



Illustration: Ramboll

Review of the Development and Implementation of IFC compatible BIM

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1 Executive Summary

This report is funded by Erabuild and written by a cross-country group, consisting of personnel from VTT in Finland, Eurostep in Sweden, Rambøll in Denmark and SINTEF in Norway.

A mixture of interviews with key players in the AEC/FM industry, interviews with research and development organizations involved with buildingSMART technology, a survey with questions distributed to a wide range of companies and organizations, and intimate hands-on knowledge of the field, was used to reach the findings and conclusions this report represents.

1.1 Technology

The vision behind the international open standards and neutral technology, collectively known as buildingSMART technology, is to enable efficient information flow during the complete lifecycle of the building and beyond. IFC compliant BIMs form part of the foundations to this vision. An Integrated BIM stores all the building information relevant during the total lifecycle of the building and provides access to that information for the participating members.

In general, to be able to share information, three specifications must be in place:

- An exchange format, defining HOW to share the information. IFC (an ISO standard in development) is such a specification.
- A reference library, to define WHAT information we are sharing. The IFD Library (an implementation of ISO 12006-3) serves this purpose.
- Information requirements, defining WHICH information to share WHEN. The IDM/MVD approach (also an ISO standard in development) forms that specification.

For example whenever you exchange your contact information in an email, to a potential business partner, you use three open international ICT standards:

- RFC 822, the open international exchange format for email.
- The ASCII code system, our reference library for exchanging textual information.
- RFC 2821, the protocol defining what information two email servers must exchange, and when, to deliver an email from one person to the other.

However, all these three pillars for information exchange related to email, are so well integrated and implemented into our software tools and habits, so we do not think about them. They just work. This report provides recommendations for the next actions required to achieve similar level of usability for the information flow related to the entire lifecycle of a building.

1.2 Open International Standards

As email exchange over the Internet has proved, open international standards is an essential ingredient for information sharing. To unleash the full potential of more efficient information exchange in the AEC/FM Industry, both high quality open international standards and high quality implementations of these standards must be in place.

Through the results of our survey we show that CAD is still the major form of technique used in design work (over 60%) while BIM is used in around 20% of projects for architects and in around 10% of projects for engineers and contractors. IFC compliant BIM is actually used less than manual drafting for architects and contractors, and show about the same usage for engineers.

The IFC standard is generally agreed to be of high quality and is widely implemented in software. However, the certification process allows poor quality implementations to be certified and essentially renders the certified software useless for any practical usage with IFC. The IFD Library is also generally seen to have the potential to solve many real world problems. However no implementation support in off the shelf software exists at the moment. As for IDM/MVD, the standards are still under development, and although certain proofs of concepts exist, it is not yet ready for implementation in off the shelf software.

1.3 Necessary Future Steps

We recommend a set of steps to improve the deployment and usage of Integrated BIM, which depends on the three open international standards, IFC, IFD and IDM/MVD, and their implementation in software and business processes.

1.3.1 Technical Recommendations

- Continued incremental improvement of the IFC specification with predictable release cycles is necessary. The improvements should be user driven, dictated from business needs. The specification should move towards a modular base, enabling focused improvements with less overall impact of existing implementations
- Implementation of IFD in real usage scenarios should be started, preferably with software in the early phase of the building process, and continue with other software as the process demands. Continued efforts to improve the technical aspects of the IFD Library must be ensured. Standard IFD based Product Libraries should be developed
- Development of software products according to the IDM/MVD specifications is necessary to gain success in real project scenarios. This should be done in parallel with the standard specification of IDM/MVD
- An Integrated BIM depends upon ability to merge models from various sources, efforts to develop open technology to improve this process is called for

1.3.2 Process Recommendations

- The software certification process for IFC is currently insufficient to ensure dependable software in real world projects. This must be improved, and using IDM/MVDs to build a new certification process looks promising. Similar care must be taken when developing certification for IFD related software
- USA, Finland, Norway, Denmark, Germany, Singapore and Korea are all currently working on or have released BIM Guidelines. It is important to ensure that continued high quality efforts goes into this work, and that proper funding can be secured for an international BIM Guideline
- Integrated BIM will have impact on contractual and process issues in the AEC/FM Industry. Continued collaborative efforts to study this impact and suggest solution to challenges presented is important and must be secured
- Studies to demonstrate the business impact of implemented buildingSMART technology in the AEC/FM Industry should be carried out

