and semantic description of objects in BIMs is yet to be defined. Currently buildingSMART Data Dictionary is the most mature solution.
- The AEC sector is moving into the model server era.

- The UK, US, Singapore and the Nordic countries are at the frontier of BIM adoption.
- Hong Kong, Korea and Japan are focusing on BIM and developing fast.
- Some research into benefits experienced from BIM has been done, especially in the UK. Among reported benefits are cost and time reduction. Exact benefits are difficult to predict.

Automatic compliance-checking

- Building regulations that before were formulated as prescriptive requirements are today performance based. This is a global trend. Performance based regulations are challenging to present as machine-readable rules.
- There are several software vendors developing applications for compliance-checking. The technology appears to be mature. Hence ByggNett probably can be based on existing solutions for automatic compliance-checking.
- In all surveyed applications the regulatory data representation is hard-coded into the system and is subject to manual updates by software experts. This makes maintenance and revision demanding and resource consuming.

Regional initiatives for developing application and permission platforms

CORENET in Singapore was the first serious effort into developing a platform for automated building application and permission. This may be seen as the catalyst which promoted the development of similar solutions in a series of countries. The initiatives found to be of significant interest are:

- CORENET (Singapore)
- The Planning Portal (UK)
- SMARTcodes (US) (not currently active)
- DesignCheck (Australia) (not currently active)

In addition there are projects with many similarities to the ByggNett concept in the pipeline in Korea, Japan and Denmark. The EU has recently initiated and funded a similar project in Iceland.

Seven central issues relevant to all projects are identified. These are presented in the following table. The parameters can be used in further investigations into the above mentioned initiatives.

Service automatization	The degree of automatic collection of relevant information and degree of automatic assessment of the application.
Functional code compatibility	To what extent the solution is compatible with functional descriptions from building codes.
System integration and interoperability	The solutions level of integration and interoperability with relevant systems and databases. (Similar to Norwegian government's architectural principle 2 for ICT solutions.)
Flexibility and generality	The solutions capability of processing structures of different classification, scale and complexity. (Similar to Norwegian government's architectural principle 6 for ICT solutions.)
Degree of openness	To what extent the solution is developed as an open platform based on non-proprietary technology. (Similar to Norwegian government's architectural principle 5 for ICT solutions.)
Scaling potential	Potential for future scaling in data volume and number of users. (Similar to Norwegian government's architectural principle 7 for ICT solutions.)
Maintainability	Capability of being maintained by non-experts on software technology. (Similar to Norwegian government's architectural principle 5 for ICT solutions.)

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

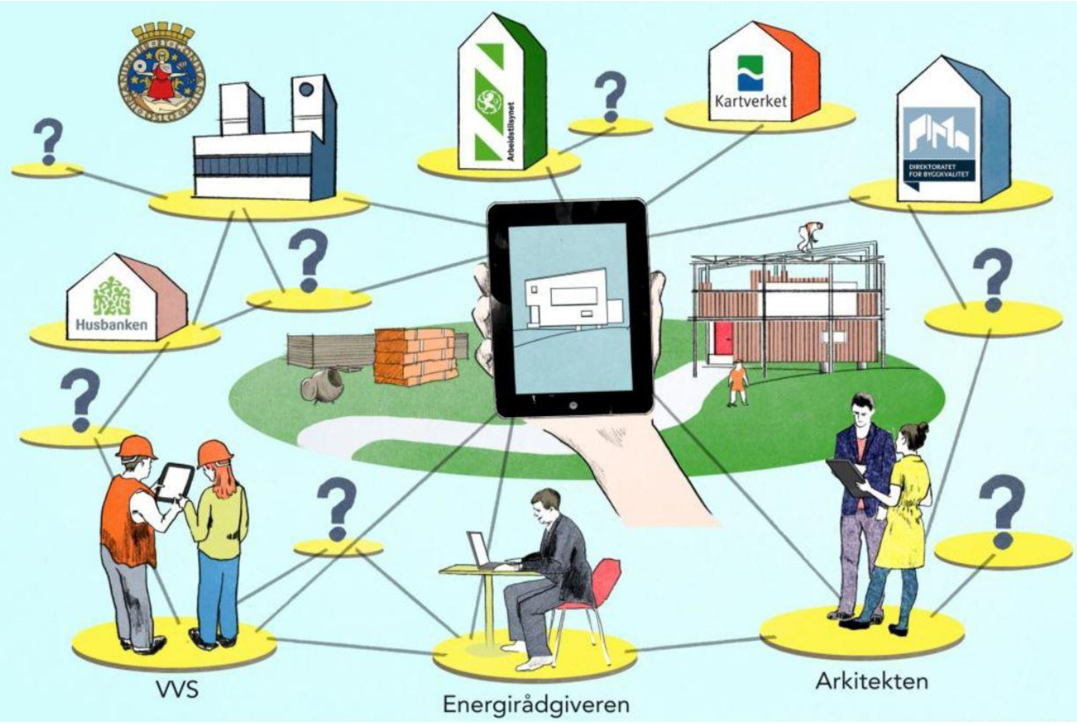
1. INTRODUCTION

BACKGROUND

The Norwegian building authority (DiBK) has been commissioned to formulate a strategy for developing an online collaboration platform for the AEC sector. This project has been called ByggNett. The directorate's mandate is to outline the concept and prepare the strategy for development and implementation.

ByggNett will consist of online services and tools provided by several independent organizations. Although many such services exist today, there is significant potential to improve the interaction between them. ByggNett is also intended to facilitate the development of new services and utilities.

Figure 1: ByggNett concept illustration (DiBK, 2013)



The common denominator is the construction project. The user base will consist of owners, developers, government agencies and suppliers of goods and services to the industry. The project will establish and maintain standards for data, processes and communication. Furthermore, it should promote and drive the organizational processes needed to lift the use of ByggNett above critical mass. The directorate's primary interest is related to the building application and permission process.

SCOPE AND PARAMETERS

ASSIGNMENT AND SCOPE

Holte Consulting has been assigned the project to conduct a status survey of solutions and issues relevant to the development of ByggNett. This survey should include topics such as technology, standards, regulation and legislation. Three topics are central to the survey:

- Existing automated and digital solutions for the building application and permission processes;
- Overview of initiatives to develop solutions for model checking and digitalization of building application and permission processes;
- Use of BIM based on open international standards within the AEC industry and government agencies.

A core team of four people has been responsible for the work, with support from relevant resources from Holte Consulting AS and Holte AS. The assignment was carried out within a limited timeframe. The extent and detail of the survey that was obtainable is therefore limited and the report should be read with these limitations in mind. Despite this, we consider the status survey to be thorough and comprehensive. It should give the reader a complete picture at a regulatory level.

PARAMETERS

During the studies we have found it necessary to define some precise parameters for the survey. These are:

- This survey includes only the section of the Norwegian Planning and Building Act relating to building applications and permits. Area planning is outside its scope.
- This survey reviews only that part of the interaction between a building project and the building authorities that relates to the building application and permission process.

The project on relevant business models for the development and implementation of ByggNett covers the economic and commercial aspects.

The concurrent ByggNett concept survey shows the big picture and puts ByggNett in a wider context.

METHODOLOGY

GENERAL METHODOLOGY

Research methodology is the systematic approach used to shed light on a chosen topic. It may seem advanced and distant, but in reality it is not any more complicated than a thorough attempt to provide clarity and understanding. The description of methodology is important as quality assurance, to enable the reader to consider the basis of the conclusions and to enable others to continue the work.

As required by the client, this survey is based on a literature survey and information-gathering by means of interviews. The literature survey was started first, but the two activities have been run in parallel during most of the project. Changes to and auditing of both the literature survey and the interviews have been necessary as the information base has developed and expanded.

The information obtained is systematized, analyzed and compiled. This work forms part of qualitative methodology, where the information is given in textual or verbal terms. Qualitative methodology requires an objective perspective to be maintained. The aim is to present a holistic and thorough picture of the topic under examination.

LITERATURE SURVEY

To ensure thoroughness and objectivity, a literature survey should be based on a pre-defined search strategy. In our work we have developed and made use of a simplified search strategy.

To obtain the best results, we have chosen databases that match the theme surveyed. The focus has been on technical databases, along with databases that include management and strategy. The Internet has been important as a source for preliminary and complementary search. Quality assurance has been carried out by examining the originating organization, the author(s), the empiricism and the arguments.

INTERVIEWS

Planning of the interviews has been done on the basis of the information received from the client and the information gathered in the literature survey. Together, the interviewees represent all parts of the AEC sector, including both private and government stakeholders.

ABBREVIATIONS AND TERMS

Table 1 presents central terms. Table 2 presents central abbreviations.

Table 1: Terms central to the status survey report

Hard-code	The software development practice of embedding the configuration data directly into the source code of a program.
Expert system	A computer system that emulates the behavior of human experts.
Hypertext	A database organized as a network of nodes and links that has cross references.
Building Information Modeling	A process for managing the information produced during a construction project, in common format, from the earliest feasibility stages through design, construction, operation and finally demolition.
Building Information Model	A representation of a building project in BIM format, usually consisting of a three-dimensional model integrated with a database about materials, products, components, systems and their properties and performance.
buildingSMART International	The organization that develops, maintains and promotes Industry Foundation Classes (IFC) as a neutral common data standard for BIM.
Construction Operations Building information exchange	A standard format for organizing, holding and transmitting information about new and existing buildings through the handover process, to support their operation; COBie is a non-geometric subset of IFC.

Table 2: Abbreviations central to the status survey report

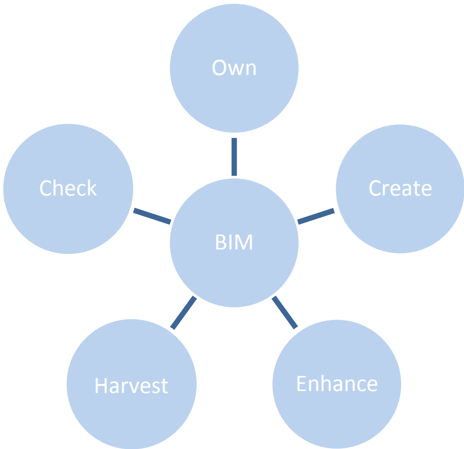
IFC	Industry Foundation Classes
bSDD	BuildingSMART Data Dictionary (former IFD)
IDM	Information Delivery Manual
AEC	Architecture Engineering Construction
BIM	Building Information Model/Building Information Modeling
EDM	Express Data Manager
DDS	Data Design Systems
SMC	Solibri Model Checker
ISO	International Organization for Standardization
DiBK	Direktoratet for Byggkvalitet (Norwegian building authority)
RASE	Requirement, Applicabilities, Selection and Exceptions
ICC	International Code Council
LKIF	Legal Knowledge Interchange Format
ESTRELLA	European project for Standardized Transparent Representations in order to Extend LegaL Accessibility
OASIS	Organization for the Advancement of Structured Information Standards
NBS	National Building Specification
CAD	Computer aided design.
COBie	Construction Operations Building information exchange
gbXML	Green Building XML
RIBA	Royal Institute of British Architects
STEP	Standard for Exchange of Products
SQL	Structured Query Language
AIA	American Institute of Architects
AIA	Accessibility Interoperability Alliance

REPORT STRUCTURE

The building model which is developed through the design phases is central to this status survey. The building model is created by the architect, owned by the project owner, enhanced by engineers and harvested from by a range of analysts and advisors. Sometimes referred to as CRUD (create, read, update, delete) operations (Beetz et al., 2011).

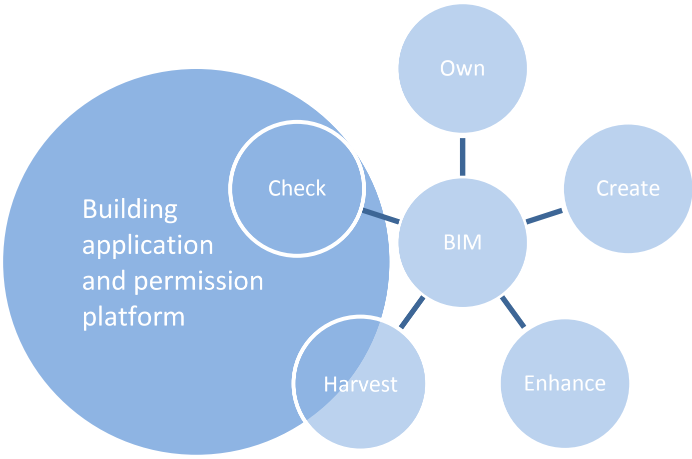
Figure 2 illustrates a simplified model of how the BIM is the central repository of data.

Figure 2: The BIM as central repository of data



The building model contains the information which necessarily must be subject to review in an automatic building application and permission process. This is illustrated by the larger circle in Figure 3.

Figure 3: Relation between the BIM and the building application and permission platform



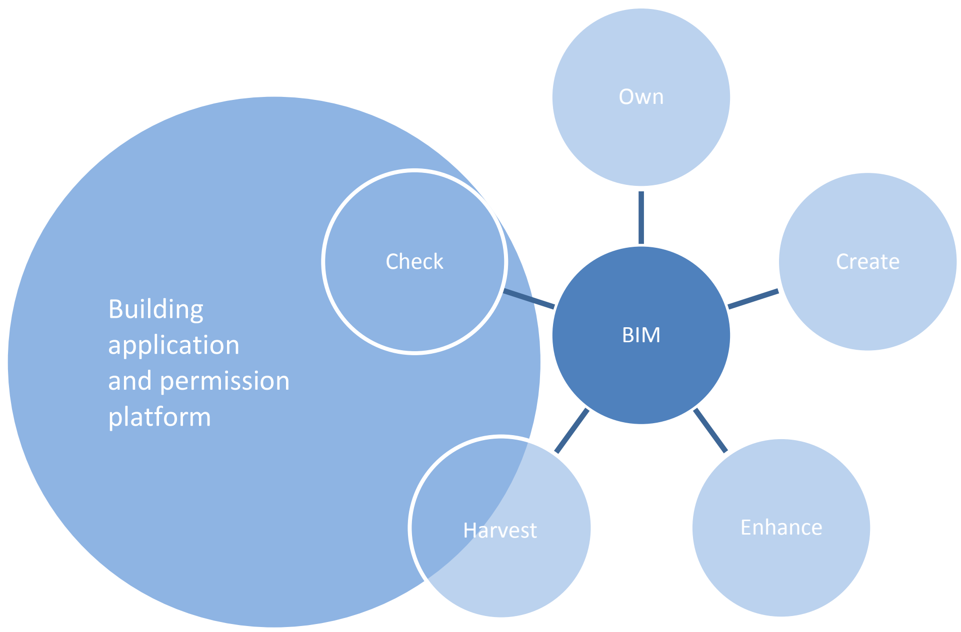
The “BIM”, the “Check” and the “Building application and permission platform”, in this order, will be investigated in this survey. We will start each chapter with a short introduction and a graphic where the element in focus is highlighted.

2. BIM

Over the last ten years the focus on gathering all the information for a building project in one place that is accessible by all involved parties has been increasing. The number of applications for Building Information Modeling (BIM) in building design, construction production planning and 4D simulation is growing rapidly (Sulankivi et al., 2013).

A number of project collaboration methods and tools exist that allow the controlled spread and integration of information among project stakeholders (Beetz et al., 2011). In contemporary construction projects, collaboration through an electronic platform has become commonplace. In the last few years BIM has emerged as the common solution for managing, representing and sharing information in building projects.

Figure 4: The BIM in context



BIM – BOTH A PROCESS AND A PRODUCT

BIM is an abbreviation for both a process and a product. There exist several different definitions of both the modeling (process) and the model (product).

Building Information Modeling
A process for managing the information produced during a construction project, in common format, from the earliest feasibility stages through design, construction, operation and finally demolition (Construction Products Association, 2013).

Building Information Model
A representation of a building project in BIM format, usually consisting of a three-dimensional model integrated with a database about materials, products, components, systems and their properties and performance (Construction Products Association, 2013).

In interviews and workshops with government parties and AEC (Architecture, Engineering, Construction) industry players we have asked whether the M in BIM is viewed as the "model" or the "modeling". It is obvious that both terms are in use. Some have awareness of the meaning of the word and the message they are sending, while many use the abbreviation without any awareness of whether they are using the word "model" as a noun, meaning a product, or verbally, meaning the process of modeling. This is consistent with the findings of several research studies, for instance Wong et.al (2009), which state that the terms are currently being used interchangeably.

Some argue that the M in BIM stands for "managing". Through the interviews we have done with industry players, it is obvious that Building Information Managing as a term is little used.

BIM extends building design from geometric 3D models to 4D and 5D (time and cost) models, potentially enriched with all the information connected to the object to be built, for example, material quality requirements, energy performance, fire resistance of elements and vendor information. The BIM can be used for all types of analysis, from structural analysis, like static loads and earthquake resistance, to air flow and daylighting.

The as-built BIM describes the building as it actually was built. It contains information important for building operation and maintenance.

Figure 5: A typical model view of a BIM

BIM COMMUNICATION PROTOCOLS – CLOSED OR OPEN

A prerequisite for efficient information exchange is a data model common to all project stakeholders and a database allowing individual operations of single building components (Beetz et al., 2011). Models fall into two categories: open BIM and closed BIM. (In addition to these two solutions there is also the bespoke solution where everybody learns everyone else's language. This is inefficient and in most cases to be avoided, if possible.)

Closed BIM is the single platform solution, where all parties involved must "talk the same language". This typically involves proprietary solutions from commercial software vendors, where information exchange must be carried out in a specific file format. Closed BIM is relatively simple to implement within large organizations offering a single discipline service. With a company-wide solution the software interfaces are seamless and information exchange is relatively uncomplicated. A common challenge results from different analysis and specific design tasks being carried out in different software applications. Further problems emerge when the different disciplines are allocated to various companies using applications from different vendors, which is the case in most construction projects.

> ***"IFC is just XML under the hood."***
> *Jonatan Schumacher, Thornton Tomasetti*

Open BIM is a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows (buildingSMART International, 2013). It is a common platform solution where all parties involved can "talk their own language" and communicate through a common interpreter. Open BIM is the initiative of buildingSMART International, an independent non-profit organization with contributors across the global AEC industry. In Open BIM information exchange is carried out using the Industry Foundation Classes (IFC) format, which is based on a XML schema. More information on openBIM standardization and underlying technology is given in Table 3. The IFC model provides a predefined standard that covers a large scope of interoperability, including architecture, structure, fire engineering and building service domains, and consequently it is complicated (Ding et al., 2006). Many players within the AEC industry argue that trying to develop one information exchange format that suits all disciplines and purposes makes IFC big and complicated, and hence slow and cumbersome to use.

BuildingSMART

BuildingSMART is a world-wide alliance driving the development of open, non-proprietary, internationally recognized standards, tools and training to support the wider adoption of BIM (buildingSMART International, 2013).It is a non-profit organization with contributors across the global AEC and FM industries. BuildingSMART International is the global overarching organization. The International Council (IC) is the legal governing body of buildingSMART International. The Executive Committee (ExCom) is the IC's surrogate during the intervals between meetings. The Norwegian chapter, BuildingSMART Norway, is a central and active part of buildingSMART International. It is currently lead by Steen Sunesen.

Thornton Tomasetti develops a simplified alternative to IFC
Thornton Tomasetti is an American engineering company established in 1956. The company has worldwide activities within structural engineering, building skin, building performance and sustainability. They have participated in some of the world's largest, tallest and most innovative building projects (Thornton Tomasetti, 2013).

Thornton Tomasetti is investing more in R&D than most AEC engineering firms. They are focusing on developing models for analysis and iterations in early design stages. They believe this is important to value creation, though it demands frontloading of design costs.

Thornton Tomasetti has experienced IFC to be very large and demanding, and believe this to be a consequence of it being tailored to fit all parties. They experience export/import to be slow and the models not trustworthy when imported to some applications. As an answer to this Thornton Tomasetti has developed TTX. This is a simplified format of IFC based on a relational database instead of XML. TTX allows export/import between different applications. They say that relational databases are more efficient to work with than XML files.

Whether the AEC industry will move in the direction of proprietary solutions or open BIM standards is unclear. The large commercial software vendors have used their position to promote their own proprietary solutions. They have long held on to their proprietary file formats and information exchange protocols. Today many applications are compatible with the open BIM schema from buildingSMART. Exporting of information in IFC format is possible in most software applications, but updating/altering exported information and feeding this back into the software applications is in most cases not possible. Some within the industry argue that one standard for all is the wrong way to go, while others are convinced that open BIM is the only way to make information exchange efficient. This survey hasn't found a basis for any conclusion in one direction or the other. What is obvious, though, is that openBIM and IFC have a strong position and support in Europe, while proprietary information formats have a stronger hold in the US and in Asia.