1.3.3 Political Recommendations

- Large public clients should be early adapters and set proper demands in the market to drive the implementation and development of buildingSMART technology forward. Public authorities must follow up with significant funding to ensure the proper long term development and implementation speed. We acknowledge that a free market approach will not suffice to ensure the necessary open standards based foundation. However, when sufficient demand in the market is created, a free market approach is desired for further development. This is in agreement with similar earlier efforts, like the development of the Internet
- Further stimulation and support to academic institutions to ensure long term research and educational programs in this field is important
- Finally, continued and increased international collaboration is important to ensure the full potential of these open international standards

2 Introduction

This report “Review of the Development and Implementation of IFC compatible BIM” is the result of the work initiated and funded by members of Erabuild.

Erabuild is a network of national R&D programmes, which focuses on sustainable tools to improve construction and operation of buildings. The network includes funding organisations from Austria, Denmark, Finland, France, Germany, the Netherlands, Sweden, Norway and United Kingdom.

This project has been funded by the following organisations:

- Danish Enterprise and Construction Authority, Denmark
- PSIBouw, Netherlands
- Tekes, Finland
- Formas, Sweden
- The Research Council, Norway

VTT, Eurostep, Rambøll Denmark and SINTEF have carried out the work on behalf of Erabuild. The team participated in a call from Erabuild in April 2007 and fulfilled the task between June and November 2007.

The report is based on experiences from the team, literature study, a survey distributed in Denmark, Netherlands, Finland, Sweden and Norway and interviews with a number of key persons in these areas.

2.1 Technology

buildingSMART is a marked friendly term coined by the International Alliance for Interoperability (IAI), to be used in place of cryptic acronyms like “IFC”, “IFD”, “BIM”, “IDM” and “MVD”. It covers all the international specifications and technologies developed to meet the vision of IAI.

Building Information Modelling (BIM) is a new and promising building design and documentation methodology. It is characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction.

Before the construction sector can benefit from BIM, a need to exchange meaningful information between different partners in a construction project must be recognised and met. To be able to exchange information freely between partners, you need the following ingredients (Bell, 2006):

- Something telling you **HOW** to exchange or share the information
- Something telling you **WHAT** information you exchange or share
- Something telling you **WHICH** information to exchange or share, **WHEN**

As an example, let us look at what happens when you send your contact details to another person in an email. First of all, you do not know anything about the other persons ICT infrastructure. Is he using the same email application as you are? Does his company have the same type of email server as your company does? Is he on the same operating system as you? How about versions? There are many variables that can exist in many different combinations.

The main point is that we do not know, and cannot make any assumptions. We must rely on open international standards.

First, you compose your email in your favourite email application. Most likely you start by filling out his email address, then the subject field, and finally you write the email itself and enter your contact details. When you push the send button, your email application will automatically take the information you entered, and format it according to a standard known as RFC 822, using ASCII characters and pass it over to your email server. The email server will then contact the email recipients' server and use a standard protocol known as RFC 2821, and deliver the necessary information.

To summarize:

- Format email according to RFC 822 (HOW to share information)
- Use data widely understood by all types of systems, the ASCII code system (WHAT information to share)
- The protocol RFC 2821 defines WHAT information to share WHEN

The buildingSMART vision is to achieve a similar efficient flow of all building information in the AEC/FM Industry. To this end, three open international standards are in development:

- Industry Foundation Classes (IFC), to define HOW to share or exchange building information
- International Framework for Dictionaries (IFD), to define WHAT building information we are sharing or exchanging
- Information Delivery Manual/Model View Definition (IDM/MVD), to define WHICH building information to share or exchange, WHEN

IFC is the most mature standard, and has reached a reasonably advanced level of development. This standard is also implemented in a wide range of software applications. The IFD standard (ISO 12006-3) is implemented in the IFD Library, an initiative slated to have a global reach but initially ran by Norway, the Netherlands, USA and Canada. IDM/MVD is currently under development, both the resulting outcome of the methodology and the standard methodology framework itself.

All experience so far tells us that in the long run, open international standards for information exchange provides the most efficient approach. Internet is a prime example of this.

In addition, the industry requests the development of detailed modelling standards/guides (methods), for the different partners in consensus to follow.

It is the overall objective of this report to document the state of the art in regard to development, implementation and deployment of BIM and the exchange format, IFC, in addition to the status of IFD and the IDM/MVD development, to the rest of the world. Furthermore the objective is to identify the conditions for which it is possible to use BIM with benefits, and for the appropriate steps needed to promote BIM, IFC, IFD and IDM/MVD.

3 List of Terms

AEC/FM	Architecture, Engineering and Construction / Facilities Management.	A phrase that may be used as an alternative to describe the building construction industry and subsequent building operations. Prevalent in US and related practice.
BIM	Building Information Model.	An object-oriented, AEC-specific model – a digital representation of a building to facilitate exchange and interoperability of information in digital format. The model can be without geometry or with 2D or 3D representations. Integrated BIM, when you share information, requires open standards.
Bips	Byggeri, informationsteknologi, produktivitet og samarbejde	bips: construction - IT - productivity - cooperation was established March 26, 2003 as a result of a fusion between BPS, ibb and IT-Bygge-Net. The idea of bips is to concentrate the efforts of the building sector in one effective organisation with a distinctive profile. This will make it possible to give priority to the needs and efforts of developments of common methods and tools across the various parties within the building industry.
buildingSMART	buildingSMART	A term representing a collection of open standards and related neutral technology to achieve effective flow of information in the AEC/FM industry.
CAD	Computer Aided Design	A class of software application that performs a design function.
IAI	International Alliance for Interoperability	An open consortium to develop, promote and for implementation support of IFC.
IDM	Information Delivery Manual	Collectively, the set of process maps, exchange requirements, functional parts, business rules and BIM guidance that enables close control of the information exchange process within a project.
IFC	Industry Foundation Classes.	An international specification for product data exchange and sharing for AEC/FM. IFC enables interoperability between the computer applications for AEC/FM. A subset of IFC is approved as ISO/PAS 16739.
IFD	International Framework for Dictionaries	An international development of an object library for the AEC/FM industry that is compatible with IFC and can be used to get more detailed information in and out of a construction design. An alternative identity for the conceptual model within ISO 12006 Part 3

Integrated BIM	Integrated Building Information Model	A Building Information Model whose information needs to be shared and thus warrants open international standards for information sharing
ISO	International Organization for Standardization	A network of the national standards institutes of 157 countries.
MVD	Model View Definition	IFC Model View Definitions document how the IFC Model Specification is applied in the data exchange between different application types.
RECC	Real Estate and Construction Cluster	The industry cluster responsible of designing, producing and maintaining the built environment, i.e. RECC consists of building owners, facility managers, construction companies, civil, structural, building services engineers, architects and other building professionals.
XML	eXtensible Markup Language	A language for defining and exchanging structured, computer interpretable information. It provides a method for both the definition of information, and the encoding of data based on the definition into an exchange format.

Table 1: Terms and definitions, partly based on Guidance Report: IFC for Sustainability, STAND-INN (Wix et al., 2007).

4 Methodology

To arrive at this report, we approached the challenge through different means. Basically we can divide this into four:

1. A survey
2. Interview with key personnel
3. Careful reading of existing reports
4. Our own experience

4.1 The Survey

We created a questionnaire, based on a previous survey from VTT Finland, and distributed this in the five relevant countries. Basically the receivers had to log onto a website and fill out some questions. Completing the survey would take about ten minutes.

The results were then analyzed, sorted and presented in easy to understand graphs. Some of the results were not included, due to a skew distribution of answers, or other problems with the data we have.

4.2 Interviews

Various key personnel from the industry was contacted directly and informally interviewed. Most of the responses are not directly quoted or used, but most of these interviews would support existing results from the survey or known status from other written reports. Some new perspectives was discovered, but only included here if it was collaborated independently from different people.

4.3 Existing reports

Existing reports from previous projects were carefully studied and adds value and validity to our own report. Our conclusions are based on indications from several reports and/or interviews or our own experience.

4.4 Our own experience

Our own experience in BIM and IFC related projects have also contributed to the results in this report. However they have not been used directly. Again we have used several sources to collaborate our conclusions and recommendations to ensure the validity and quality of this report.

5 Area 1 - State of the art regarding development, implementation and deployment of BIM and IFC

This chapter presents the current situation regarding development and research for the standards, the implementations and also the deployment of software in companies in the domain of Building Information Models, BIM, and IFC.

The information for this chapter comes from interviews of people, studies of literature and the use of questionnaires to define state of the art in these fields.