Table 3: Open BIM - underlying technology

Open BIM – underlying technology	
IFC	Industry Foundation Classes (IFC) is the open and neutral data format for openBIM. The IFC specification is developed and maintained by buildingSMART International as its "data standard". IFC is registered as an ISO standard (ISO16739). The current version is IFC4 released on March 12. 2013 (buildingSMART International, 2013).
IDMs (former IDM)	The buildingSMART standard for processes (IDMs) (formerly known as the Information Delivery Manual or IDM) specifies when certain types of information are required during the construction of a project or the operation of a built asset. It also provides detailed specification of the information that a particular user (architect, building services engineer etc) needs to provide at a point in time and groups together information that is needed in associated activities: cost estimating, volume of materials and job scheduling are natural partners.
bSDD (former IFD)	BuildingSMART Data Dictionary (bSDD) is a mechanism that allows for creation of multilingual dictionaries or ontologies. It is a reference library intended to support improved interoperability in the building and construction industry, and is one of the core components of the buildingSMART data standards program. bSDD is based on the ISO12006-3.

EXPRESS	EXPRESS is a standard data modeling language for product data. IFC files are written using EXPRESS. EXPRESS is registered as an ISO standard (ISO 10303-11).
XML	Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. It is defined in the XML 1.0 Specification produced by the W3C, and several other related specifications, all open standards.
STEP	Standard for Exchange of Products is an open computer modeling standard for the industrial and manufacturing industries, developed by the International Standards Organization during the 1980s (Construction Products Association, 2013).

"National BIM Standard is all about nuts and bolts."
James Vandezande, HOK

Some national building authorities and building owners have developed manuals setting out BIM guidelines and requirements. In general these describe how models are to be specified and/or how the modeling process should be carried out. These manuals typically seem to focus more on technical specifications and software solutions than on the process of modeling. Among the front runners in this area are: the UK BIM Task group, the US General Services Administration (GSA), National Institute of Building Sciences (NIBS) and Construction Industry Institute (CII), Senate Properties in Finland and Statsbygg in Norway.

The role of the commercial software vendors - AutoDesk
AutoDesk is the largest international software vendor for computer aided design (CAD). The company is based in the US with offices and a strong market position worldwide. AutoDesk delivers software for 2D and 3D design as well as BIM to the construction, manufacturing and entertainment industries. Within the AEC sector AutoDesk software is used by architects, engineers and project managers among others (Auto Desk, 2013).

AutoDesk, like any other software vendor, is doing a lot of research and development. Efforts are done in the area of information exchange, cloud BIM and automatic rule checking, among others.

Phillip Bernstein, Vice President at AutoDesk, claims that BIM must be approached with a bottom up perspective. He sees the building information modeling process as closer related to the World Wide Web with its indexing than to reference libraries and Enterprise Resource Planning which is adopted by manufacturing sectors. The AEC industry has certain intrinsic characteristics that make it different from manufacturing industries like petroleum or automobile, he states. It is based on traditional guilds and is extremely fragmented. "It will be very hard to get the small manufacturer of door knobs to adopt BIM and a reference library."

AUTODESK.

INFORMATION EXCHANGE AND MODEL SERVER

> ***"We are moving into the model server era."***
> *Charles Eastman, Georgia Institute of Technology*

The construction project work flow is never linear. Especially in the early stages when the process is undefined and conceptual changes and iterations take place frequently. Most companies have file servers, but today these are not able to cope with the BIM. As stated by Charles Eastman at Georgia Institute of Technology, we are moving into the model server era.

When information is delivered from one discipline to another, or from one design phase to the next, knowledge is lost. This is the case for all information exchange, regardless of industry. Model servers can contribute to reducing the loss of information by having the AEC professionals continue the design in the same model, instead of handing over files by means of data drops.

Figure 6: Information drops from one phase to the next

With the model server concept the BIM is located on a server accessible to all parties involved. Model servers enable efficient information exchange, with all parties working in the same model. Model servers have been pointed out time and again to be a crucial requirement for an increase in efficiency and productivity for the AEC industry (Eastman et al., 2008). Model servers fall into two categories:

- Persistence tools for open, vendor-neutral models resulting from heterogeneous applications. (E.g. the BIMserver project.)
- Persistence tools for proprietary, native application models enhanced with versioning and multi-user capabilities. (E.g. software packages such as ArchiCAD™ and Revit™.)

Though a lot of research is being done in the field of model servers, the AEC industry is facing many challenges. Perhaps the largest current challenge is the synchronization problem: when you make a change, how can you make sure that this change is synchronized among all design disciplines? The level of interdisciplinary integration does not seem to have come far enough to deal with this problem.

Another challenge related to all parties working in the same BIM located on a server arises when the construction element suppliers are contractors (e.g. the supplier of precast concrete). They make their own models in applications connected to their manufacturing process. These models are seldom or never fed back into the central BIM and hence as-built information is lost. Information that is crucial to building operation, maintenance and eventually demolition.

INDUSTRY MATURITY AND ADOPTION OF BIM

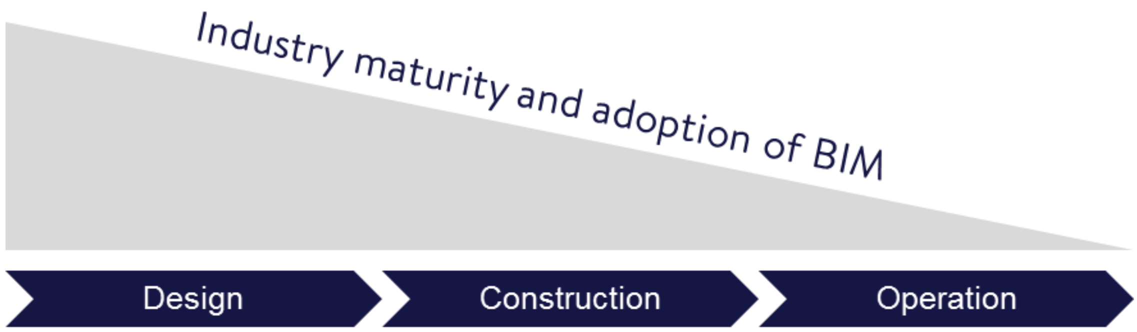
Although the technology has been around for some time, BIM is still relatively new to the AEC industry. The adoption of BIM is depended on, and varies with, some key variables. These have been found to be:

- Regional culture differences;
- Governmental incentives;
- Company size;
- Focus on research and development.

We expand briefly on this in later chapters where we look at the regional differences in the maturity and adoption of BIM.

The maturity and adoption of BIM also varies through the building lifecycle, as illustrated in Figure 7. BIM is used a lot in early phases and in many construction projects by all disciplines in during the design phase. During the construction phase BIM is at present relatively little used and the application is unsophisticated in technology terms. When the building is handed over for operation much information is lost and the use of BIM is not well defined. The most sophisticated solution for operational advantages from BIM is the US COBie initiative, but this is still at an early stage and not much more than an advanced spreadsheet.

Figure 7: Industry maturity and adoption of BIM through the building lifecycle



bimSCORE
bimSCORE is a start-up company based in San Francisco, US. The company currently has approximately twenty employees at offices in North-America and Asia (bimSCORE, 2013).

bimSCORE is an evaluation model for the maturity and adoption of BIM within building and construction projects. The concept is a spin-off from the Center for Integrated Facility Engineering at Stanford University. The model is to be used for advising building owners, designers and builders to functional and business performance in all stages of the building life cycle. A light version of bimSCORE is available online free of charge.

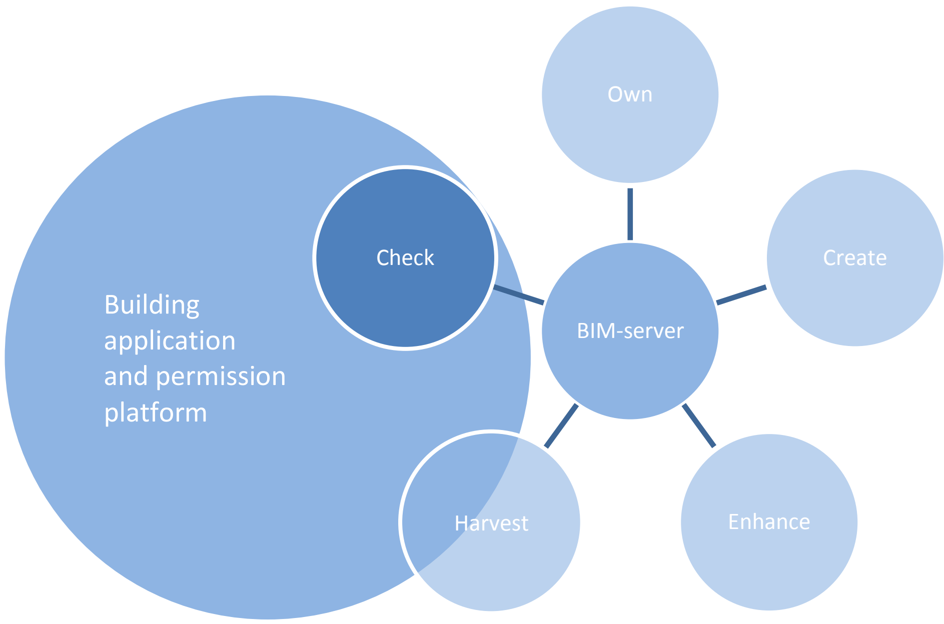
BIM Score is used in the 2013 issue of the McGraw-Hill SmartMarket report on global BIM adoption.

3. AUTOMATED COMPLIANCE-CHECKING

Several studies have identified the checking of building design against building regulations as time-consuming and error-prone (Shih et al., 2012). These challenges result largely from the manual certification processes conducted by the building authorities and are compounded by increasing complexity in both the building specifications and the building regulations.

Over the last four decades there has been an extensive amount of research conducted in the area of automated and semi-automated regulatory compliance-checking for the AEC industry (Dimyadi and Amor, 2013). The focus has been on the development of suitable digital representations of both the building and the regulations, and making these capable of communicating. Previously CAD and currently BIM, together with IFC, were established as reasonable methods and generally accepted protocols for digital representation of buildings. However, the complexity of representing building codes as computable objects has been a major challenge, and the contribution from the legal sector has been insufficient. Since the early 1990s more attention has been focused on this challenge and researchers have expended a lot of effort in formulating digital representations for both prescriptive and performance-based regulations. The legal sector has entered the field and is contributing to current research and development.

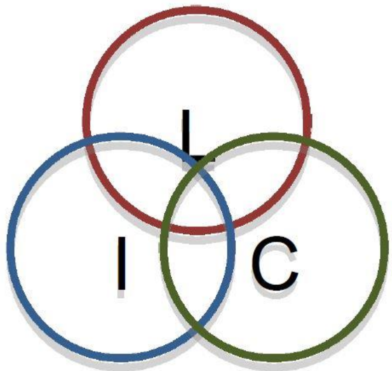
Figure 8: The "check" in context



NEED FOR AN INTEGRATED APPROACH

Several studies have identified the checking of building design against building regulations as time-consuming and error-prone (Shih et al., 2012). Manual compliance-checking is inefficient and unpredictable. An automated code-checking software tool is needed to identify potential problems early and correctly assess designs for compliance (Ding et al., 2006). An example often used is the checking of safety codes. What today is being checked manually by local building authorities is possible to check automatically through the use of BIM-based rule-checking (Sulankivi et al., 2013). The benefits should be obvious.

Figure 9: Interface between informatics, legal and construction (Hjelseth, 2013).



Building application and permission processes take place in the interface between the legal field, the informatics field and the building construction field. Hjelseth (2013) argues that an increased integration between these three areas can enable a shift in the development of regulations adapted for automatic model-checking. Through the interviews conducted in this survey it has become clear that this view is supported by both government bodies and AEC industry parties.

Development in advanced informatics and a growing focus on information exchange protocols in the legal field, along with BIM’s entry into the AEC sector, seem to have prepared the ground for an integrated approach to developing solutions for automatic compliance-checking.

PERFORMANCE-BASED OR PRESCRIPTIVE REGULATIONS

> ***“Building practices, technology and construction techniques are constantly evolving. We need to make sure that building regulations are fair, efficient, up to date and effective.”***
> *UK Government Policy*

Building regulations are a statutory instrument that seeks to ensure the intentions set out by the Planning and Building Act. The regulations set out the rules for work in new or converted buildings to make them safe and accessible, and at the same time limit waste and environmental damage (GOV.UK, 2013b). Those carrying out building work must usually arrange for their work to be checked by an independent third party to make sure that the building specifications meet the required standards, i.e. the building regulations. In Norway the role of the independent third party is played by the local building authority, while the regulations are published by the national building authority (DiBK).

There are two different ways in which regulations can be presented, prescriptive and performance-based.

Prescriptive regulation
Imposes rules containing detailed requirements to which technical solutions must comply.

Performance based regulation
Prescribes the outcomes to be achieved by the technical solutions.

The current Norwegian building codes, TEK 10 (FOR-2010-03-26-489), are performance-based.

Performance-based regulations are formulated as legal text, open to interpretation and discretionary use. Representation of these regulations as computable objects is challenging.

Prescriptive codes have their advantage in being formulated as rules, with binary and quantified measures to which technical solutions must comply, and consequently they are easier to represent as computable objects.

Building codes in many countries around the world are shifting from prescriptive to performance-based. This allows industries as well as individual companies to take different approaches to achieve the required outcomes or performance targets. The shift is also due to economic and social reasons, to advances made in science and engineering and to the global harmonization of regulation systems. Performance-based codes are more flexible in permitting innovation. They permit the incorporation and use of the latest building research, data and models. Models can be used as tools for measuring the performance of any number of design alternatives. The optimum design meets the code objectives and at the same time the needs of both the designer and the user.

A challenge in the area of performance-based as against prescriptive regulations is the part of the building application and permission process that deals with aesthetic issues. The building codes contain both the technical specifications of a building and the aesthetic elements. These are two very different perspectives which must be approached in different ways. The technical specifications are often uncomplicated to present using quantifiable measures and can be formulated in prescriptive terms, while the aesthetic aspects have inherent characteristics that require them to be evaluated differently.

Separating aesthetics from technique
Charles Eastman, a researcher at Georgia Institute of Technology, has done a lot of research in the area of virtual design, model servers, data exchange and automated compliance checking. He argues that to make automatic compliance checking possible aesthetics must be separated from technique. He sees aesthetics as connected to the form and visual characteristics of a building's exterior. Technique is related to floor plans and vertical infrastructure/communication within the building envelope. An effort to develop automatic compliance checking should begin with the parts of the building codes that are most suited for rule checking, i.e. quantifiable measures. "We all walk on floors" he states.

REPRESENTATION OF REGULATORY REQUIREMENTS

Traditionally legal documents are presented in a format that requires them to be interpreted manually. To enable automatic compliance-checking, the context and content of building regulations need to be defined in logical, readable ways so that they can be related to the BIM data being checked (Shih et al., 2012).

Researchers have expended a lot of effort in formulating an ideal digital representation of regulatory requirements for compliance-checking applications (Dimyadi and Amor, 2013). In other words, writing the regulations so that they can be read by computers, with no room for interpretation or discretionary use. This means that the semantic structure of each regulation is translated into rules or parametric tables (Shih et al., 2012).

Early work in the representation of requirements area focused on knowledge-based systems (e.g. decision tables), hyper document modeling and mark-up technology.

Through the 1990s effort focused particularly on knowledge-based systems and expert systems. These methods seek to encode regulatory information for use in design into rules, which depends on the underlying knowledge base being kept up to date at all times. Despite this reliance on manual updates, research is still being carried out in the field of automated or semi-automated extraction of information from regulatory texts into rules and other computable objects (Dimyadi and Amor, 2013).

Today the concept of marking up regulatory text to create computable representations is receiving much attention. RASE is perhaps the mark-up initiative which receives the most attention. The RASE mark-up concept builds on semantics. The foundation for the RASE concept is using mark-up based on the four operating parameters: requirements (R), applicability (A), selection (S) and exception (E) to regulatory text (Hjelseth and Nisbet, 2011). This approach makes it possible to capture regulatory documents as rules which can be read digitally, which again permits implementation into BIM/IFC based model checking software. RASE rules can be represented in the IFC schema which enables rule-checking applications to be adapted to use the model. Hjelseth and Nisbet (2011) conclude that widespread use has not been achieved and expectations regarding semantic web use have not moved forward as expected.

Table 4 gives a short introduction to four initiatives in respect of common and computable representation of legal information.

Table 4: Four initiatives to common and computable representation of legal information

Initiative	Description
Legal XML	The LegalXML initiative was started in 1998 as collaboration on non-proprietary standards for the legal community. The initiative has developed information standards for the various parts of the legal knowledge domain (e.g. eContract, Legal Transcripts, Online Dispute Resolution) (OASIS, 2013). The work is organized by The Organization for the Advancement of Structured Information Standards (OASIS).
RuleML	Rule Markup Language is a unifying family of XML-serialized rule languages spanning across all industrially relevant kinds of Web rules. The current specification of RuleML is Version 1.0 released on April 3. 2012. The RuleML Initiative is an international non-profit organization covering all aspects of Web rules and their interoperability (RuleML, 2013). The structure of the organization and execution of the work is much the same as in OASIS. The two organizations also collaborate frequently.

LegalRuleML	LegalRuleML was initiated in 2012 by OASIS. The goal of the LegalRuleML project is to reuse and extend RuleML with features specific to the formalization of norms, guidelines and legal reasoning (Palmirani, 2013). The didactical standard is oriented to support legal knowledge engineers and the syntax is annotated more effectively, descriptive and readable for users with legal background.
LKIF	The Legal Knowledge Interchange Format (LKIF) is a standardized terminology and language for interchanging legal knowledge (Estrella Project, 2007). LKIF builds on Semantic Web and the XML standards, and extends the W3C standards. LKIF was developed by The European project for Standardized Transparent Representations in order to Extend LegaL Accessibility (Estrella). The project ran from 2006 to 2008 and was coordinated by the Universiteit van Amsterdam (Estrella Project, 2008).

REQUIRED INFORMATION FROM THE MODEL

When an automatic compliance check is to be done, what information is required for it, and what data format should be used for information exchange both need to be defined. This is similar to the challenge every building design team must deal with when information is exchanged between the different players. What information is required and what information is excess?

As stated by Shih et al. (2012), several significant challenges need to be overcome in defining the information that needs to be extracted from BIM models to allow for automatic code-checking. The check that is going to be carried out should always define what information is required from the BIM. Exchange of the entire BIM will be inefficient and in most cases unnecessary.

> ***"When you want to book a flight you don't go to United Airlines and download their entire database. You go to a search engine and extract the information you require from different databases."***
> *James Vandezande, HOK*

The problem of defining how the information exchange should take place, and in what format, is closely interconnected to the proprietary versus open BIM debate, cf. Ch. 2.

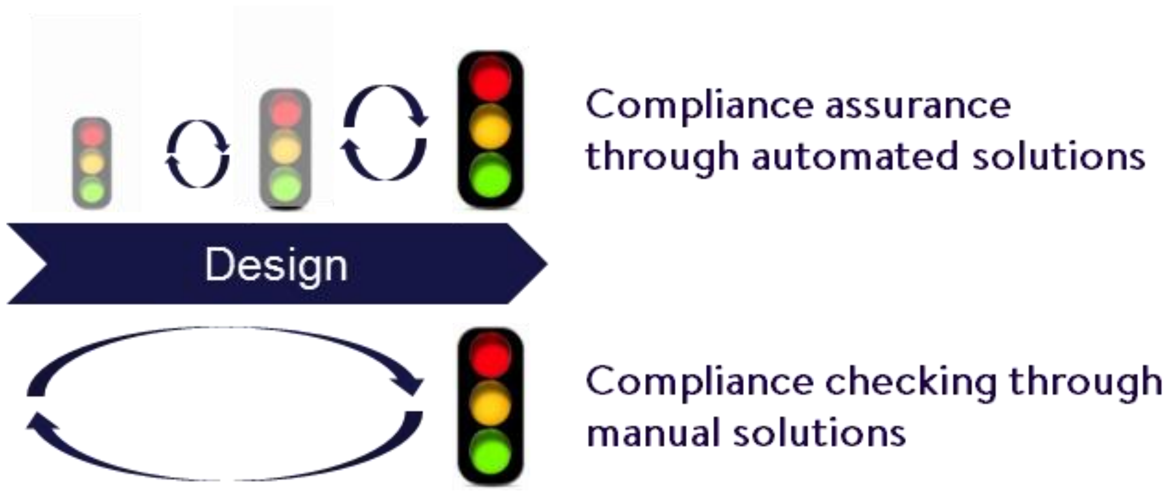
Some argue that a compliance-checking solution should be followed by a guideline that sets out how models should be designed and specified so they can be checked. This aligns with other initiatives that emphasize the importance of guidelines covering how models should be specified and how, and what information is to be delivered at what time. The Statsbygg BIM manual, cf. Ch. 2, is an example of this.

FROM COMPLIANCE-CHECKING TO COMPLIANCE ASSURANCE

In addition to making the compliance-checking process more effective, automatic compliance-checking solutions have the potential to improve collaboration and communication among project stakeholders and between the project and the building authority. An important benefit from the use of automatic building permission systems is the possibility of checking design solutions in advance, which might give a higher degree of predictability and reduce total production time (Hjelseth, 2013). This is supported by Shih et al. (2012) which emphasizes that a framework for a code-checking system should facilitate designers in various phases of the design process.