The questionnaire was answered by 391 persons in Denmark, Finland, the Netherlands, Norway, and Sweden. Figure 1 below illustrates that a large number of the answers came from people already involved in the IAI and buildingSMART work. The numbers of answers were from Denmark 51, Finland 58, the Netherlands 20, Norway 198, and Sweden 64.

In addition, an extra question about the usage of BIM and IFC based BIM software was sent to the persons answering the first questionnaire.

More information about the questionnaires, to which it was sent, and also analysis of the results can be found in the appendixes.

In Figure 1 the percentage of IAI and/or buildingSMART involved respondents is shown. The respondents' involvement in BIM and IFC development can possibly tilt the results in the favour of slightly more BIM and IFC usage throughout the questionnaire.

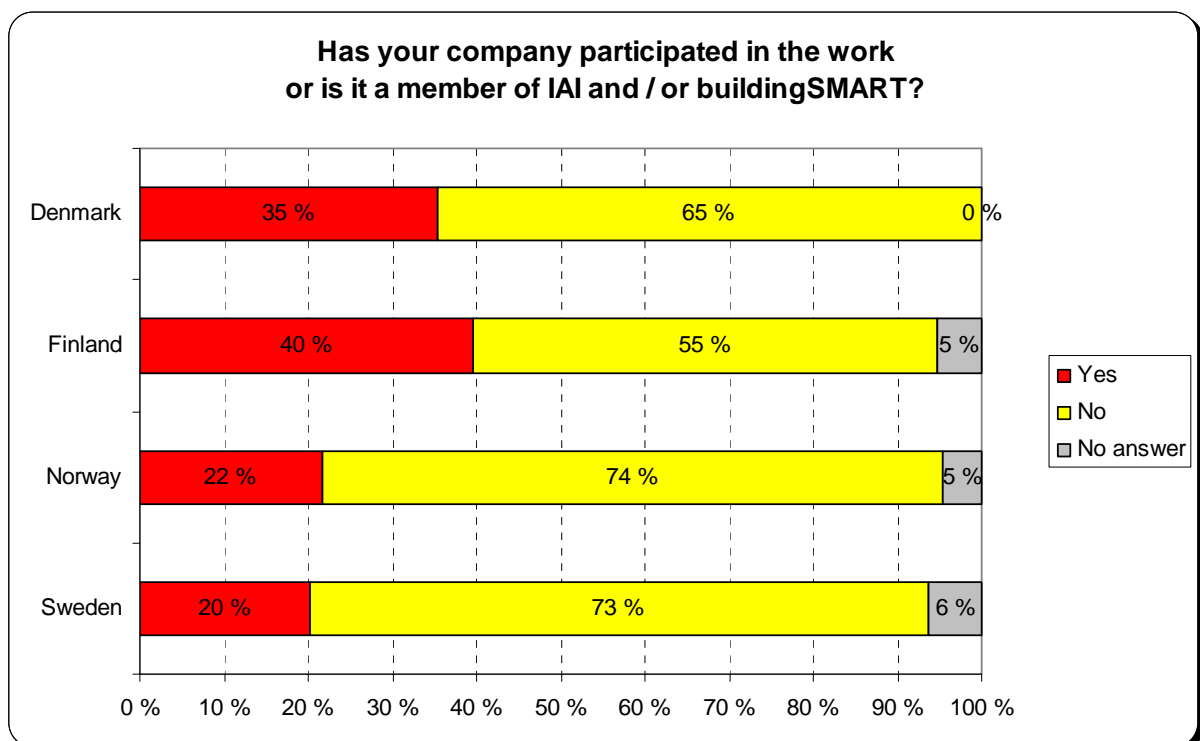


Figure 1: The relative share of “already involved” among the respondents.

One important part of the work is to discuss the concept BIM and how it is interpreted by the industry. BIM is now well established among all the main CAD vendors, and there is an understanding that when the building industry continues to evolve, the need for generic and

vendor-specific intelligent objects will become more important in order to perform more advanced operations and analysis. These can be engineering calculations, extraction of specifications, avoiding construction interferences, and quantifying sustainable design. By the definition of BIM, the data in these objects is required from the beginning of the design process until retirement or reuse. The “only” problem is that communication and collaboration over department and company borders are not on the agenda for most of the BIM users. That is, the need for standardizing these BIMs is only mentioned in very few definitions.

To support the extended enterprise and later the virtual enterprise where the brand of the software does not dictate the information exchange or information sharing, standardization using IFCs, IFD and IDM/MVD, or other open international standards, is a prerequisite.