Instead of spending a lot of resources developing a design that might not be accepted, the building design can be checked for compliance against the building codes in parallel with design development. Small iterations can ensure that the building design is developed in accordance with the applicable building codes from the beginning of design to as-built specifications, and so ensure that time, cost and quality targets are met.

Figure 10: From compliance-checking to compliance assurance



COMPLIANCE-CHECKING APPLICATIONS

Numerous initiatives to develop compliance-checking applications are in existence. Some have their origin in government projects and others are strictly commercial ventures.

International initiatives to develop compliance-checking applications are presented in Table 5. The initiatives are presented in the same order as they appear in the timeline at the end of this chapter.

An important observation on the properties of the surveyed application is that the regulatory data representation is hard-coded into the system and is subject to manual updates by software experts.

Table 5: Compliance-checking applications

Application	Owner organization
EXPRESS Data Manager™ (EDM)	**Jotne EDM Technology, Norway**

EXPRESS Data Manager™ (EDM) Suite was developed by Jotne EDM Technology in Norway in 1998. 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. EXPRESS Data Manager™ implements the methodology of ISO 10303 (STEP) and is used by several international open standards, such as STEP, PLCS, buildingSMART, POSC/CAESAR and others.

EDM started as a collaboration platform but has since incorporated several additional models including EDM Model Checker that supports open development using the EXPRESS data modeling language (ISO 10303-11).

The Australian DesignCheck and the Singapore CORENET initiatives uses EDM as a platform for encoding building codes and linking them with building models.

Website: http://www.epmtech.jotne.com/express-data-manager-edm

Application	Owner organization
SOLIBRI Model Checker (SMC)	**Solibri Inc., Finland**

Solibri Model Checker (SMC) originates in Finland. It was initially developed as a tool for quality assurance and validation of IFC BIM models. SMC has since developed into a stand-alone graphically driven rule-based compliance checking and reporting application. The application has a set of built in rules that can be managed by a rule-set manager. The rule-sets can be changed, but user customization is limited due to a restricted range of objects and parameters for encoding building codes and domain knowledge.

Statsbygg has developed a code checking solution for accessibility utilizing SMC as checking platform. The rules in this solution are presented as parametric tables.

Website: http://www.solibri.com/

Application	Owner organization
FORNAX™	**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 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: (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.

Website: http://www.novacitynets.com/fornax/index.htm

Application	Owner organization
CORENET BP-Expert and CORENET e-PlanCheck	**Building Construction Authority, Singapore**

The CORENET BP Expert System was launched in 1997. The first step was an electronic consent submission system incorporating an in-house developed Building Plans (BP) Expert System to Check 2D plans for compliance. In 2002 CORENET was upgraded and the 2D BP Expert System replaced with 3D IFC data model.

e-PlanCheck allows designs for new buildings to be digitally checked against building codes, using automated procedures. e-PlanCheck is implemented on top of the FORNAX plan checking tool. As the name suggests, checking functions are the core functionality of the e-PlanCheck system.

Website: http://www.corenet.gov.sg/

Application	Owner organization
Avolve ProjectDox	**Avolve Software**

ProjectDox Eplan Review Software is a web-based, enterprise-class application. It can run as a stand-alone system, but typically ProjectDox is integrated with permitting and other government software applications and databases.
The ProjectDox core is built on the Windows .NET 2.0 development platform, making ProjectDox an open standards application that can be integrated with a wide-range of support programs and their services.

Avolve ProjectDox supports most standard CAD formats. It is unclear whether the application supports the IFC format.

Website: http://www.avolvesoftware.com/projectdox/electronic-plan-review/

Application	Owner organization
AutoCodes	**Fiatech, US**

The Auto Code software is currently a prototype that promises an integrated compliance checking capability for the US building codes.

The long-term objectives of the AutoCodes project include development of an extensive, open-source rule set library that will be approved and adopted by industry and regulatory bodies alike. The rule sets are to be used by technology developers in commercial applications and by code officials for the next generation of design, construction, and facility management(Fiatech, 2013).

AutoCodes is developed in collaboration between a series of companies and organizations. The participants are:

- Fiatech
- ICC
- Solibri
- Avolve software
- Burnham International
- Kaiser Permanente
- Computecture
- Target Corporation

In March 2012, the Fiatech Regulatory Streamlining Steering Committee released its final report on the successful completion of "AutoCodes Project, Phase 1, Proof-of-Concept." The project is currently in Phase 2 which is focusing on (1) expanding development of rule sets for other occupancy classifications and construction codes and (2) developing training materials to aid jurisdictions in transitioning from traditional electronic plan review and ultimately to automated checking. Phase 2 of the AutoCodes project is scheduled to finish in October 2014.

From interviews with AEC industry actors in the US it is clear that few believe that the AutoCodes initiative is able to deliver everything they promise. It seems to be a consensus that Fiatech are more focused on promoting their initiatives than developing them into solutions ready for implementation.

Website: http://www.fiatech.org/the-autocodes-project

Application	Owner organization
REScheck™, COMcheck™	**Department of Energy, US**

REScheck (Residential Compliance) and COMcheck (Commercial Compliance) was developed and published by the US Department of Energy. The applications goal is to allow anyone to check a buildings energy performance against the applicable energy standards, e.g. IECC and ASHRAE Standards 90.1. Both applications have all criteria hard-coded into the tools.

COMcheck 3.9.2 is the current version of COMcheck. REScheck 4.5.0.2 is the current version of REScheck. The user can download the applications or use an online version. Both free of charge.

The COMcheck and REScheck user interface gives the user an ability to review, verify, and document mandatory and prescriptive energy code requirements that are listed in the Inspection Checklist.

The US General Service Administration (GSA) Courts Design Guide automation project also incorporates an independent rule-set manually derived from the textual standards.

Website: http://www.energycodes.gov/compliance/tools

Application	Owner organization
SMARTcodes	**International Code Council (ICC), US**

Introduced by the International Code Council (ICC) in 2006. ICC develops model codes and writes many of the US building codes.

The desired outcome of the initiative was an understanding of how automated checking for compliance with codes, standards and other documents can be implemented using building information models. SMARTcodes contained official representations of a few central standards and provided the legislative body with a tool to manage the amendment of codes.

Digital Alchemy and AEC3 Ltd. was contracted by ICC to develop SMARTcodes. The system is based on a mark-up concept and use of openBIM. A proof of concept implementation for the system was developed and demonstrated in several venues in 2007 and 2008.

Development of SMARTcodes ended in 2010 due to a lack of f funding.

The SMARTcodes initiative is described in detail in Chapter 4.

Website: http://www.iccsafe.org/

Application	Owner organization
AEC3 RASE tools	**AEC3, Germany/UK**

AEC3 is an international consulting company in the field of process optimization in the building industry. Two independent companies operate under the roof of AEC3 Ltd: AEC3 Deutschland GmbH and AEC3 UK. The company is involved in the development of the Information Delivery Manual in Norway.

The AEC3 RASE tools builds on the concept from SMARTcodes.

Website: http://www.aec3.com/

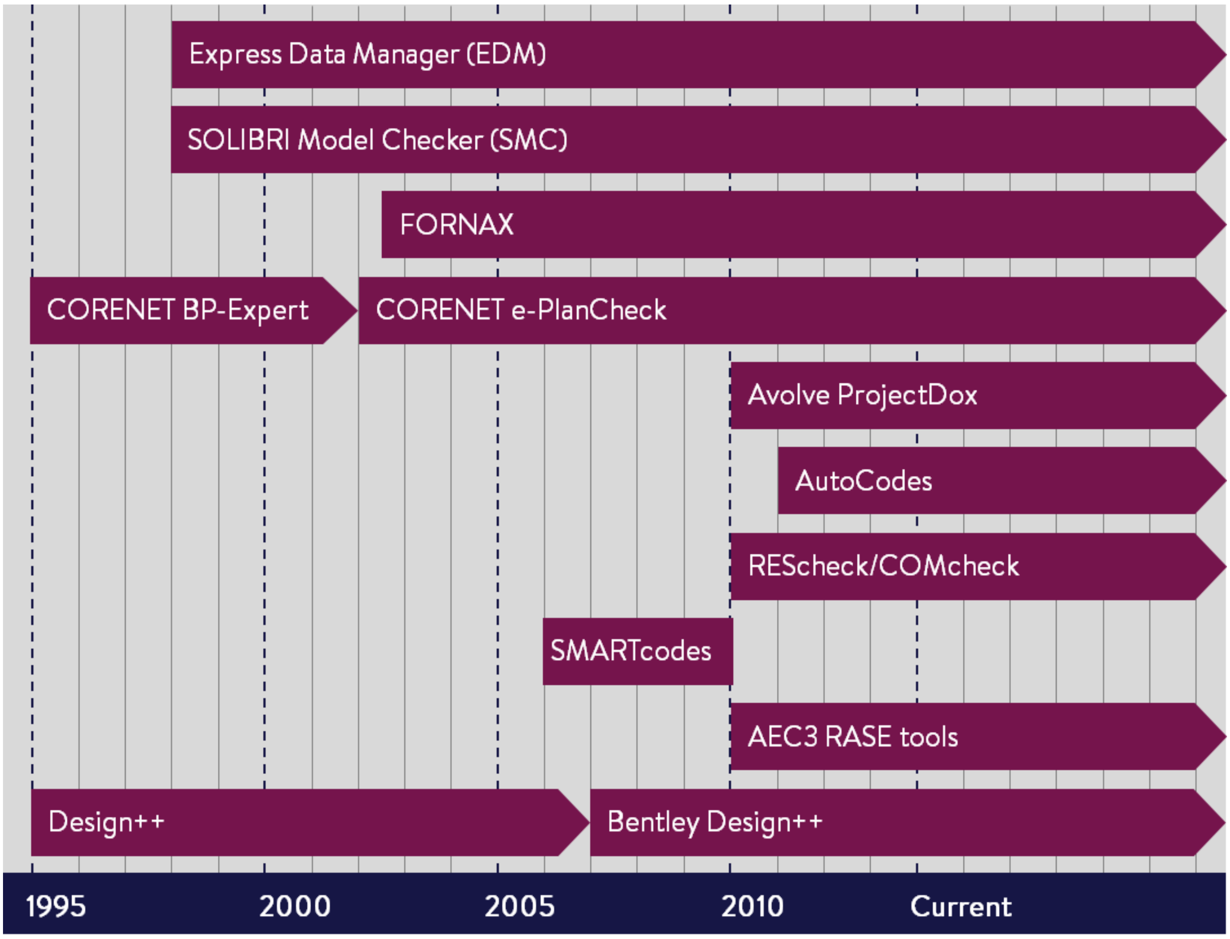
Application	Owner organization
Bentley Design++	**Bentley Systems, Incorporated**

Design++ is an expert system developed in the nineties by Design Power. In 2007 Bentley Systems Inc acquired Design Power. The current version is Bentley Design++ V8*i*.

Design++ is a knowledge-based, multi-dimensional engineering solver. Design++ captures in-house engineering expertise through flexibly extended business rules to automate design iterations in engineering platforms such as Bentley's MicroStation. It has been incorporated into several commercial applications such as Bluethink's House Designer. The rule-set is coded into the application and consequently needs to be managed within the application.

Website: http://www.bentley.com/en-US/Products/Design/

Figure 11: Timeline of development of compliance-checking applications. Based on Dimyadi and Amor (2013).



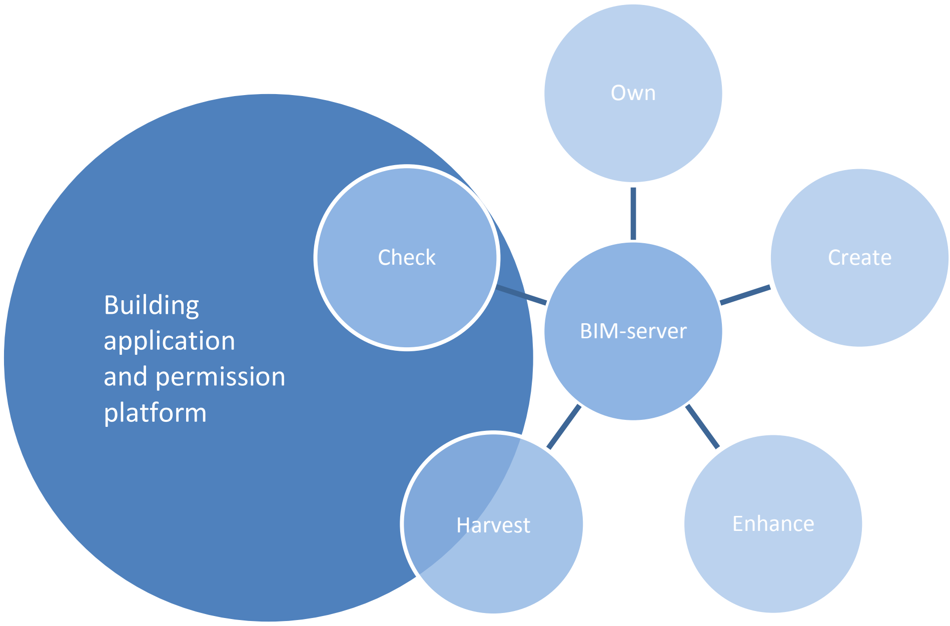
4. REGIONAL INITIATIVES FOR DEVELOPING APPLICATION AND PERMISSION PLATFORMS

Over the last few decades, especially since 1990, there has been an extensive amount of research conducted in the field of computerized compliance-checking for the AEC industry and several initiatives have been begun to develop solutions to make this technology operational. Initiatives are coming both from government agencies and commercial players.

The recent adoption of BIM, the standardization work done by buildingSMART and the push for innovation and increased productivity within the AEC industry are preparing the ground and making automatic, digitized building application and permission platforms more viable than ever.

This chapter contains a review of existing initiatives to develop application and permission platforms relevant to the development of ByggNett. The chapter is structured on a geographic basis.

Figure 12: The building application in context



NORWAY

REGIONAL AEC INDUSTRY

The AEC industry is the second largest sector in Norway in terms of revenue and number of employees. The Norwegian AEC industry employs approximately 200 000 employees in 51 000 companies, with a total revenue of NOK 362 billion (Statistisk Sentralbyrå (SSB), 2011).

The revenue for the hundred largest companies is approximately 30 percent of the total revenue for the AEC industry in Norway (Byggeindustrien, 2011). This is the result of an industry which is fragmented, consisting of numerous small companies.

Several types of contracts are in use, but the turnkey contract is the most common in large projects. In recent years integrated contracts have also been introduced. These are contracts where the contractor is involved in the development of the project. Often there is a sharing of profit or loss relative to a target price.

In turnkey contracts it is common that the main company employs craftsmen working with concrete and timber, while contracts for M&E (mechanical and electrical work) are conducted by individual firms or overall technical suppliers.

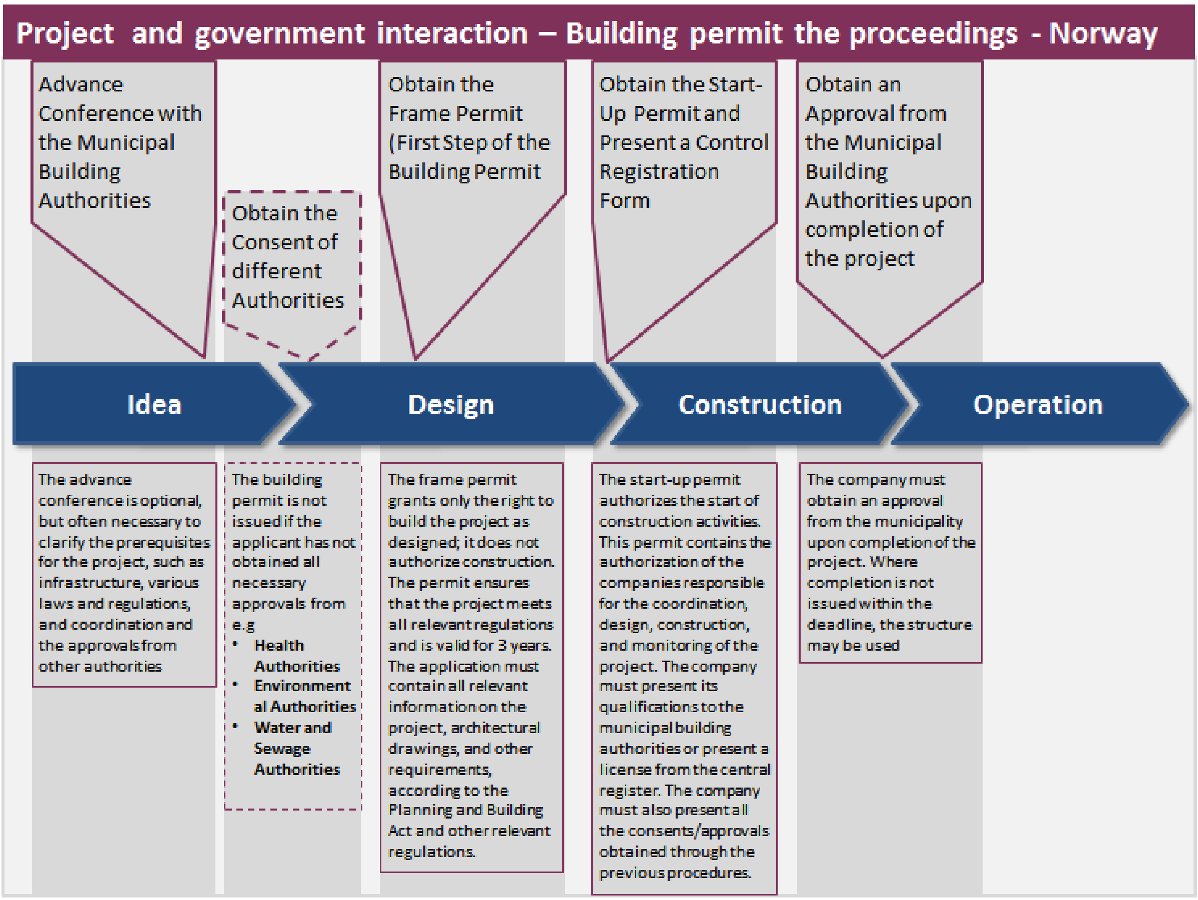
The architect, advisors and consultants are all involved in design. In turnkey contracts the contractor is involved during the design phase, while in bid-build contracts the contractor is solely responsible for constructing the building.

The project owners and developers in the Norwegian building and construction industry are both public and private players. The main difference is that the government has a long-term perspective on investment, while private investors' perspectives vary. The use of public funds requires greater documentation related to quality assurance, engineering and cost-benefit analyzes, compared with private developers.

THE BUILDING APPLICATION AND PERMISSION PROCESS

Figure 13 provides an overview of the building application and permission process in Norway (The World Bank - International Finance Corporation (IFC), 2012).

Figure 13: The building application and permission process in Norway



ADOPTION AND IMPLEMENTATION OF BIM

Statsbygg, the public property developer and owner, and buildingSMART Norway are the main champions of BIM implementation in Norway. Statsbygg has published the Statsbygg BIM Manual. The manual contains generic requirements for BIM in projects and facilities with the purpose of describing Statsbygg's requirements in terms of BIM using the IFC format. The current issue of the manual is Version 1.2 (Statsbygg, 2011).

Over 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.

Norway is among the first few countries in world to adopt the buildingSMART reference library, bSDD.

The National Museum of Art, Architecture and Design
The National Museum in Oslo is the world's first construction project with an international architectural contest requiring openBIM. The project is currently in the detailed design phase and scheduled to be finished in 2019.

The projects website contains extensive descriptions, footage and videos (only available in Norwegian): http://statsbygg.no/Byggeprosjekter/Nasjonalmuseet/

(Illustration reprinted with permission from Statsbygg.)

INITIATIVES FOR AUTOMATIC BUILDING APPLICATION AND PERMISSION PLATFORMS

ByggSøk

ByggSøk is the Norwegian solution for electronic communication in building application processing (DiBK, 2011). The first version was launched on July 1, 2003. The current version (Version 3.2) was launched on January 7, 2013. ByggSøk is divided into three separate solutions: ByggSøk information, ByggSøk planning and ByggSøk building.

ByggSøk information works as an information provider for users. This is a one-way information channel.

ByggSøk planning is a web-application developed to serve the application for zoning plan proposals (Jotne EPM Technology, 2012). The application enables electronic filling in and submission of zoning proposals over the Internet, in accordance with the Planning and Building Act (PBL). The ByggSøk planning initiative was shelved in 2010.

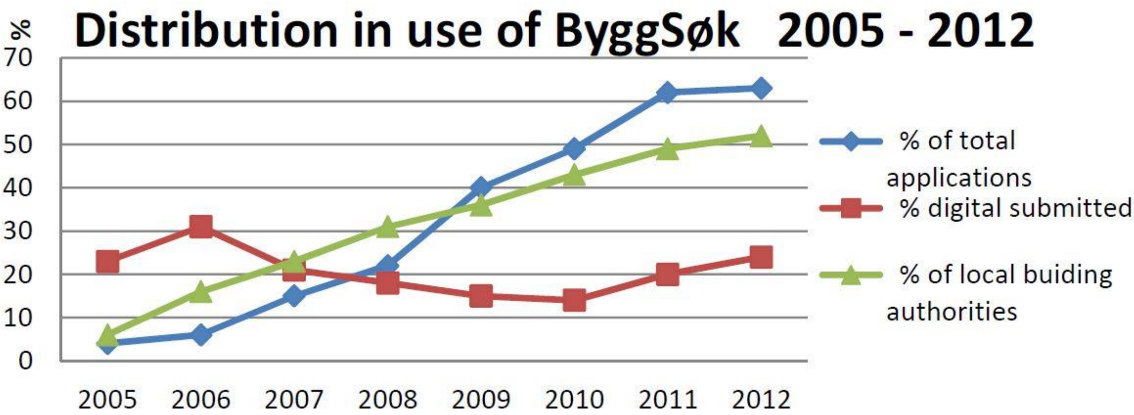
ByggSøk building is a web application developed for applications for building permits. The application enables electronic filling in and submission of building applications over the Internet, in accordance with the Planning and Building Act (PBL). The applicant is guided through the application process and if necessary receives help, and the application verifies that all fields in the form are filled in before submission. Finished applications are submitted by email with digital, static attachments. Applications are processed in the same way as traditional applications. Use of ByggSøk is free of charge. It is possible for local authorities to integrate ByggSøk with existing GIS solutions for maps, estate information, neighbors, etc. ByggSøk is defined as a semi-automatic solution. ByggSøk will contribute to standardization, simplification and streamlining of the planning and building process.

Unified classification system for the AEC sector
A report commissioned by Standards Norway, shows the diversity of AEC classifications in Norway and internationally. The report calls for a more holistic classification in Norway and stresses the need to link the national tables up to that employed in the Nordic countries and internationally. The report is the basis and background for the creation of Standards Norwegian's Committee for classification in the construction industry. The committee's main goal is to prepare a proposal for the development of Norwegian standards for a unified classification for the AEC industry in Norway. The Committee will revise NS 3457 and create a table for spatial functions (Standards Norway, 2013).

The technical specification of ByggSøk was drawn up internally by the Norwegian Building Authority (Asplan Viak, 2011). Development was contracted to EPM Jotne Technology and the programming was primarily completed by one developer employed by EPM Jotne in Russia. 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. ByggSøk allows for data to be printed on special purpose forms.

In 2012 110 000 applications were submitted to the local building authority in Norway. Of these approximately 63 percent were submitted through ByggSøk. Figure 14 shows the distribution of ByggSøk from 2005 to 2012 (Hjelseth, 2013).

Figure 14: Distribution in use of ByggSøk 2005-2012



The figure shows that while the percentage of total applications submitted through ByggSøk has increased steadily since 2005, the percentage of digitally submitted applications shows no increase. The Norwegian Building Authority points out two possible explanations (Hjelseth, 2013):

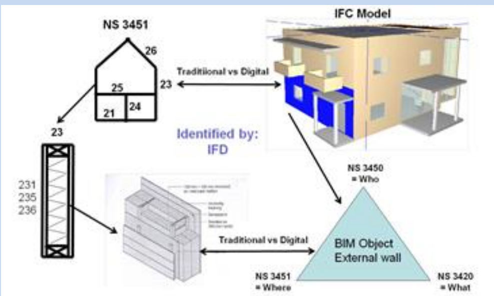
- A large amount of information from different sources has to be digitized (applicant side);
- Lack of systems to process applications digitally (building authority side).

ByggLett

ByggLett is an initiative closely related to ByggSøk. ByggLett is a pilot project with a vision of preparing the ground for future development of ByggNett through small successes and incremental development. The project is delimitated to developing an automatic web-application for basic building application processes, in effect garages and sheds. Currently ByggLett is only an outline for a future solution.

Automated compliance-checking – checking BIM models against Norwegian standards

Catenda and ICE-consult are conducting a pilot project on assignment from Standards Norway. The aim of the projects is to develop a solution for automated compliance-checking against EN 15978 for open BIM. The pilot should be scalable, i.e. be applicable to other standards. Easier use of standards will streamline the construction process and unsure the use of best practices.



Workshop with Norwegian AEC industry actors

As a part of the status survey a selection of actors across the Norwegian AEC industry were collected at two workshops. The workshops took place in October 2013. The participating organizations are presented through the logos on the bottom of this page. In the following we present the main findings.

CURRENT APPLICATION AND PERMISSION PROCESS

The current application and permission process is inefficient. A lot of time is spent already in choosing what application form that should be used. When 450 local authorities shall manage the regulations in their own manner the process becomes unpredictable. The outcome of an application often seems to be left to discretionary and personal preferences. The risk associated with time consumption and outcome of the application process must be borne by the project owner.

ByggNett should create an intuitive and uncomplicated user interface on both the applicant and the building authority side. The new platform should contribute to streamlining the process, making it less time consuming and more predictable.

BIM

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 owner 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 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. As for the rest of the world Norwegian industry actors experience the social and cultural aspects of technology adoption to be the largest challenge.

We asked the AEC industry actors to identify the most important barriers and drivers for the adoption and implementation of BIM. The top four of both are listed here.

BIM – DRIVERS

- *Requirements from public project owners*
- *Requirements from building authorities*
- *Effective and agile design process*
- *Job satisfaction and recruitment*

BIM – BARRIERS

- *Conservative culture*
- *Fragmented industry*
- *Lack of competence*
- *Current contractual standards*

DENMARK, SWEDEN AND FINLAND

REGIONAL AEC INDUSTRY

Denmark

The building and construction industry is one of the main industries in the Danish business sector. The industry maintains and develops Denmark's buildings and infrastructure, which together represent 80 percent of Denmark's assets. The Danish Construction Association comprises approximately 6,000 Danish companies in the building and infrastructure industries, which together employ around 70,000 people (Ministry of Buisness and Groth, 2013).

The Palaces and Properties Agency, the Danish University and Property Agency and Defense Construction Service are the main public property owners in Denmark.

Sweden

The construction industry is essential for the development and prosperity of Sweden. Its turnover in recent years has been about SEK 500 billion. The built environment accounts for about half of national wealth. In 2012, there were 312,000 employed in the Swedish construction industry and building investment was SEK 309 billion, representing approximately 9 percent of GDP. The industry covers contractors, property management, manufacturers of building materials, architects and technical consultants. The industry consists of about 94,000 companies of which 87 percent had fewer than five employees. The ten largest companies employ 44 000 people and have annual revenues totaling SEK 133 billion (Sveriges Byggindustrier, 2013).

Finland

In the Finnish construction industry about 140 000 workers (100 000 blue collar workers) are employed in 30,000 companies. In recent years these figures have remained very stable. Since 2004 the development of the construction industry has been characterized by steady growth of between 3 percent and 6 percent, though after the start of the new century stagnation was apparent (European Federation of Builder and Woodworkers, 2010-2011).

ADOPTION AND IMPLEMENTATION OF BIM

Denmark

Denmark's level of development in the overall implementation of BIM has been promising compared with the other Scandinavian countries, which are themselves ahead of most countries.

The Palaces and Properties Agency, the Danish University and Property Agency and Defense Construction Service have initiated efforts to implement and use BIM in the Danish EAC sector (Wong et al., 2009).

As from 2013 Denmark requires all public construction projects costing of DK 5 million or more, excluding tax, to use BIM (Retsinformation.dk, 2013).

The Danish government initiated and funded the Digital Construction (Det Digitale Byggeri) program. It ran from 2005 to 2011. The aim was to implement ICT communication such as electronic tendering, project web, BIM, and electronic hand-over. The Digital Construction program published BIM guidelines similar to the manuals in Norway, Finland and the UK.

Sweden

Some key AEC technology vendors such as Tekla and Solibri are based in the Nordic countries. As a result, these countries were among the earliest to adopt model-based design, and also pushed for interoperability and open standards in AEC technology, as drawn up primarily by the IFC.

Thus while there is no official government requirement for the use of BIM in these countries, it seems to have grown up on its own in response to the need of AEC firms for technology more advanced than drawing-based CAD files for designing and constructing the kind of buildings that were needed in this region (AECBytes, 2012).

Sweden is trying to promote BIM and it is currently developing an information handbook on IFC standards. It is involved in a two-year ERAbuild project with Finland, using web services and model servers.

In Sweden there is no, or very little, development related to BIM and IFC by public owners, compared with other Nordic countries. However in Sweden the major contractors play an important role in the construction sector and have most likely influenced the use of BIM in Sweden (Mulenga and Han, 2010).

Finland

In 1997 the R&D program Information Networking in the Construction Process (Vera) was initiated in Finland. It continued for six years at a total cost of EUR 47 million (Vera, 2002). Professor Arto Kiviniemi, currently based at the University of Salford, Manchester, was the program manager. The target of the program was to promote implementation of IT in the construction process, and it is one of the main reasons for Finland’s position at the frontier of BIM internationally.

Finland has progressed beyond the pilot phase. Several international studies conclude that Finland is the leading country in BIM implementation worldwide. In a survey conducted in 2007, the use of BIM and IFC-compliant BIM applications in Finland was estimated to be 33 percent. In the same survey, it was observed that in Finland 93 percent of architecture firms were using BIM for some part of their projects, whereas engineers’ use was nearly 60 percent (Wong et al., 2009). This was far ahead of most countries in 2007.

Senate Properties is the public building owner in Finland. It is the country’s largest and most comprehensive provider of property services. Since 2001 Senate Properties has carried out a number of pilot projects to develop and study the use of building information models. On October 1, 2007 Senate Properties decided to require models meeting the IFC standards in its projects. They have also provided modeling guidelines for data content requirements for models for the participants in projects at each stage of the design (Wong et al., 2009). These BIM guidelines contain general operation procedures for BIM projects and specify detailed requirements for building information models (Mulenga and Han, 2010). The BIM guidelines are the result of the ProIT R&D project.

Both universities and private companies are running extensive R&D projects. Among the central commercial players are Solibri, Skanska and Tekes. The Association of Finnish Contractors is also active in promoting implementation of BIM. Among the universities, Helsinki University of Technology and Tampere University of Technology are central.

Through the interviews with AEC professionals it has become clear that Finland is viewed as a global leader in BIM implementation.

THE BUILDING APPLICATION AND PERMISSION PROCESS

Figure 15 provides an overview of the building application and permission process in Denmark (The World Bank - International Finance Corporation (IFC), 2012).

Figure 16 provides an overview of the building application and permission process in Sweden (The World Bank - International Finance Corporation (IFC), 2012).

Figure 17 provides an overview of the building application and permission process in Finland (The World Bank - International Finance Corporation (IFC), 2012).

Figure 15: The building application and permission process in Denmark

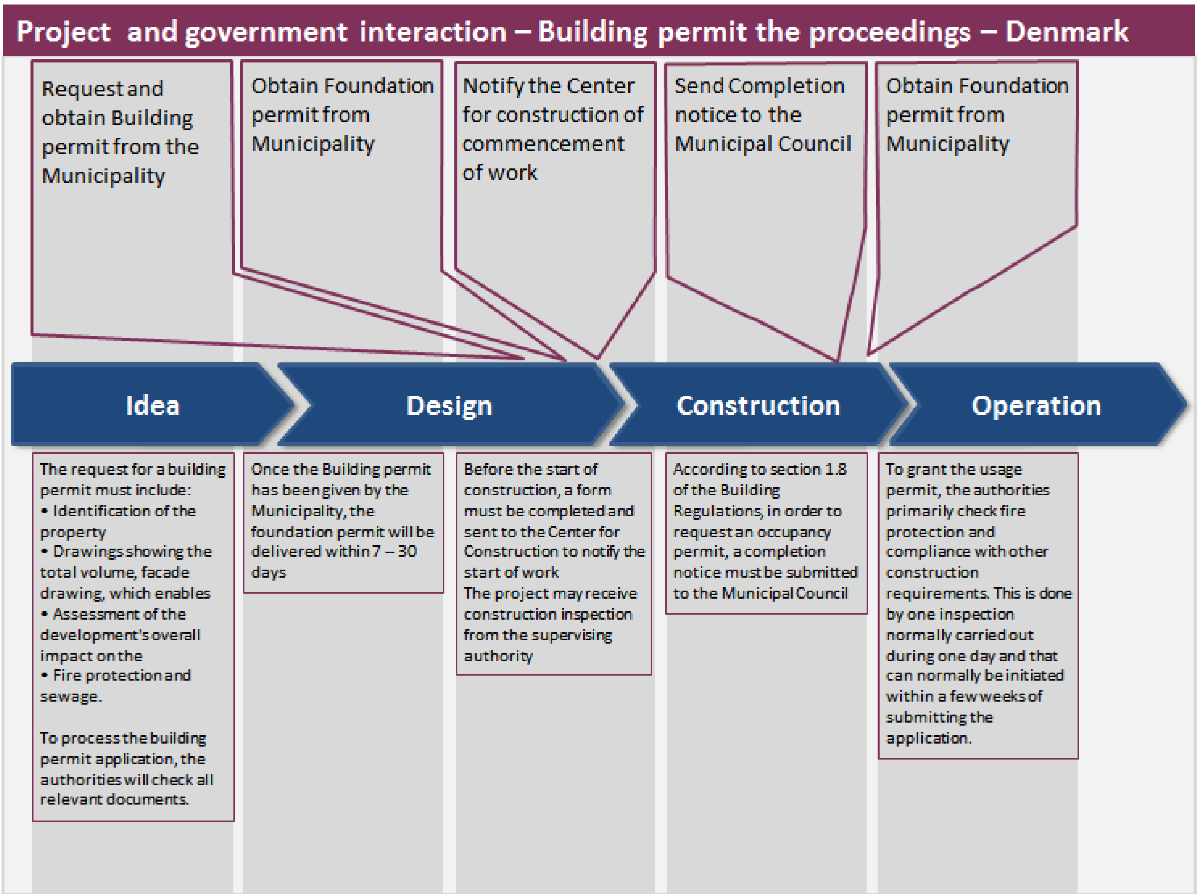


Figure 16: The building application and permission process in Sweden

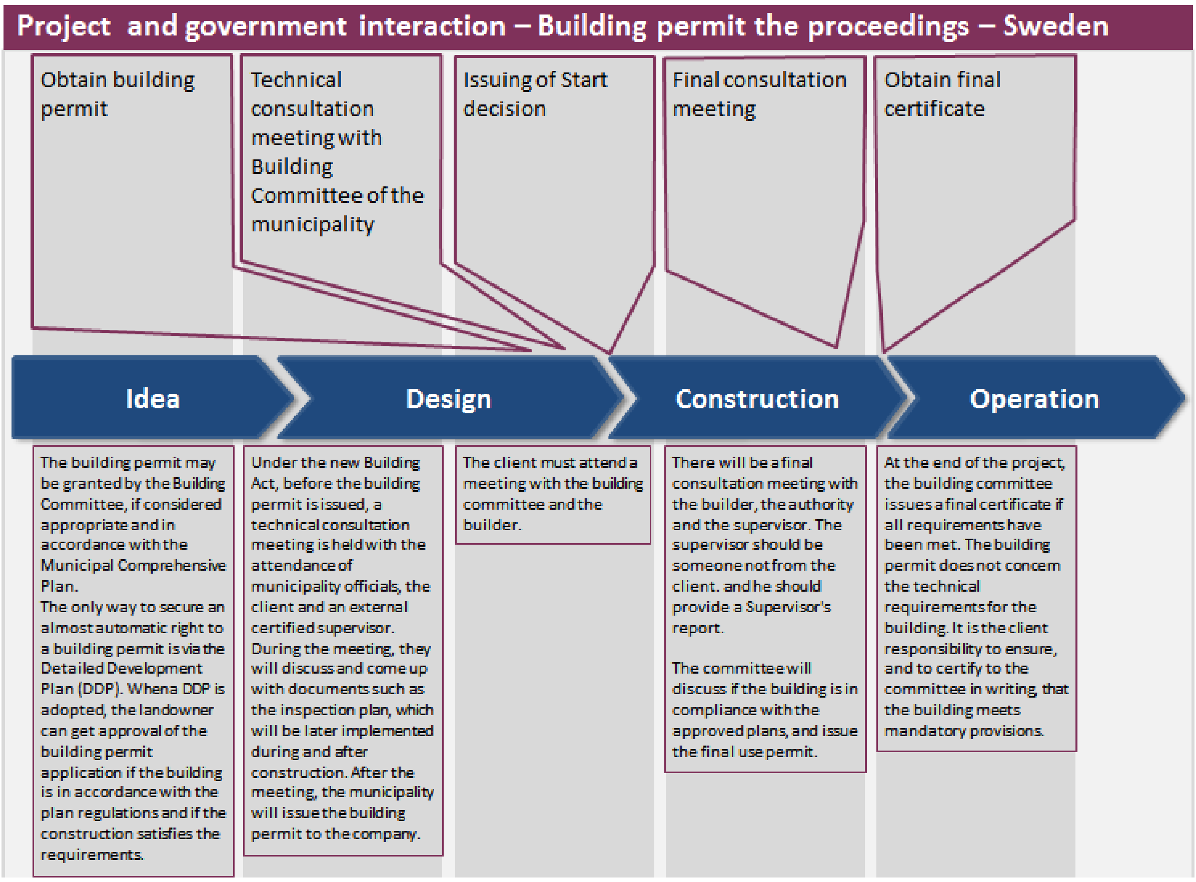
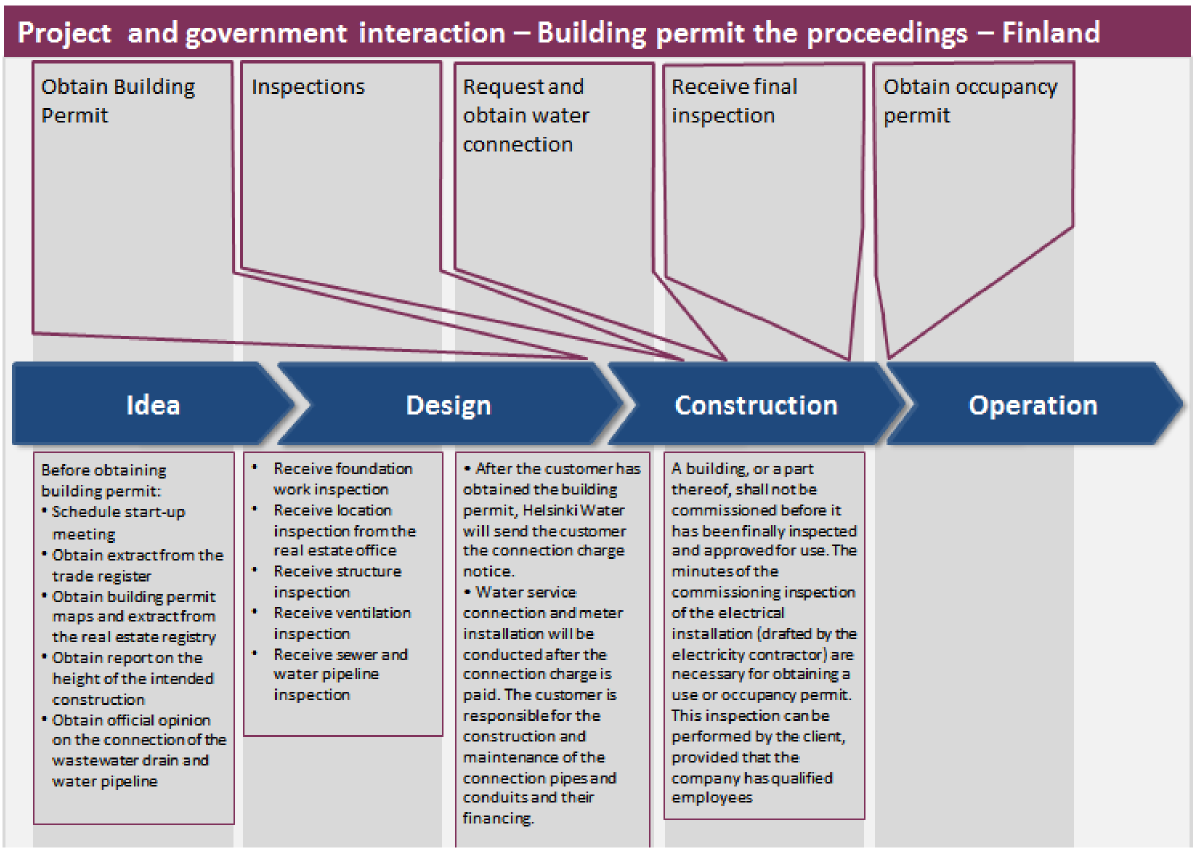


Figure 17: The building application and permission process in Finland



INITIATIVES FOR AUTOMATIC BUILDING APPLICATION AND PERMISSION PLATFORMS

Denmark

Although Denmark has come a long way in adoption and implementation of BIM in the AEC sector, it does not seem to have an active initiative to develop a platform for automated building application and permission. Still, the focus on reaping the benefits of the implementation of information technology in construction projects is very much apparent.