Our definition of BIM

The findings and conclusions in this study relate to the following definition:

BIM (Building Information Model) is an object-oriented, AEC-specific model – a digital representation of a building to facilitate exchange and interoperability of information in digital format. The model can be without geometry or with 2D or 3D representations. Integrated BIM, when you share information, requires open standards.

This definition suggests that when using BIM for internal purposes the need for standardization of interfaces is not as strong as when you are using BIM for exchange purposes. The definition aims at the information set representing a building, and not the data model structuring the information.

Other definitions

In industry, the interpretation is not so focused. BIM is the same as 3D for a large group of people. The following definitions of BIM can be viewed as the more reliable ones:

STAND-INN

The European STAND-INN project (Wix et al., 2007) defines it as: “A shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the process to support and reflect the roles of that stakeholder.”

AIA

The American Institute of Architects has further defined BIM as “*a model-based technology linked with a database of project information*” and this reflects the general reliance on database technology as the foundation. In the future, structured text documents such as specifications may be able to be searched and linked to regional, national, and international standards (AIA, 2007).

NIBS

NIBS, National Institute for Building Standards, USA, is leading the work with National BIM Standard, nBIM (NIBS, 2007), where the definition is: “A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM process to support and reflect the roles of that stakeholder. The BIM is shared digital representation founded on open standards for interoperability.”

Autodesk

Autodesk (2007), defines BIM: “Introduced by Autodesk in 2002, the term building information modelling (BIM) refers to the creation and use of coordinated, consistent, computable information about a building project in design—information used for design decision making, production of high-quality construction documents, predicting performance, cost-estimating and construction planning, and, eventually, for managing and operating the facility.”

Standardization

For BIM and IFC, standardization is relevant for:

- The data model
- The certification – content and process
- Reference libraries
- Information exchange requirements

Figure 2 illustrates the responsibilities of standardization for the different actors in the industry (Karstila, 2007). The enabler, i.e. the IFC data model, is the responsibility of all the three categories involved – standardization bodies, software industry, and the building industry. They all have an interest in defining the requirements correctly and then also secure that the software implementation process has the right input. The software implementation process, as well as the software usage process, is also dependent of input and control from all the three actor categories. Without participation from all interested parties, the realized solutions will not be accepted by the market.