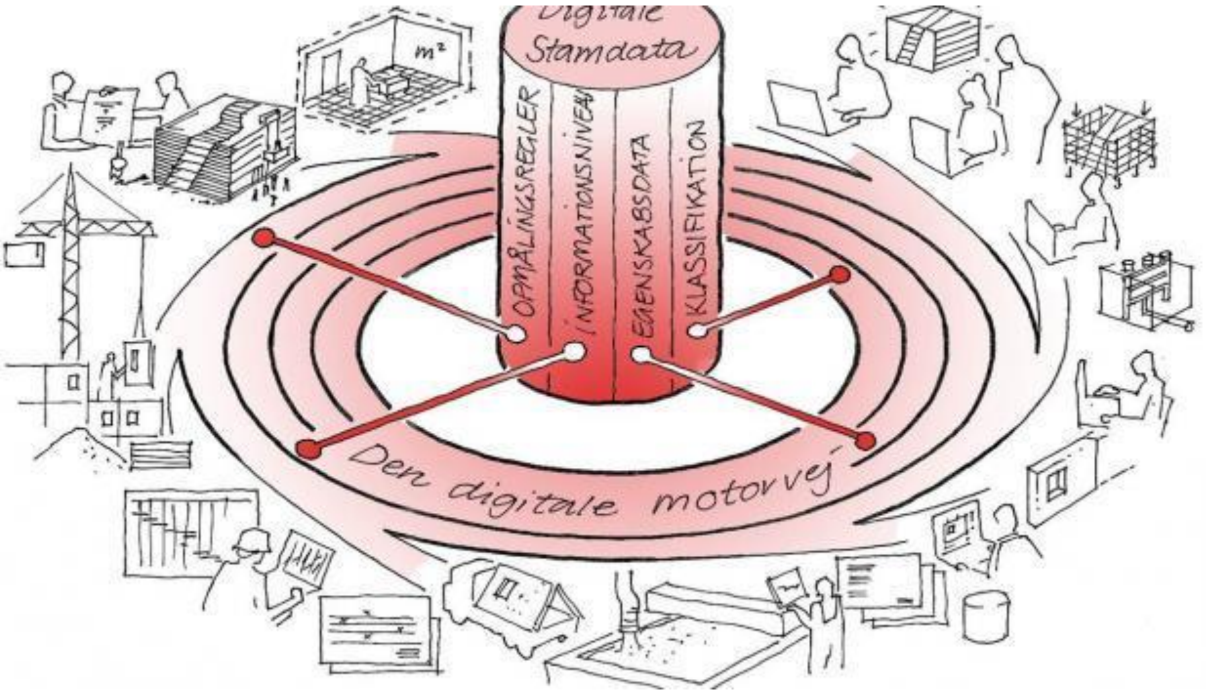
Bips

Bips is a non-profit organization working for industry-wide implementation of information technology, productivity and collaboration (bips, 2011). The aim of the initiative is to enhance productivity and collaboration in the Danish AEC sector through development of digital infrastructure and standardized use of information.

Bips inherited the results from the Digital Construction program when it ended in 2011. These included extensive information on the use of BIM in all phases of construction projects, from BIM-based energy analysis and cost calculation, to use of BIM in the construction phase. The information has been collated in a series of case studies and guidelines. Everything is available free of charge at the bips homepage.

Cuneco is a research center run under the management of bips. The Cuneco center is developing a common basis for digital collaboration in the AEC industry, with the aim of enhancing the efficiency and productivity of the construction industry. The product of the Cuneco initiative will be digital standards and tools for data exchange available free of charge for all industry actors (Cuneco, 2011). The Cuneco project shares many of the same goals as the ByggNett initiative. The Cuneco project is scheduled to end in 2014.

Figure 18: Illustration from the Digital Construction program



Sweden

We have not identified a national initiative to develop automated building application and permission in Sweden. Meanwhile there are a large number of planning activities going on, to prepare for better processes in this area. Among these is the initiative Digital Collaboration (Digital samverkan) (Boverket, 2013a).

There are also a large number of distributed initiatives on regional levels that actually have made operative achievements in making the processes more effective. Among these initiatives is "Riges", a collaboration between five municipalities in Vesternorrland where they have high expectations to redesign of work processes and use of electronic submission. The projects are well documented; EU sponsored, and part of the national preparation for stepping up to the next level of performance. There are 53 municipalities that have created and are connected to a portal named "Mittbygg.se". It provides an e-service connected to the building lifescycle. Another municipality alliance is "Bygglovsalliansen" that also focuses on better processes related to deployment of building regulations. An ongoing initiative is "Bygglovsguiden" where they deploy a web based solution to support the building parties in handling and interpreting building regulations.

On national level Sweden has conducted the second phase of the project "Sammanhållet, myndighetsovergripande, digitalisert bygglov". This project is investigating the practical prerequisites and consequences related to implementing national-wide digital legislation. There is an ongoing government initiative called "En effektivare plan-ock bygglovsprosess" (Boverket, 2013b). "Styrmedel for utveckling av sammanhållande digital planprocess" is also an interesting government initiative. Both of these initiatives are aiming on how to plan for and take out the benefits from support of digital tools. However Sweden has a longer way to go on standardization on many levels and areas.

Finland

Despite Finland's position as a leading adopter of BIM, it appears that there is no current Finnish government initiative to develop a platform for automatic building application and permission. Nonetheless the country can offer solutions that are potentially of interest for the ByggNett initiative.

The Department of Civil and Structural Engineering at Aalto University in Helsinki has an ongoing research program on BIM, the Aalto University BIM Research Group. It has two current projects: BIM and Facilities Management and BIM and Lean Construction (Aalto University BIM Research Group, 2013).

Solibri Model Checker

Solibri Model Checker is a software solution that analyzes BIMs for integrity, quality and physical safety. The software was developed by Solibri Inc., a Finnish company established in 1999. The current version of Solibri Model Checker is V9, launched on the October 3, 2013. Solibri Inc. has a patent pending on the SMC software (Solibri Inc., 2013).

SMC software was initially developed as a tool for quality assurance and validation of BIM models (Dimyadi and Amor, 2013). SMC has since developed into a stand-alone, graphically driven, rule-based compliance-checking and reporting application. The application has a set of built-in rules that can be managed by a rule-set manager. The rule-sets can be changed, but user customization is limited.

A recent research project concluded that Solibri Model Checker is well suited for BIM-based, automated safety code-checking. The strength of using Solibri Model Checker as a BIM-based tool is its capacity to use the IFC data exchange format, which makes the checking independent from BIM-based software used for modeling (Sulankivi et al., 2013).

Many of the industry players interviewed in this survey mentioned Solibri Model Checker as the most mature solution for BIM-based automated rule-checking.

Solibri Inc. is involved in several research projects, among them the US AutoCodes project run by Fiatech.

VTT

VTT Technical Research Center of Finland is the largest multi-technological research organization in Northern Europe (VTT, 2012). The organization has 3 000 employees and annual revenue of approximately EUR 316 million. VTT is a non-profit organization under the auspices of the Ministry of Employment and Economy.

VTT has been researching building product models, or BIM, since the late 1980s and actively took part in establishing the International Alliance of Interoperability (AIA) in 1996 (Wong et al., 2009). VTT focuses on technical issues related to downstream applications, tools that utilize the information in the models, such as different analysis, simulation and process management applications. Energy and environmental analysis tools are given special attention because these tools can reliably evaluate the environmental impacts or lifecycle costs of buildings through robust analyses and simulations. Researchers from VTT used BIM and web service integration technology to develop CS Collaborator, a solution for real-time information-sharing to address the problem of lack of information transparency in the construction supply chain (Wong et al., 2009).

UNITED KINGDOM

REGIONAL AEC INDUSTRY

The construction sector is a key sector for the UK economy. Construction is one of the largest sectors of the UK economy. It contributes almost £90 billion (or 6.7 percent) in value added to the UK economy and comprises over 280 000 businesses involving some 2.93 million jobs, which is equivalent to about 10 percent of total UK employment.

The public sector is the UK construction sector's largest customer, contributing to approximately 40 percent of the sector's total expenditure (Cabinet Office, 2011).

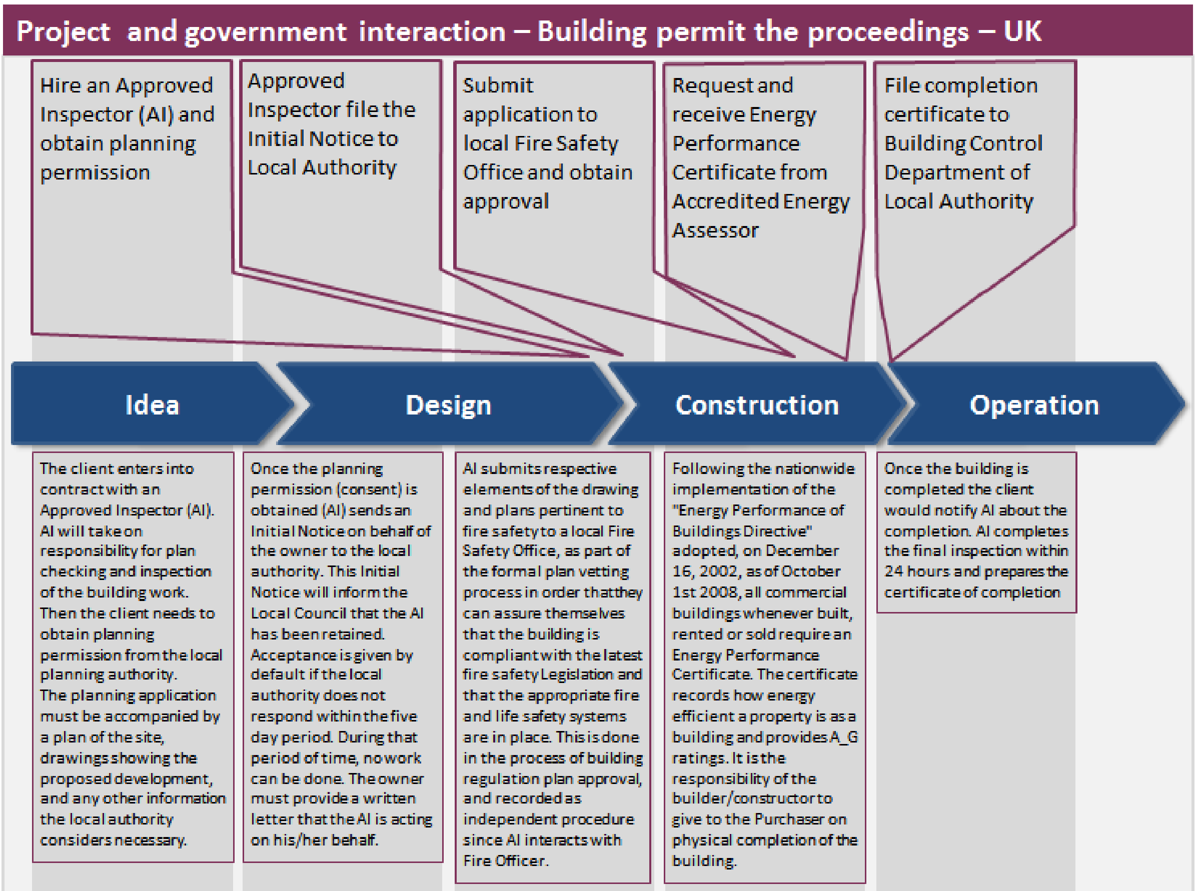
The UK construction sector has been affected disproportionately since the recession of 2008. In 2007 the construction sector accounted for 8.9 percent of the UK's GVA (gross value added) but by 2011 the sector's contribution had decreased to 6.7 percent. In early 2012 the construction contracting industry returned to recession for the third time in 5 years.

Despite the recent economic and financial crisis, which affected most of the developed economies, the UK construction contracting industry remains one of the largest in Europe, measured by employment, number of enterprises, and GVA. However, the UK construction industry is also more fragmented than its major European competitors and the evidence suggests it has higher levels of sub-contracting (Skills and Rees, 2013).

THE BUILDING APPLICATION AND PERMISSION PROCESS

Figure 19 provides an overview of the building application and permission process UK (The World Bank - International Finance Corporation (IFC), 2012).

Figure 19: The building application and permission process in United Kingdom



ADOPTION AND IMPLEMENTATION OF BIM

BIM development and adoption is an important part of the UK government Construction Strategy released in May 2011. A central strategy objective is to require fully-collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016 (Cabinet Office, 2011). There have been done several investigations into BIM adoption in the UK.

The US initiative COBie is currently being adapted to UK. COBie will be the UK government's required format for BIM data drops, as from 2016.

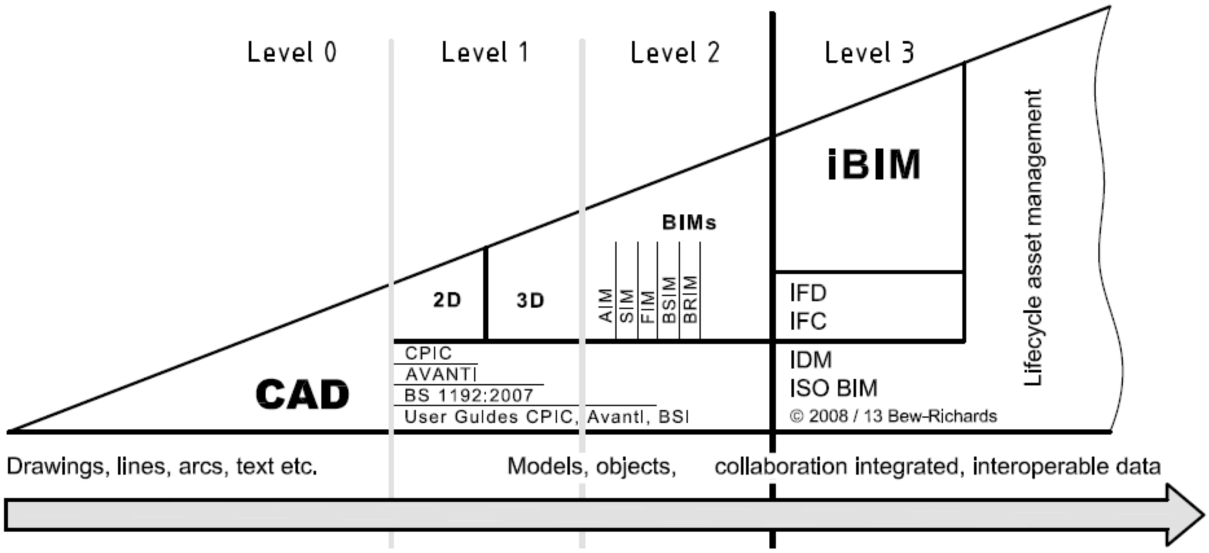
McGraw-Hill Construction (2010) estimated the adoption rate for BIM in the United Kingdom among construction professionals to 35 percent. Adoption is led by architects (60 percent), followed by engineers (39 percent) and contractors (23 percent). Among those that have adopted BIM, 45 percent believe they are advanced or expert and only 23 percent consider themselves beginners. This high level of BIM expertise corresponds with the fact that 38 percent of adopters have been using BIM for more than five years and 54 percent of adopters use BIM on 30 percent or more of projects. Thus, not surprisingly, BIM experience leads to BIM expertise, which then leads to willingness to use it more often on projects. However in the UK contractors have not fully embraced BIM. Only 7 percent of contractors use BIM on 30 percent or more of projects. As in North America, there is an indication that BIM use will surge among UK contractors with heavy use. 71 percent of UK adopters perceive a positive return on investment (ROI) from BIM, with 37 percent reporting ROI of 25 percent or more. 13 percent of UK adopters perceive negative ROI (McGraw-Hill Construction, 2010).

In the 2013 Smart Market Report on BIM adoption in Europe, McGraw-Hill Construction reports that UK users see the most value from BIM through:

- Reduced conflicts during construction (70 percent);
- Improved collective understanding of design intent (69 percent);
- Reduced changes during construction (60 percent).

BSI Group is a UK company in the field of business standards. They have published the BIM Roadmap in order to describe the activities of the BSI B/555 committee (Construction design, modeling and data exchange) in the immediate past, current and future in support of delivering clear guidance to the UK AEC industry (BSI Group, 2013). A central part of the BIM Roadmap is the BIM Maturity Model presented in Figure 20.

Figure 20: BIM Roadmap Maturity Model



The maturity levels are defined as follows:

0. Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism.

1. Managed CAD in 2 or 3D format using BS 1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.

2. Managed 3D environment held in separate discipline “BIM” tools with attached data. Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as “pBIM” (proprietary). The approach may utilise 4D Programme data and 5D cost elements.

3. Fully open process and data integration enabled by IFC / IFD. Managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes.

The UK BIM Task Group report on benefits from the use of BIM in construction projects. Benefits experienced are reduction of time and cost, as well as better design coordination and enhanced building quality (BIM Task Group, 2013b, Build Offsite, 2013).

BIM Building Information Modelling (BIM) Task Group

The BIM Task Group are supporting and helping deliver the objectives set out by the Government Construction Strategy and the requirement to strengthen the public sector’s capability in BIM implementation (BIM Task Group, 2013a). The aim is that all central government departments will be adopting, as a minimum, collaborative Level 2 BIM by 2016. The task group brings together expertise from industry, government, public sector, institutes and academia. The BIM Task Group is led by Mark Bew. The BIM Task Group is focusing its effort in six main working parties:

Training and education. *The work package aims to raise the UK AEC sector’s BIM awareness and skills.*
COBie data set requirements. *The work-package is documenting COBie 2.4 for use in the UK.*
Plan of Works. *The work package is establishing a collective understanding and work process for BIM.*
BIM Technologies Alliance. *Established to support and assist the Government’s BIM Steering Group.*
UK Contractors Group. *The primary association for contractors operating in the UK.*
Construction Products Association. *A single voice for construction product manufacturers and suppliers.*

The BIM Task Group program is supported by four work-streams. These are:

1. *Stakeholder and media engagement*
2. *Delivery and productivity*
3. *Commercial and legal*
4. *Training and academia*

Planning Portal

Planning Portal is the UK government's online planning and building regulations resource for England and Wales. The aim of the service is to provide a one-stop-shop supplying answers, services and information to anyone involved in the planning process, from home owners and businesses to planning professionals and government officials. It is delivered by the Department of Communities and Local Government (GOV.UK, 2013a). The current director of Planning Portal is Chris Kendall.

The portal offers a user interface organized in apps that can be defined and structured by all users with an account.

The project is funded by the UK Government. It is working to generate revenue to offset the costs of running its core business, which will help to reduce its dependence on central government funding.

There are more than 800,000 monthly visits to the Planning Portal, viewing more than 2,65 million pages of content. Its trusted content and services, including the online application service, are used by three main user groups: planning professionals, the general public and government users. The award-winning Planning Portal allows businesses to direct their products and services at the audience that's right for them (GOV.UK, 2013a).

Smarter Planning is a Planning Portal initiative to encourage professionals and local planning authorities to take full benefit of online working through adopting best practice guidelines. It encourages users to deliver a faster, more transparent planning application service using the Planning Portal and to become a 'Smarter Planning Champion' (GOV.UK, 2013a). The Smarter Planning initiative is divided into "Smarter Planning for local planning authorities" (LPA's) and "Smarter planning for industry professionals". It is claimed that:

Smarter Planning will let LPAs:

- save time and resources;
- save money;
- reduce carbon.

Smarter Planning will let planning agents:

- help local planning authorities process applications more efficiently;
- save time and money;
- reduce CO^2 throughout the process.

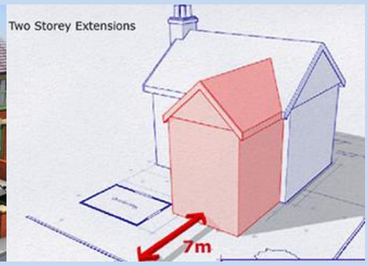
Planning Portal Interactive Guides

The Planning Portal offers interactive guides. These provide easy access to information on many common householder projects (GOV.UK, 2013a).

Interactive House
Guidance on many common householder projects, including home microgeneration, in England.

Interactive Terrace
Guidance relating to flats, shops and basements as well as many common householder projects, in England.

Mini guides
Mini guides provide visual clarification of the permitted development rules for specific projects.



To view and try out the interactive guides go to http://www.planningportal.gov.uk/permission/.

THE UNITED STATES

REGIONAL AEC INDUSTRY

As a result of the economic downturn the AEC industry has suffered severely across the United States. Today the American AEC industry consists of more than 700 000 companies and employs approximately 5,8 million people (United States Department of Labor - Bureau of Labor Statistics, 2013).