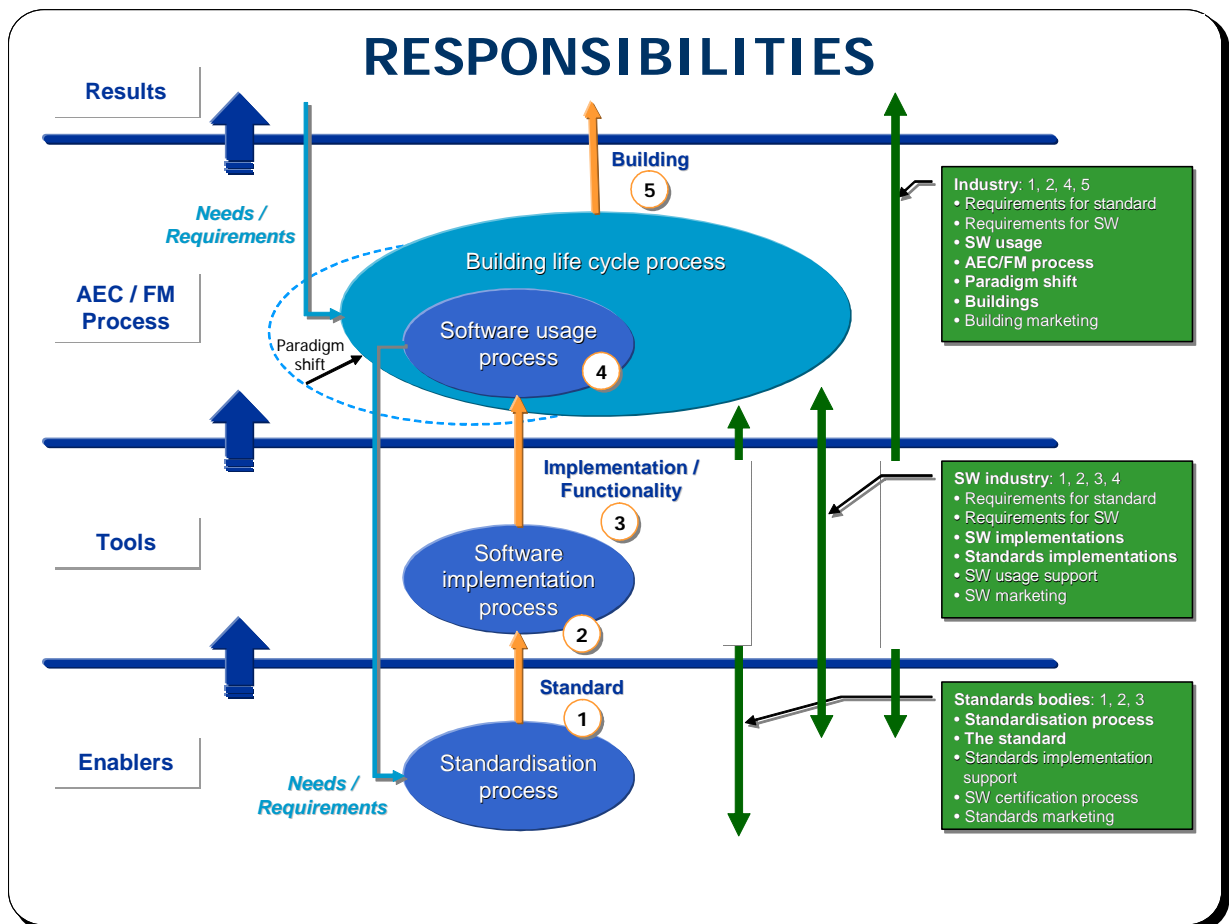


Figure 2: The responsibilities for the different standardisation areas (Karstila, 2007).

5.1 What is the state of art in regard of development/research of BIM?

This study categorizes the existing solutions into a handful of areas. These areas are Architecture, Structural, HVAC and FM.

In addition to the commercial side of the software development/research being described, the study adds a section with the standardization work going on, both BIMs in general and IFCs especially.

The conclusion regarding real object modelling in 3D is that there exists a number of 3D/model based CAD software. Only a small number of them are for the building material industry and FM.

There is research regarding product models and BIM at universities like Stanford and Georgia Tech. They are looking at very different aspects like implementation quality, steel structures and general issues regarding modelling. This is not covered by this study.

5.1.1 Development and standardisation within IAI

Within IAI there are a number of developments going on, based on the initiatives from the IAI chapters and their member organizations. This is a standardization effort and will result in additions to the IFC data model or in specifications, methodologies and guidelines how to exchange the information.

The current developments are:

Extension development projects, which are adding to the IFC model:

- Bridge [CI-2]
- Industry Foundation Classes for GIS (IFG) [CI-3]
- Electrical Installations in Buildings (EL-2) [EL-2]
- Commissioning data for facility management from IFC model [FM-10]
- Quantity take-off from the IFC model [PM-4]
- Real Estate Cost Recovery [RE-1]
- Structural Timber Model [ST-5]
- CIS/2 - IFC Harmonization [ST-6]
- Finite Element Model, Dynamic Analysis Process, and Assignment [ST-7]
- Harmonization of ISO 12006 Part 3 with IFC [XM-7]
- IFC drafting extension - Phase 2 [XM-9]

Special projects, which are aiming at general structures and issues:

- Model development for IFC2x4 [IFC2x4]
- High Level Object Classification Framework [XM-6]
- Harmonization with ISO TC184/SC4 Standards [XM-8]

The following are currently on hold and looking for resources to start again:

- Site and Ceiling design, Capture of design intent [AR-3]
- Escape Route Planning [AR-4]
- Power and Lighting systems design [BS-2]
- Process Model (information supplied to/by clients) [CB-1]
- Surveying, Road and Rail Design [CI-1]
- Temporary facility planning [CM-2]

- Performance Based Code Checking [CS-3]
- Area Measurement and Calculation [FM-5]
- Active FM [FM-7]
- Business Transaction Standards [PM-2]

The following are candidates being prepared for new project proposals:

- GeoSpatial IFC Component Development
- Legal Issues of using IFCs
- Industry Foundation Classes for Specifications (IFS) / Industry Foundation Classes for Planning (IFP)
- Proximity Testing
- Electronic catalogues
- IFC for Roads (IFR)

In addition to the IFC model there is development for the integration to the business processes and the information sources in industry:

These are very large initiatives and will last for a long time.