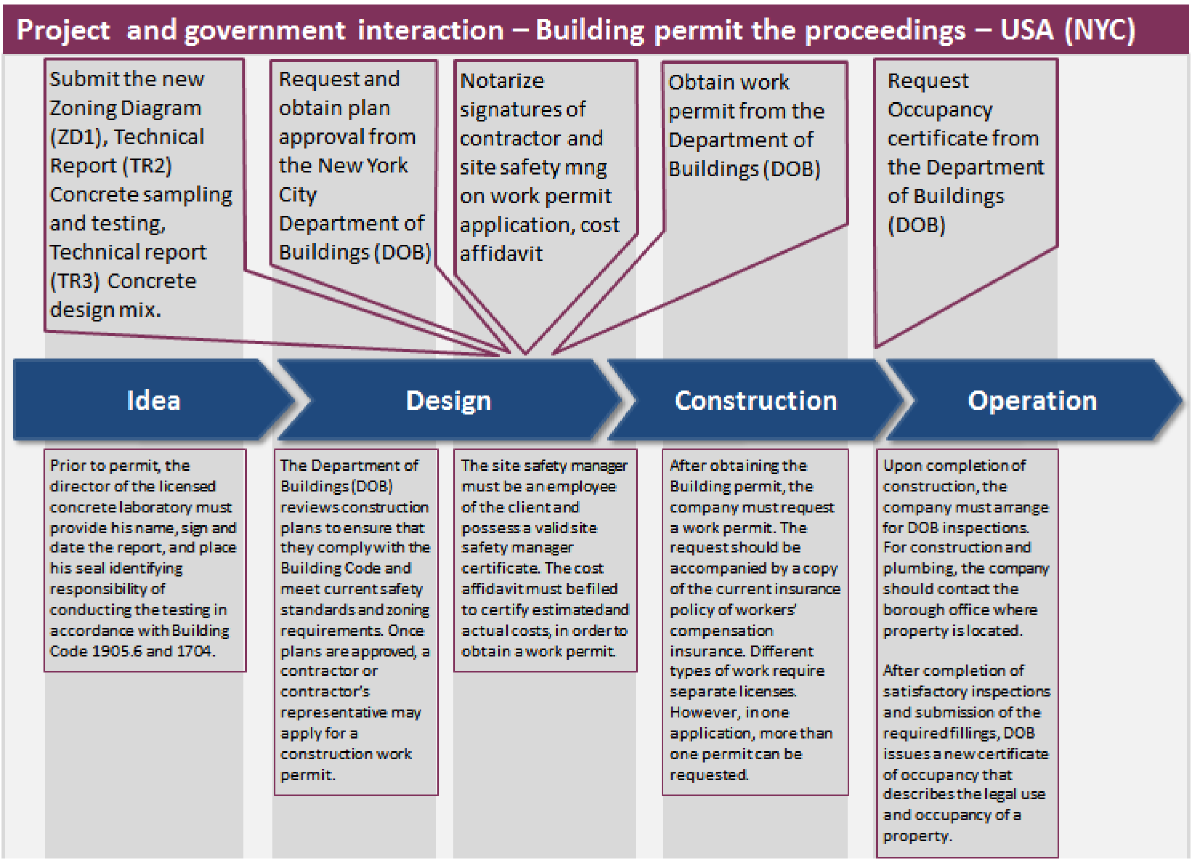
Common contracts types are: guaranteed maximum price, lump sum, unit price, cost plus, cost-reimbursable alternative and integrated project delivery/alliance. These different contract types take care of the extent of the risk for which the executing unit is responsible. The contractual relationship between client, architect, designer and contractor must take into account the peculiarities of the project and the contract type is selected on this basis.

BUILDING APPLICATION AND PERMISSION PROCESS

There are few building regulations at the federal level in the United States. It is mainly the local building authorities that decide what applies in each city when it comes to building regulations and requirements for building applications, etc. (The World Bank - International Finance Corporation (IFC), 2012).

In the interviews, New York City has been pointed out as one of the early adaptors and leaders when it comes to development in the US AEC industry. Figure 21 presents the building and application process in New York City.

Figure 21: The building application and permission process in the United States



ADOPTION AND IMPLEMENTATION OF BIM

The adoption of BIM in the US has come a long way in few years. The development is mainly driven by R&D in software vendors and commercial interests, i.e. a perception that adoption and implementation of BIM in the AEC industry will be profitable and will become a prerequisite for competitiveness in the future.

In 2003 the General Services Administration (GSA) established the National 3D-4D-BIM Program (General Services Administration, 2013). The program is currently exploring the use of BIM technology throughout a project's lifecycle in the following areas: spatial program validation, 4D phasing, laser scanning, energy and sustainability, circulation and security validation and building elements. The GSA has published the GSA BIM Guide.

National BIM Standard – United States™ (NBIMS-US™) – is an initiative of the National Institute of Building Sciences (NIBS). It seeks to provide consensus-based standards through referencing existing standards, documenting information exchanges and delivering best business practices for the entire built environment (National Institute of Building Sciences, 2013).

The Construction Industry Institute (CII) has published the BIM Projects Execution Planning Guide, Version 2.0. The goal of the execution plan is to ensure that all parties are clearly aware of the opportunities and responsibilities associated with the incorporation of BIM into the project workflow (Construction Industry Institute, 2013).

The use of BIM in the AEC industry is measured by the McGraw-Hill Smart Market report. In the United States the adoption of BIM has increased from 28 percent in 2007 to 71 percent in 2012 (McGraw-Hill, 2012, McGraw-Hill Construction, 2012). It is clear that the size of the company affects the adoption and implementation of BIM. 90 percent of large to medium-sized companies in the AEC industry are engaged in BIM compared with less than half (49 percent) of small ones. The activities of the various stages where BIM is used are: Design – establishing model, analysis of mechanical systems with design review, construction-related activities collision control and practical planning of the location of mechanical plant and equipment. There is little use of BIM in the building's operational phase. The construction and operation phase are where the use of BIM is the least advanced.

INITIATIVES FOR AUTOMATIC BUILDING APPLICATION AND PERMISSION PLATFORMS

As mentioned earlier, the US differs from the other countries discussed in this report as it is made up of 50 states, each with a high degree of autonomy. The federal government is very little or not at all involved in the building permission and application processes. All players interviewed in the US believe that an initiative to develop an automatic building application and permission platform must have its origin in one of the big cities. New York and Chicago are mentioned as candidates for taking the lead in this.

Though there is no central government initiative, some relevant US projects should be mentioned.

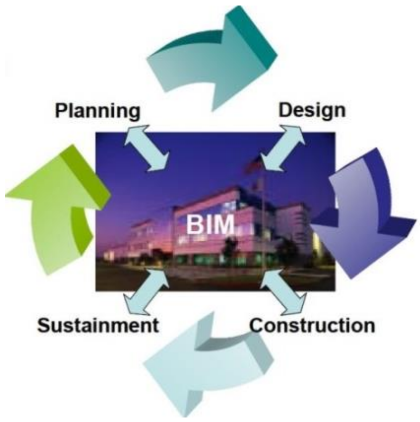
ResCheck (Residential Compliance) and ComCheck (Commercial Compliance) were developed and published by the US Department of Energy. The goal of the applications was to allow anyone to check a building’s energy performance against the applicable energy standards, e.g. IECC and AHRAE Standards 90.1.

Both ResCheck and ComCheck have all criteria hard-coded into the tools.

The US General Service Administration (GSA) Courts Design Guide automation project also incorporates an independent rule-set manually derived from the textual standards (Dimyadi and Amor, 2013).

SMARTcodes

SMARTcodes was introduced by the International Code Council (ICC) in 2006 (Dimyadi and Amor, 2013). ICC develops model codes and writes many of the US building codes.



The desired outcome of the initiative was an understanding of how automated checking for compliance with building regulations, codes, standards, guidelines and other documents can be implemented using building information models (See, 2008). SMARTcodes contained official representations of a few central standards and provided the legislative body with a tool to manage the amendment of codes.

The basis of the SMARTcodes initiative has much in common with the ByggNett idea. BIM has been placed at the center of building design, construction and operation. BIM should be a shared knowledge-source or database that can be seamlessly used by all involved parties throughout the building's lifetime. Compliance-checking should be developed into a more circular and integrated process, manpower resources should be used more effectively, and the probability of errors should be decreased.

Through a case study at General Motors, SMARTcodes claim to have resulted in 27 percent faster completion (See, 2008).

Digital Alchemy was contracted by ICC to develop SMARTcodes. The UK/German company AEC3 was also involved in the development. The system is based on a mark-up concept and use of open BIM. A proof of concept implementation for the system was developed and demonstrated in several venues in 2007 and 2008.

Development of SMARTcodes ended in 2010 due to a lack of funding.

Several of the players interviewed in the US highlight SMARTcodes as a good project with potential for further development.

SINGAPORE

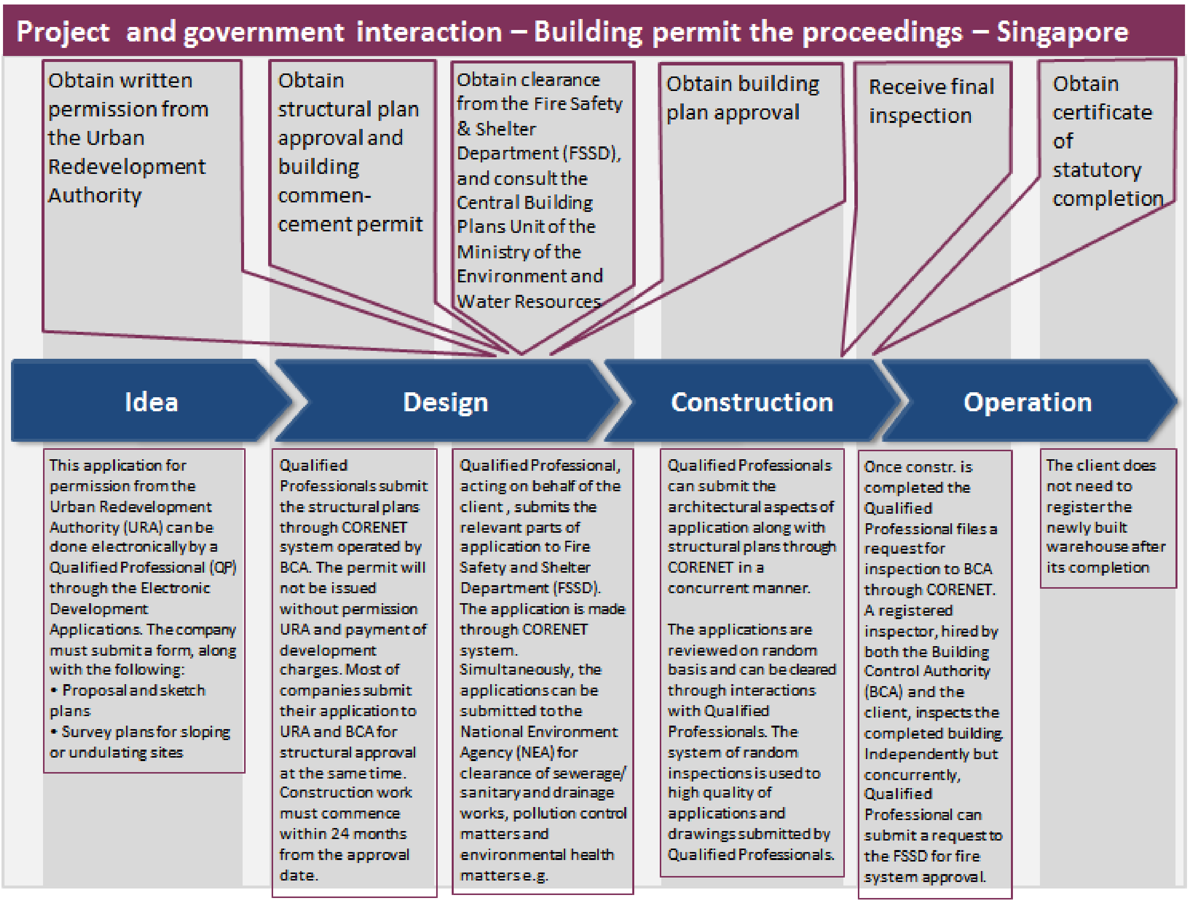
REGIONAL AEC INDUSTRY

The AEC industry in Singapore consists primarily of labor migrants in terms of building workers. Overall, 300 000 work permits were granted for migrant workers in the construction industry in June 2013 (Singapore Government - Ministry of Manpower, 2013). The high proportion of labor means that the industry is slowing, taking productivity into account. The government has initiated a program for productivity improvement (Building and Construction Authority, 2013).

BUILDING APPLICATION AND PERMISSION PROCESS

Figure 22 presents the building and application process in Singapore (The World Bank - International Finance Corporation (IFC), 2012).

Figure 22: The building application and permission process in Singapore



ADOPTION AND IMPLEMENTATION OF BIM

> ***"The soft issues are the hard issues."***
> *Dr. Evelyn Teo, University of Singapore*

The adoption of BIM in Singapore is estimated at 65 percent. 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 percent 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.

INITIATIVES FOR AUTOMATIC BUILDING APPLICATION AND PERMISSION PLATFORMS

CORENET

The idea of an artificial intelligence planning checking system was first conceived in Singapore as early as 1982. During the eighties two attempts to test the idea were aborted, but in the early nineties research and development showed that the idea was technically feasible.

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) (BuildingSmart, Unknown).

The first step was an electronic consent submission system incorporating an in-house developed Building Plans (BP) Expert System to Check 2D plans for compliance (Dimyadi and Amor, 2013). The BP Expert System was launched in 1997.

In 2002 CORENET was upgraded and the 2D BP Expert System replaced with 3D IFC data model. CORENET currently has three strands: 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 PAVO™, a suite of the J2EE application, which enables submission logic-handling and rules validation. It provides built-in business intelligence and secure transmissibility.

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 IAI 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 which has been certified as capable of producing the IFC 2x2 model data expected by the system. This data is complemented by client-side functions which capture the additional information required by the checking functions. UK consultancy company AEC3 provided model development assistance to the Singapore government.

Available since 2002, the e-Info System 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 (Ai Lin, 2006). It was decided that full development would be based on an international standard for 3D CAD, in fact the IFC open standard.

In Singapore, almost 100 percent 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 percent of the respondents indicated they had experienced cost and time savings related to printing of plans, transportation/dispatch services and increased staff productivity (BuildingSmart, Unknown). 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 (BuildingSmart, Unknown). It should be remembered that Singapore is a small and dense country with one centralized authority.

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

HONG KONG, KOREA AND JAPAN

REGIONAL AEC INDUSTRY

Hong Kong

Hong Kong's construction industry has earned a reputation over the years for rapid construction of quality high-rise apartment blocks and office towers. The adoption of specialized construction techniques, such as reclamation and design-and-build methods, has made Hong Kong a regional leader. Most of the export markets for Hong Kong's building and construction services are in Asia, with the Chinese mainland being a major one. Asia and the Middle East are also promising markets. Major services categories include project management, contracting and engineering consulting.

Hong Kong's construction activities can be broadly classified into three categories, namely buildings (residential, commercial, and industrial/storage/service), structures and facilities (transport, other utilities and plant, environment, and sports and recreation), and non-site activities (decoration, maintenance and repair, etc.). The overall gross value of construction work carried out by main contractors in Hong Kong (in real terms) has been rising since 2009. A strong growth of 35 percent in the value of public sector sites drove construction activity up by 16 percent to HK$129 billion in 2011.

Hong Kong's construction industry employs approximately 70 000 people. It is characterized by a small number of large local contractors, a high level of subcontracting and the presence of a large number of overseas contractors, with a substantial proportion of companies being both developers and contractors. Most of Hong Kong's construction companies are small in size and those with less than HK$10 million (US$1.3 million) in annual gross value of construction work account for up to 97 percent of the construction industry. The majority of the small ones act as subcontractors to the large companies, which tend to be main contractors. There are quite a number of very big construction companies capable of handling projects requiring sophisticated technology and a strong financial background and which are expanding their business across the region (The Hong Kong Trade Development Council - Reseach, Nov 2012).

Korea

The construction industry is an important sector that takes a significant share of the national economy. It accounts for 15.4 percent of the gross domestic product (as of 2006) and 8 percent of total employment (19.34 million as of June 2007).

According to the Korean Standard of Industry Classification, the construction industry can be divided into constructors involved in "Heavy Construction" or "Building of Complete or Partial Constructions". And Heavy Construction is further divided into "Site Preparation" and "Civil Engineering Construction (roads, bridges, tunnels, waterways, dams)", while Building of Complete or Partial Construction is again divided into "Residential Building Construction" and "Non-Residential Building Construction."

In terms of project issuers, the construction industry is largely divided into two groups: public issuers such as government organizations, local municipalities, state-run corporations (Korea National Housing Corporation, Korea Expressway Corporation, Korea Land Corporation) and private issuers, which are individuals and private companies (OECD Competition Committee, 2008).

Japan

The construction industry is one of the key industries in Japan. It produces a little less than 20 percent of GNP and approximately 10 percent of the workforce is engaged in it. The industry has played an important role as a provider of residential buildings and of social overhead capital, which together constitute the foundation of both national life and industrial activity (Ministry of Land Infrastructure and Tourism (MLIT)).

According to the Construction Business Act, the “construction business” is the business of completing contracted construction work, irrespective of its name, including principal contracts and subcontracts. Japanese law defines “a construction business operator” as a company that engages in the construction business under license. Construction business licenses are classified according to the types of construction work conducted by business operators (28 types of construction work, including building construction and civil engineering) and licenses are classified in accordance with whether or not business offices are established in two or more prefectures (licenses issued by the Minister of Land, Infrastructure, Transport and Tourism or prefectural governors) (Ministry of Land Infrastructure and Tourism (MLIT)).

The number of authorized constructors is tending to increase and remains at the all-time highest level. However, construction investment has made only little progress following the collapse of the bubble economy and it is hard to expect the continuous growth experienced so far to continue in the future (MLIT).

Labor productivity for the construction business has been declining since the early 1990s, when the index reached its peak. As of 2002, labor productivity for the construction business stood at a level of approximately 70 percent of labor productivity for all businesses (Ministry of Land Infrastructure and Tourism (MLIT)).

BUILDING APPLICATION AND PERMISSION PROCESS

Hong Kong

Figure 23 presents the building and application process in Hong Kong (The World Bank - International Finance Corporation (IFC), 2012).

Korea

Figure 24 presents the building and application process in Korea (The World Bank - International Finance Corporation (IFC), 2012).

Japan

Figure 25 presents the building and application process in Japan (The World Bank - International Finance Corporation (IFC), 2012).

Figure 23: The building application and permission process in Hong Kong

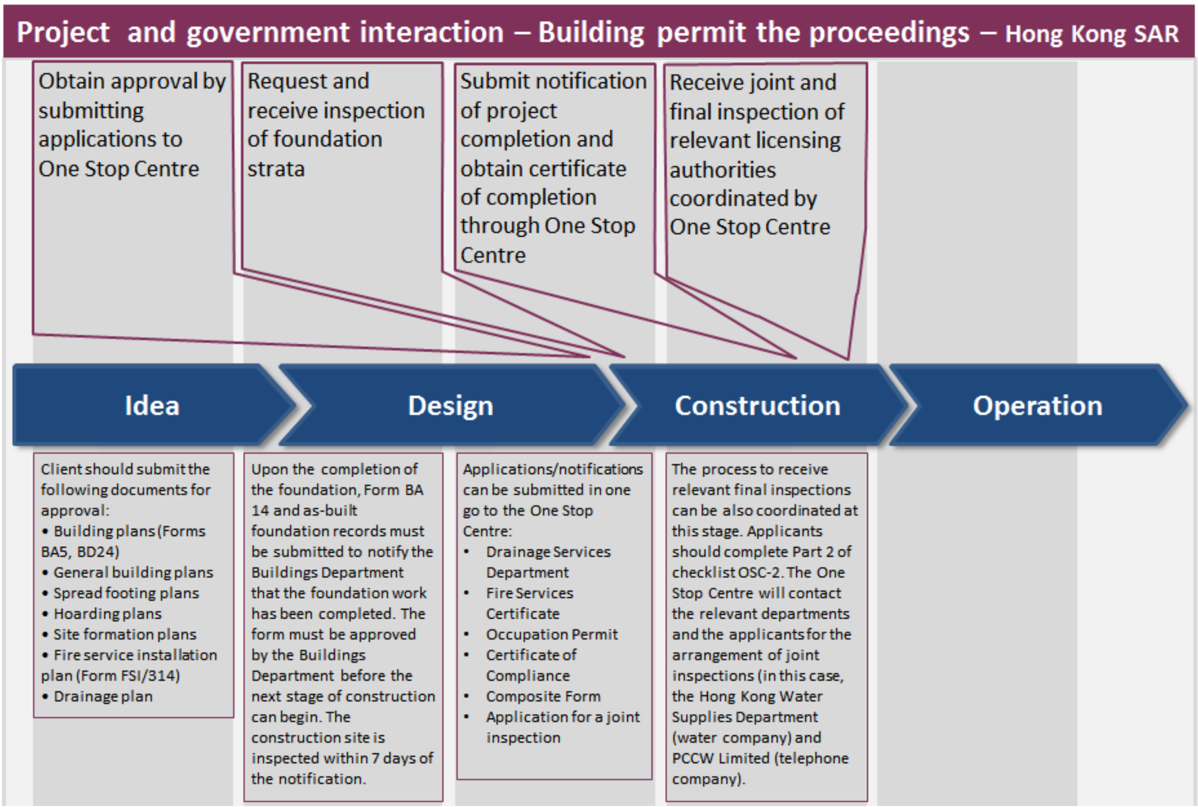


Figure 24: The building application and permission process in Korea

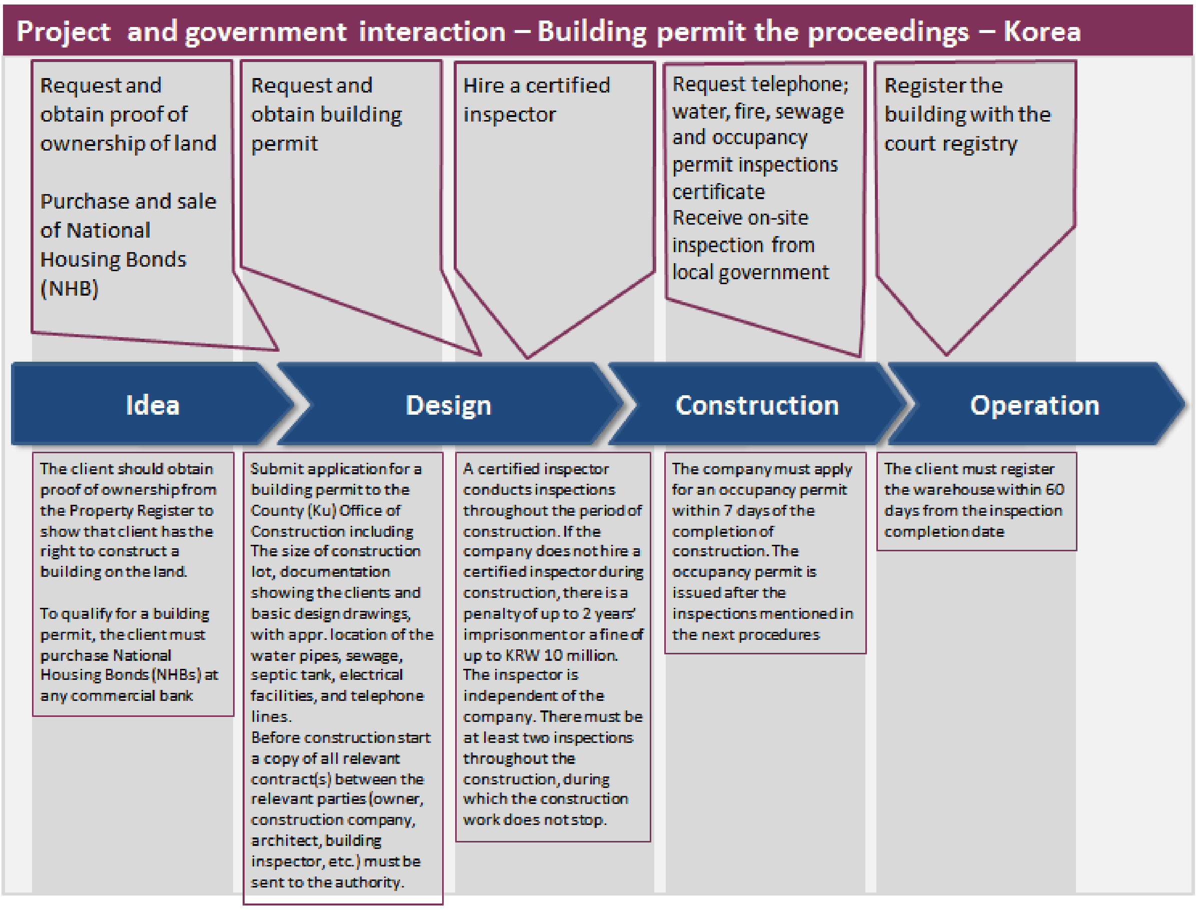
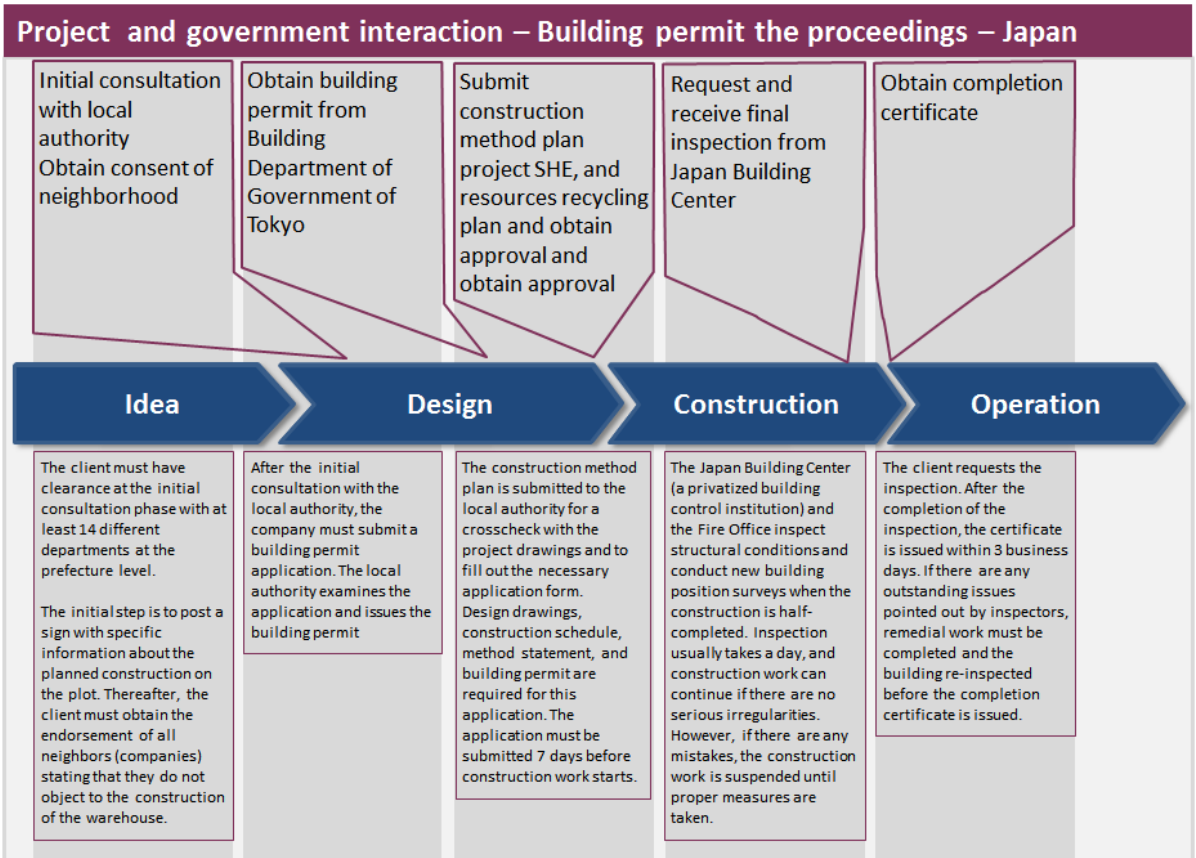


Figure 25: The building application and permission process in Japan



ADOPTION AND IMPLEMENTATION OF BIM

Hong Kong

Hong Kong has much to learn from the international experience in the adoption and integration of BIM. Different countries have taken different approaches. Different organizations have taken the lead in that adoption: government, private sector, and industry associations.

In 2007 the Hong Kong Construction Industry Council was founded. It focuses on improving the industry's productivity and procedures, and is funded by the industry itself. CIC consists of a chairman and 24 members representing various sectors of the industry, including employers, professionals, academics, contractors, workers, private individuals and Government officials (CIC, 2012). For the past two years CIC has been reviewing the international experience and has recently released its draft roadmap for a comprehensive, holistic approach to the wider adoption of BIM in Hong Kong's construction industry.

Given the sophistication of Hong Kong's construction industry, it is notable that so far this seems to have been an ad hoc adoption. As a whole, BIM implementation in the construction industry in Hong Kong is still at a primary stage. Individual participants' knowledge of BIM and capability to utilize BIM differ widely.

Compared with international BIM practice with respect to planning, adoption, technology and performance, Hong Kong is lagging behind the majority of developed countries. The CIC considers it necessary to catch up with the fast pace of the global adoption of BIM to maintain the competitiveness of Hong Kong's AEC services, in the region and internationally. Without sufficient skilled manpower and associated facilities in the BIM area, Hong Kong's industry will find it difficult to stay competitive outside the Hong Kong market.

Moving ahead, two key tasks have been identified for immediate action. First, a task force has been set up to focus on identifying and leading the preparation of standards, specifications, common practices, or reference documents to facilitate the industry to adopt BIM more fully. Second, the CIC will look to collaborate with active BIM practitioners to promote BIM. As part of that collaboration, the CIC is planning a 'BIM Year 2014', aiming to raise awareness in the industry through a year-long program of events (BIMAcademy and CIC, 2013).

Korea

BIM did not receive much attention in Korea until the late 2000s. The first industry-wide BIM conference was held in April 2008. After this, BIM spread and has been adopted rapidly in Korea.

The Korea BIM Society Foundation was established in 2010.

The Korea Public Procurement Service has stated that use of BIM will be compulsory for all projects over $Singapore 50 million (approximately EUR 30 million) and for all public sector projects irrespective of size by 2016 (BCA, 2011).

BuildingSMART Korea was established in 2008.

Japan

The situation with regard to BIM adoption in Japan appears to be much like the situation in Korea. Currently the focus on BIM is substantial and good progress is being made.

The Building Research Institute is the Japanese public sector institute for R&D for housing, building construction and urban planning. It was established in 1942. The Department of Product Engineering researches and develops systems for building production, responding to development within advanced information technology. It focuses on integrated information technology throughout building design, construction and maintenance (Building Research Institute, 2013).

The Building Research Institute of Japan and the Japan Federation of Construction Contractors (JFCC) hosted an international one-day seminar on the topic of Integrated Design & Delivery Solutions (IDDS) and BIM on November 1, 2013.

Obayashi Corporation is one of Japan's leading construction contractors. To promote active use of BIM technology, Obayashi Corporation has established specialized BIM departments within every branch. Obayashi is taking steps to apply BIM in all of its design and construction projects by the fiscal year ending March 31, 2016 (Obayashi Corporation, 2013).

INITIATIVES FOR AUTOMATIC BUILDING APPLICATION AND PERMISSION PLATFORMS

Hong Kong

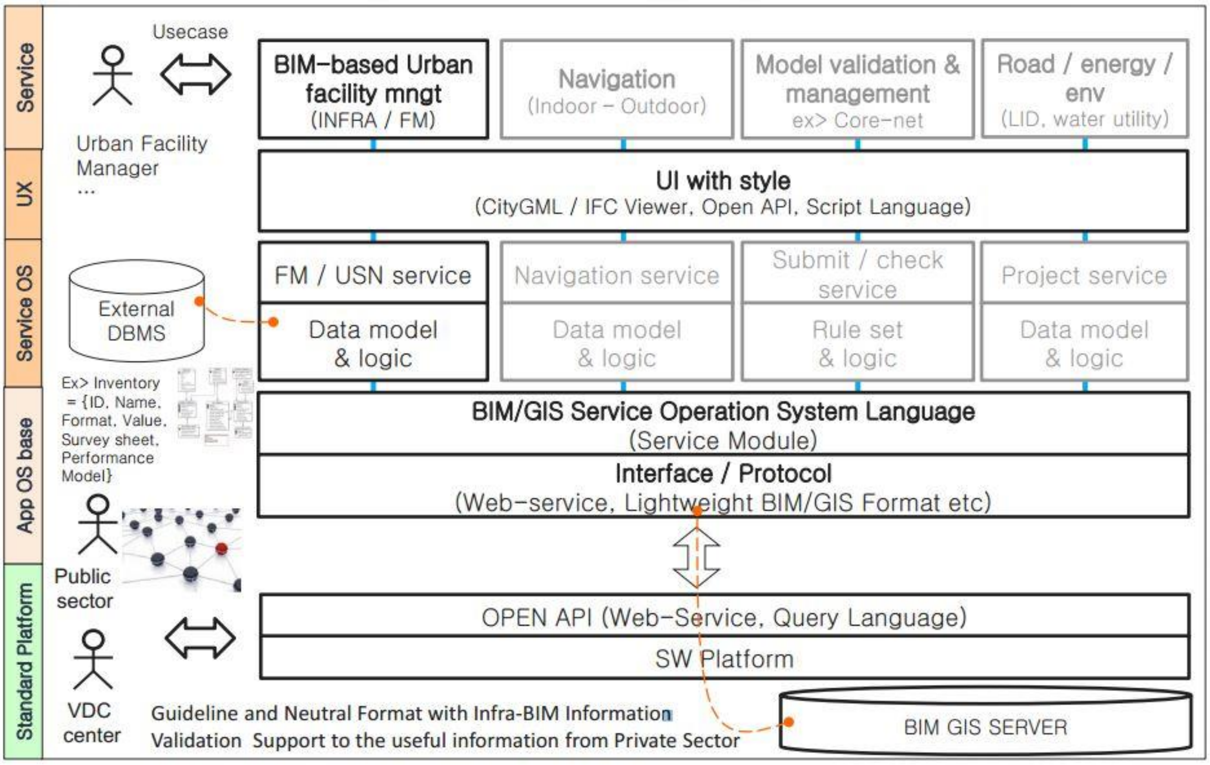
There is currently no common platform for BIM collaboration in Hong Kong. BIM is not used in any way as part of the building application and permission process. Ms Ada Fung at the Hong Kong Housing Authority is currently carrying out a survey to explore automatic submission issues.

Korea

Korea Building Information Management (K-BIM) is a consortium of commercial, academic and government organizations. They are working on the development of a national standard for BIM. The aim is to improve efficiency and to reduce waste, duplication of work and overall cost of construction projects.

Korea has a BIM on GIS project running from 2012 to 2016. The project seeks to develop a platform for interoperability between BIM and GIS. The platform is funded and developed by the authorities and will deliver a user interface for industry players based on open APIs. The project is run by Korea Institute of Construction Technology (Kang, 2013).

Figure 26: Information architecture for the Korean BIM on GIS project



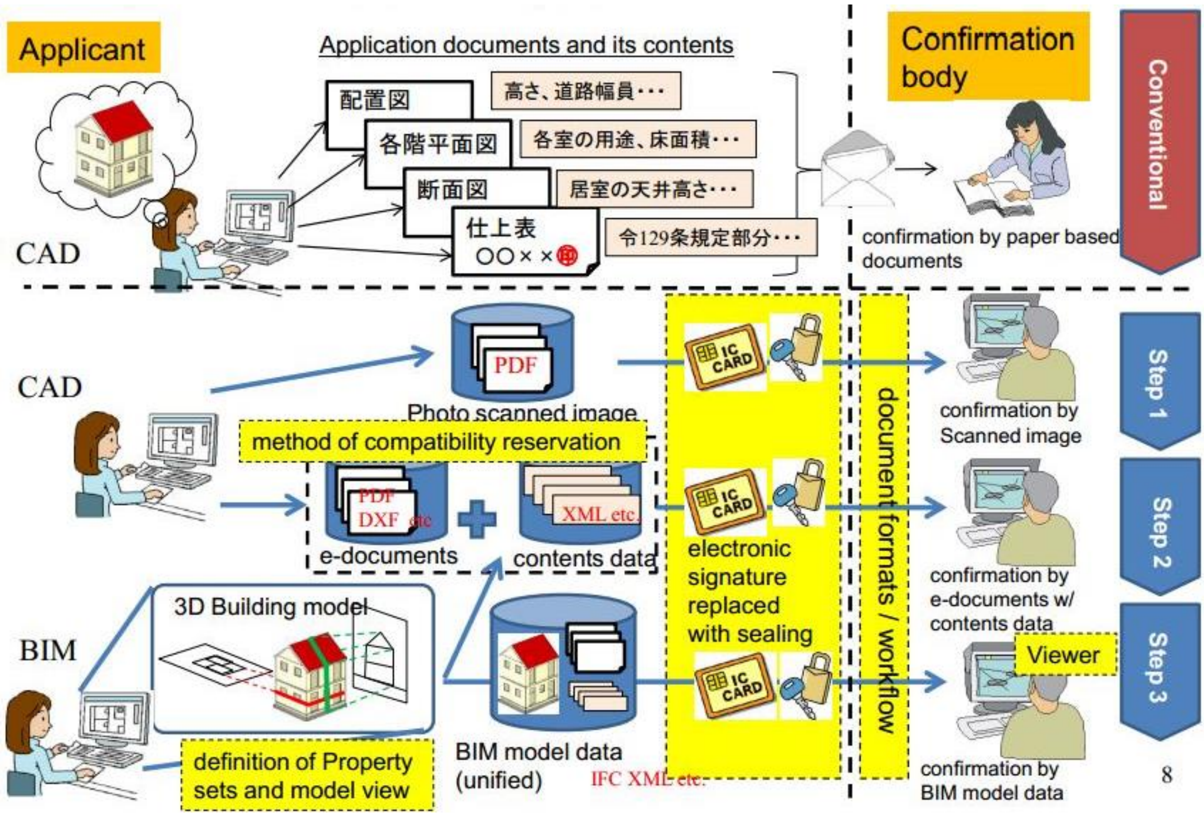
It seems Korea has been lagging behind in the field of BIM and solutions for automated rule checking, but it is currently investing heavily in R&D and consequently fast catching up with the global leaders.

Japan

Building Research Institute Japan is carrying out a project which aims to identify the bottlenecks in the existing Japanese procedures for building application and permission (Masaki, 2013). This is the first step in developing a platform for automatic building application and permission.

The plan for the development of an electronic solution is to carry out the implementation in steps. On the applicant side, the submission documents will first be required to be delivered as photo-scanned images, before e-documents (XML, etc.) and eventually BIM will be required. On the authority's side, confirmation will be provided first by confirmation of scanned image, then by confirmation of e-documents with content data, and eventually by evaluation of the BIM.

Figure 27: Information architecture for the Japanese initiative to develop a platform for automatic building application and permission



Japan has looked to Singapore and is using the IFC format in development of the electronic submission system, and a lot of the current research is being conducted on the challenges related to compatibility with different software applications.

Japan plans a trial of a prototype system and to decide on technical specification for an electronic submission system during 2014. The prototype has been developed for small wooden houses.

AUSTRALIA

REGIONAL AEC INDUSTRY

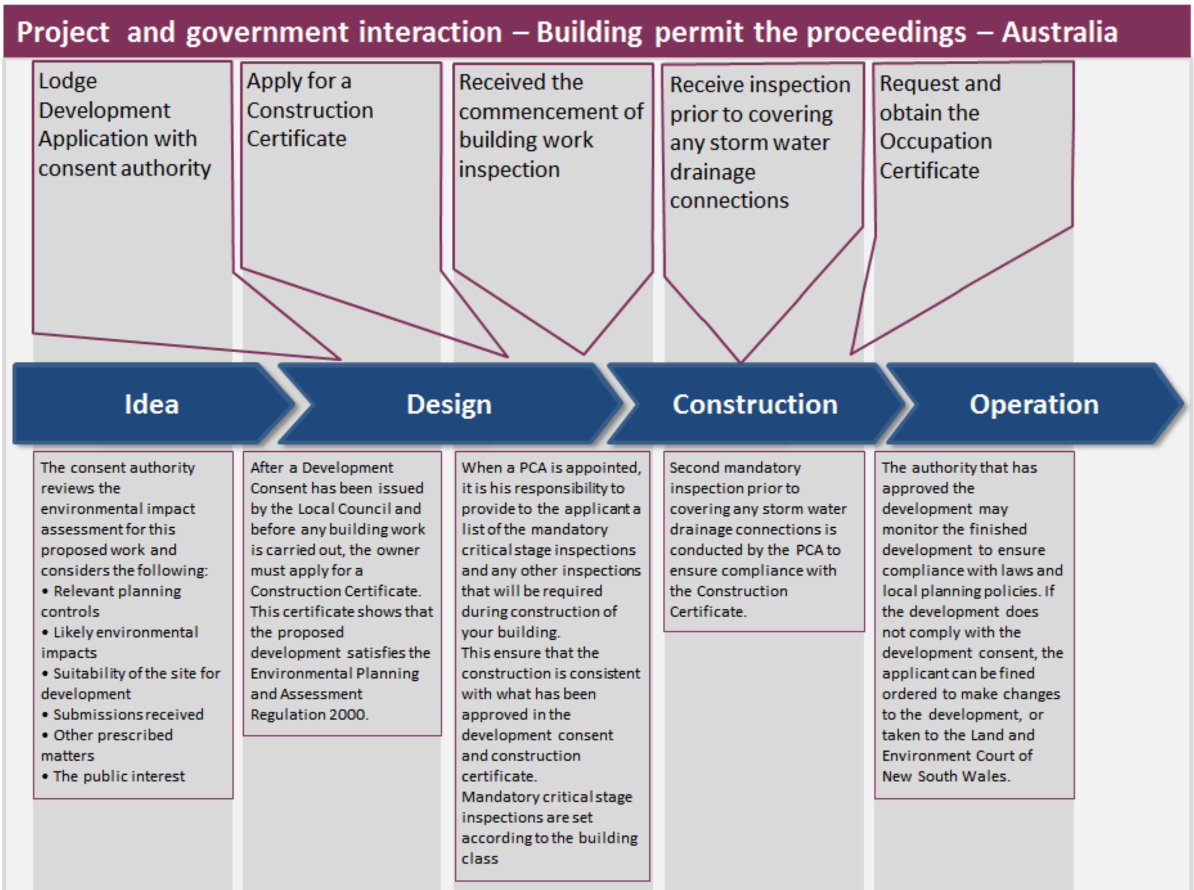
The Australian construction industry has been growing at a steady rate over the last decade. From an income of around Aus$ 100,000 million in 2008-09 to an income of nearly Aus$ 300 000 million in 2011-12, the industry has seen significant growth. The building and construction industry's current contribution to GDP is a little under 10 percent (CSIRO, 2011). The construction industry is made up mainly of residential and commercial builders. However, infrastructure, industrial, and institutional construction also plays a major role in the development of the economy.

In 2008-2009 the Australian construction industry experienced a relative shrinking of its annual income and its overall growth due to the global economic crisis. The economic recession slowed down the steady growth of the construction industry in Australia. However, it did not affect the Australian construction industry as much as it did other western countries, like the US and the UK (Australian Construction Resources, 2013).

BUILDING APPLICATION AND PERMISSION PROCESS

Figure 28 presents the building and application process in Australia (The World Bank - International Finance Corporation (IFC), 2012).

Figure 28: The building application and permission process in Australia



ADOPTION AND IMPLEMENTATION OF BIM

Australia's Federal Government, through the Built Environment Industry and Innovation Council (BEIIC), recently commissioned a report that puts forward a cogent economic case for the widespread adoption of BIM in the Australian construction sector.

The report states, "the use of BIM has the potential to streamline processes throughout a building's lifecycle through the integration of design, engineering, construction, maintenance and decommissioning information" and, "the use of digital modeling tools can have wider benefits for the Australian community when the use of this technology is extended to, for instance, urban planning, infrastructure development and the designing and understanding of city environments."

The BEIIC report highlights a range of issues that constrain adoption or prevent the maximum potential being realized. It suggests that these drawbacks should be turned into seven key priorities for concerted action (BuildingSmart Australasia). The seven priorities are:

- Adoption of Common BIM Guidelines;
- Product Information and BIM Libraries;
- Compliance and Certification;
- Information Exchange;
- Procurement, Legal Issues & Insurance;
- Process Change;
- Multi-disciplinary BIM education.

The responsible Australian authority, the Department of Industry, is actively implementing BIM in collaboration with different players and organizations in the industry. The central initiatives are:

- The Built Environment Industry Innovation Council's Final Report to Government 2012 outlines achievements against its ten recommendations with future suggested actions for progressing BIM.
- An additional report, the National Building Information Modelling Initiative, was presented to the Council to inform its activities to promote the widespread adoption of BIM and support for BIM pilot projects.

A further report, Building Information Modelling Industry Research, was presented to the Council to provide a survey of current industry BIM capabilities and future preparedness across a diverse range of supply chain players. The report provides a snapshot of current 2012 industry adoption, with those surveyed commenting, "BIM offers users an inherent ability to proactively resolve design limitations before they impact upon construction, leading to huge benefits in overall productivity."

INITIATIVES FOR AUTOMATIC BUILDING APPLICATION AND PERMISSION PLATFORMS

DesignCheck

In 2006 CSIRO announced DesignCheck as the successor to BCAider (*see bottom of page*). It is the only application that is specific to Australia. It checks for compliance against the disability codes incorporated in Australian Standard AS1428.1 of the Building Code of Australia (BCA) (Shih et al., 2012).

The initiative has been awarded national building industry awards in Australia (CSIRO, 2011).

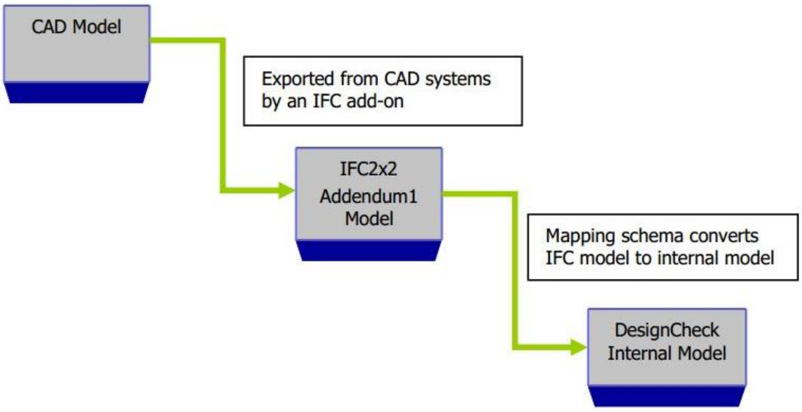
The DesignCheck system develops an object-based rule system using EDM for encoding design requirements from building codes. It defines a DesignCheck internal model based on IFCs for modeling extended design information. The advantages in the DesignCheck system beyond existing tools provide an automated code-checking process, flexibility by allowing a design to be checked by selected clauses or object types and support for checking various stages of design during the design process, such as at the early stage of design, detailed stage of design and specification stage of design (Ding et al., 2006). The DesignCheck system is targeted broadly at use by building authority certifiers as well as architects and designers.

For a domain-specific application such as code compliance-checking, detailed application-specific information may be missing in the IFC model. An internal model has been developed for DesignCheck to solve this problem. The DesignCheck internal model extends the IFC model to cover enriched application-specific information, i.e. the information required by building codes. The mapping schema for automated translation from IFC to the internal DesignCheck model is presented in Figure 29.

BCAider
BCAider was released by the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia. The first version of BCAider was released in 1991 to a target market of building surveyors, architects, engineers and educational trainers (CSIRO, 2011). The software was licensed for distribution initially by Butterworth's from 1991 for about 6 years and then licensed to CBH. CBH ceased distribution around 2005 and CSIRO decided to withdraw BCAider.

BCAider was a commercially available expert system for compliance checking against the Building Code of Australia (Dimyadi and Amor, 2013). The system was unsophisticated compared to current information technology, not being much more than a digital library of building codes and a guide asking the user to answer a series of questions. Hypertext was used to provide background information and examples.

Figure 29: Mapping schema for automated translation from IFC to internal DesignCheck model



Ding et al. (2006) CSIRO and (2011) proposed the following benefits that could be gained from DesignCheck:

- Automating the design checking process for compliance with building codes;
- Providing more reliable assessment with less errors;
- The ability to interrogate 3D object-based CAD systems;
- Allowing the checking at various stages - sketch design, detailed design and specification;
- Allowing the checking of a design by selected building code clauses;
- Allowing the checking of a design by selected building object types;
- Providing a friendly and interactive reporting system;
- The ability to check 'on-the-fly' the compliance of the design to building codes, and to reduce the lead-time of a design process.

Shih et al. (2012) highlights some of the challenges remaining in the development of Design Check:

- DesignCheck uses rule-based engines to interpret the building code and it is difficult for designers and non-computer experts to revise the rules.
- DesignCheck only allows for compliance-checking against the building codes for disability.
- Checking reports cannot be presented in visual format.

The plan has been to develop the solution for check against more building codes, but this is not yet done. DesignCheck has never been launched commercially. Currently it appears that there are no further plans for development.

5. MAIN FINDINGS

BIM

- The terms Building Information Model (product) and Building Information Modeling (process) are being used interchangeably. People have a conception of the meaning they attach to the term. This may cause significant communication challenges.
- Change in human behavior is the greatest challenge regardless of profession, project role or geographic location.
- The software for BIM-based design, construction and operation is mature and available.
- Maturity and adoption of BIM-based work processes diminish from best practice in the design phase to hardly being present in the operation phase.
- Open BIM (IFC) has a stronger position in Europe than in the rest of the world.
- There is an inconclusive debate whether one data format for all purposes (IFC) is the right solution for data exchange between involved parties.
- A consensual solution for unique identification and semantic description of objects in BIMs is yet to be defined. The reference library buildingSMART Data Dictionary (bSDD) currently is the most mature solution.
- The AEC sector is moving into the model server era.
- The UK, US, Singapore and the Nordic countries are at the frontier of BIM adaptation.
- Hong Kong, Korea and Japan are focusing on BIM and developing fast.
- Some research into benefits experienced from BIM use has been done, especially in the UK. Among reported benefits from construction projects are cost and time reduction, but exact quantification is difficult to predict.

AUTOMATED COMPLIANCE-CHECKING

- Building regulations that before was formulated as prescriptive requirements are today performance base. This is a global trend. Performance based regulations are challenging to present as machine readable rules.
- There are several software vendors developing applications for compliance-checking. The technology appears to be mature. Hence ByggNett probably can be based on existing solutions for automatic compliance-checking.
- In all surveyed applications the regulatory data representation is hard-coded into the system and is subject to manual updates by software experts. This makes maintenance and revision demanding and resource consuming.

REGIONAL INITIATIVES FOR DEVELOPING APPLICATION AND PERMISSION PLATFORMS

CORENET in Singapore was the first serious effort into developing a platform for automated building and application processes. This may be seen as the catalyst which promoted the development of similar solutions in a series of countries. The initiatives found to be of significant interest for the development of ByggNett are:

- CORENET (Singapore)
- The Planning Portal (UK)
- SMARTcodes (US)

- DesignCheck (Australia)

The SMARTcodes and DesignCheck projects are not currently active.

In addition to the above mentioned initiatives there are projects with many similarities to the ByggNett concept in the pipeline in Korea, Japan and Denmark. The European Union has recently initiated and funded a project to develop a platform for automatic building application and permission in Iceland.

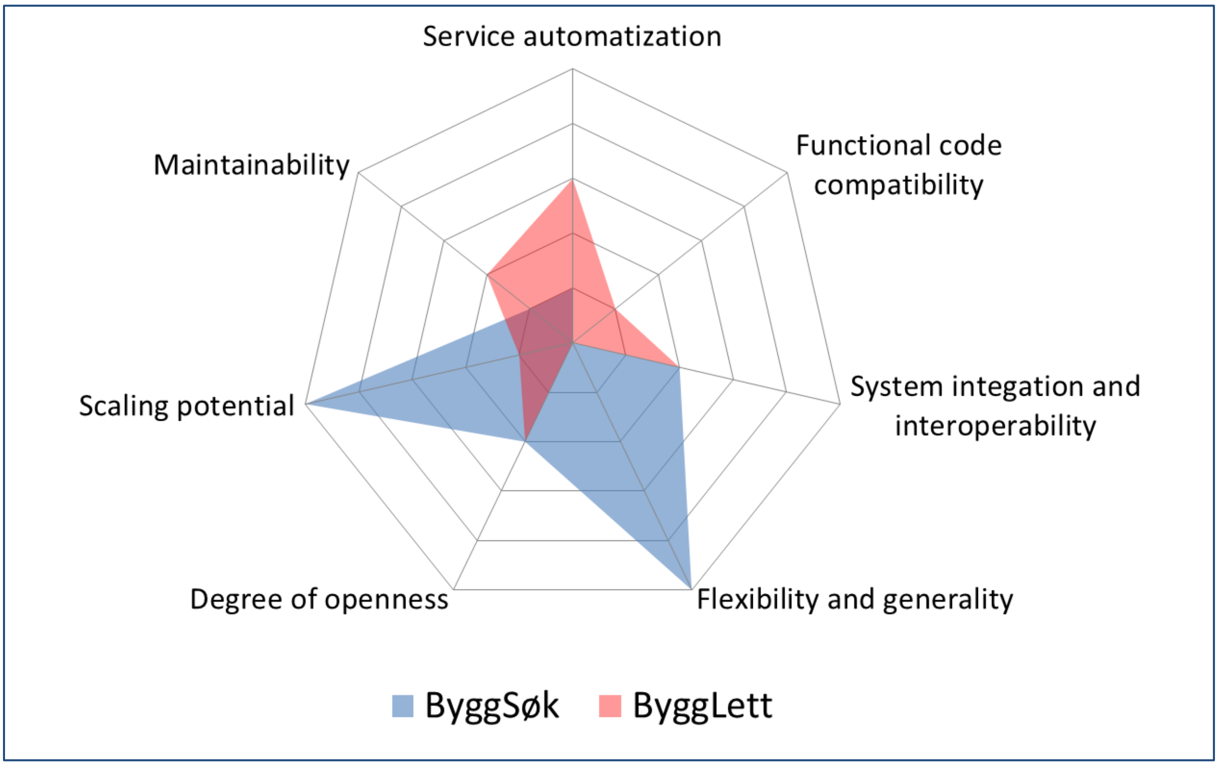
It is evident that the issues being discussed to a large extent are the same in the projects, regardless of culture, organizational belonging or geographic location. We have identified seven central issues that all initiatives into developing solutions for automatic building application and permission processes must consider. These are presented in Table 6. The parameters can be used in further investigations into the above mentioned initiatives, for instance with the use of a structured model as proposed by Hjelseth (2013).

Table 6: Seven central issues that every initiative to develop a platform for automated building application and permission must consider, together with the current situation in Norway.

Parameter	Definition	Current situation in Norway (with ByggSøk)
Service automatization	The degree of automatic collection of relevant information and degree of automatic assessment of the application.	Electronic filling and submittal of building applications over the Internet. Application verifies that all fields in the form are filled in before submission. Email with digital, static attachments is the media for submission. Applications are processed in the same manner as traditional applications
Functional code compatibility	To what extent the solution is compatible with functional descriptions from building codes.	No automated rule checking functionality.
System integration and interoperability	The solutions level of integration and interoperability with relevant systems and databases. (Similar to Norwegian government's architectural principle 2 for ICT solutions.)	Possible for local authorities to integrate ByggSøk with existing GIS solutions for maps, estate information, neighbors etc.
Flexibility and generality	The solutions capability of processing structures of different classification, scale and complexity. (Similar to Norwegian government's architectural principle 6 for ICT solutions.)	No restriction in building types.
Degree of openness	To what extent the solution is developed as an open platform based on non-proprietary technology. (Similar to Norwegian government's architectural principle 5 for ICT solutions.)	Any data exchange is done using XML format. HTML, PDF, FTP and XML files can be exported. ByggSøk allows for data to be printed on special purpose forms.
Scaling potential	Potential for future scaling in data volume and number of users. (Similar to Norwegian government's architectural principle 7 for ICT solutions.)	ByggSøk can potentially be used by all applicants.
Maintainability	Capability of being maintained by non-experts on software technology. (Similar to Norwegian government's architectural principle 5 for ICT solutions.)	The technical specification of ByggSøk is done internally by the Norwegian Building Authority. Development is contracted to EPM Jotne Technology and the programming is primarily done by one developer employed by EPM Jotne in Russia.

Figure 30 presents the current situation for building application and permission processes in Norway in blue color. The red color depicts how the situation can be if ByggLett is developed and implemented as outlined. ByggNett will expand the graph area by reaching a higher performance level on one or more axes. This is something one must consider when setting the level on ambition for the ByggNett project.

Figure 30: Visualization of the current situation in Norway based on the seven parameters for assessment of platforms for automated building application and permission.



Through this status survey we have been met with hospitality and a sincere interest of sharing knowledge. The possibility of harvesting competence and experience from existing initiatives, both public and commercial, is evident. This should be utilized by the ByggNett program. All persons that have contributed to the status survey are listed in the appendixes.

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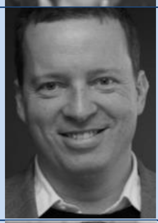
APPENDIX 1 - PERSONS INTERVIEWED

Norway			
Roger Stenbakk Senior Advisor/Customer Manager Altinn		**Andreas Hamnes** Architect and Senior Advisor Altinn	
Trine Tveter Managing Director Standards Norway		**Frode Mohus** Senior Lecturer Telecommunication and Automation Statsbygg	
Ingvild G. Mathisen Marketing manager AEC Standards Norway		**Petter Eiken** Chairman Bygg 21	
Steen Sunesen Managing Director buildingSMART Norway		**Vidar Offigstad** Norwegian Food Safety Authority	
Diderik Haug Project manager R & D - BIM Statsbygg		**Jan Myhre** Vice technical resource center Statsbygg	
Adam Matheus Altinn		**Trond Molseth** Head of Electrical Department Statsbygg	
Scandinavia except Norway			
Maria Rydqvist Utredare Boverket Sweden			

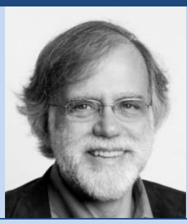
UK

Adam Matthews
Head of Departmental Delivery &EU
Development Director
UK BIM Task Group

USA

Jim Becker
Corporate Senior Vice President, Skanska US

Boston Massachusetts



Patrick McLamey
Chairman and CEO, HOK architects

Chair, buildingSMART Int.

San Francisco, California

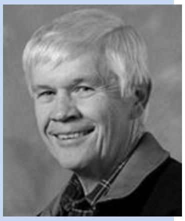
Dr. Calvin Kam
Director Industry Programs
Consulting Associate Professor, Stanford University

Founder and CEO, bimSCORE

San Francisco, California

Charles M. Eastman
Director, Digital BuildingLaboratory
Professor, College of Architecture and Computer Science, Georgia Institute of Technology

Atlanta, Georgia



Phil Bernstein
Vice President, Building Industry Strategy & Relations, Autodesk, Inc.

New Haven, Connecticut

James Vandezande
Principal, HOK architects
(Director of HOK’s buildingSMART initiative)

New York, New York

Tony Rinella
Director, bimSCORE

San Francisco, California

Robert C. Wible
Founder and Principal, Robert Wible & Associates

Senior Project Manager, Fiatech

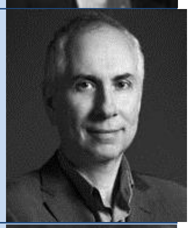
Austin, Texas

Ian Peter Atkins
Firmwide BIM Application Manager, KPF architects

New York, New York

James Brogan
Director, Firmwide Technology,
KPF architects

New York, New York

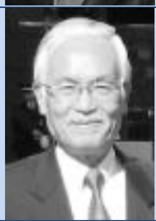


Jonatan Schumacher
Director of Advanced Computational Modeling, Thornton Tomasetti,

New York, New York

Martin Fischer
Professor of Civil and Environmental Engineering and Computer Science
Stanford University

Stanford, California

Asia			
Julian Lee Research Manager, Construction Industry Council Hong Kong		**Cheng Tai Fatt** Deputy Managing Director, BCA Academy Singapore	
Dr. Tan Kee Wee Director, Information Technology Director, Centre For Construction IT, Building and Construction Authority Singapore		**Dr. Evelyn Teo** Associate Professor Director of External and Alumni Affairs, National University of Singapore, Department of Building Technical Coordinator, buildingSMART Singapore Singapore	
Dr. Sangki Hong Professor, Anyang University, Dept. of Urban Information Engineering Seoul, Korea		**Inham Kim** Professor, Kyung Hee University Chief vice-president, buildingSMART Korea Korea	
Chanwon Jo, Ph.d Director of research center Japan		**Yoshinobu Adachi** Technical Coordinator, buildingSMART Japan	
Junichi Yamashita Chairman, buildingSMART Japan		**Kenji Yamamoto** Manager, NEC Corporation, 2nd Manufacturing and Automotive Industries Solutions Division, Solutions Promotion Departement Japan	
Megumi Iwamatsu NEC Corporation, 2nd Manufacturing and Automotive Industries Solutions Division Japan		**Katsumi Sakakibara** Advisor, C.I.Lab Inc. Japan	
Woon-Jae Lee Strategic Planning Team Manager buildingSMART Korea Korea			

APPENDIX 2 - WORKSHOP PARTICIPANTS

Name	Position	Company / organization
Steen Sunesen	Managing Director	buildingSmart Norway
Jøns Sjøgren	BoligBIM	Bolig produsentenes forening
Jorulf Ragnes		EPM Jotne
Tore Ulvin	Project manager	Storebrand Property
Anita Moum	Senior advisor	AB Faculty Norwegian University of Science and Technology
Elisabeth Heier	BIM-responsible	Region East Rambøll Norge AS
Terje Josefsen		Skanska Norway AS
Ole Jørgen Karud	Business Developer	Catenda/SINTEF
Anton Burger Eygelaar	Cost estimation systems and BIM	Veidekke Entreprenør AS
Morten P. Staubo	Group leader	Link Arkitektur
Maria Puhr		Forsvarsbygg
Kai Andre Jellum		Forsvarsbygg
Morten Andre Gullhaugen-Revling	Contracts	Forsvarsbygg
Siv Brunes Røtvold	Seksjonsleder tilstand og bygningsvern	Multiconsult AS