- IDM (Information Delivery Manual)
- IFD (International Framework for Dictionaries)
- MVD (Model View Definition)

5.1.2 Development at universities and research organizations

European projects in the construction domain are involving universities, research organizations and private companies. Several of them are using BIM and IFC. There are several large programmes like the 7th Framework, ECTP, Stand-INN, and Erabuild, which fund large numbers of projects in this field (Terry and Groome, 2007). Most of them are small and will not impact the development of the models and the standards. Some of the large ones are:

Finland

- Helsinki University of Technology and VTT
 - ECPT, Engineering and Construction Project Information Platform Finland – integrates BIM into actual construction and building management
- VTT and Tampere University of Technology
 - VBE Virtual Building Environments
- Tampere University of Technology
 - Industrial Processes Supported by an Open Virtual Building Environment – based on IFC based BIM

Norway

- SINTEF
 - Internal, cross-department buildingSMART project
 - Several ongoing research projects with significant buildingSMART content
 - BIM Guidelines development
 - Converting over 800 design sheets to buildingSMART friendly knowledge
- buildingSMART
 - A national coordinating effort to focus and collaborate on all buildingSMART development and implementation projects

- NTNU
 - Several student projects and thesis proposals focused on buildingSMART technology
 - Initial collaboration with industry and research organizations to develop student courses

Denmark

- Aalborg University
 - IFC Model Servers
 - 3D Models – B3D
- Aarhus School of Architecture
 - Product configuration
 - Design intent
 - IFC model server
- Technical university of Denmark
 - Interoperability

Sweden

- Luleå Technical University
 - Construction synchronization – based on IFC based BIM – (Erabuild programme)

The Netherlands

- TNO
 - The InPro project
 - The ManuBuild Project
 - iBuild
 - PSIBouw Instrumentarium
- TU (University Delft/Eindhoven)
 - Benchmarking buildingSMART-effects
- PSIBouw
 - Several ongoing research projects with significant buildingSMART content

5.1.3 Development by public owners

There is very little development related to BIM and IFC by the public owners. The exceptions are the ones listed below.

Finland

- Senate Properties
 - Pilot projects using BIM and IFC

Norway

- Statsbygg
 - Pilot projects using BIM and IFC

Denmark

- The Palaces and Properties Agency
- The Danish University and Property Agency
- Defence Construction Service
 - Initiate work related to BIM and IFC

USA

- GSA; General Services Administration
- US Coast Guard

5.1.4 Development in private companies

Most of the development related to BIM and IFC in the private sector is when the companies participate in European or national research projects. This list is not complete as many companies prefer not to publish their internal research and development work.

Finland

- Skanska Oy
 - Integration of Project Specific Building Information Model into Industrialised Building Process

Norway

- Selvaag – Bluethink
 - BIM, ICT solutions based on BIM

Sweden

- NCC
 - The UnPro Project

Denmark

- bips
 - Guidelines
- Rambøll
 - Rambyg - IFC collaboration

5.1.5 BIM applications

All the traditional CAD vendors within the AEC sector have BIM supporting applications. Below is a list of the dominating applications. For architectural applications the market leaders are listed based on surveys. The USA applications are taken from (Khemlani, 2007), and the Danish, from (B3D-konsortiet, 2006a). The applications listed for Finland, Norway and Sweden are from an extra question to the respondents of the primary survey in this report, see chapter 11 Appendix– software used. For the other disciplines there is no available information.

Architecture

- ArchiCAD
- AutoCAD Architecture
- Revit Architecture 2008
- Gehry Digital Project
- Vectorworks Architect (Nemetschek)
- Bentley Architecture
- DDS-CAD House Partner

USA: Revit Architecture, ArchiCAD, Bentley Architecture

Denmark: AutoCAD Architecture, ArchiCAD, Revit Architecture, Bentley Architecture

Finland: ArchiCAD, AutoCAD Architecture, Revit Architecture, Bentley Architecture

Norway: AutoCAD Architecture, ArchiCAD, Revit Architecture, Bentley Architecture

Sweden: ArchiCAD, Revit Architecture, AutoCAD Architecture, Bentley Architecture
Among the Architects the use of NavisWorks is frequently mentioned as an important BIM tool.
It is not a design tool, but used for model comparison etc.

Structural

- Tekla Structures
- Bentley Structural
- Allplan (Nemetschek)
- StruCAD
- ScaleCAD
- ProSteel 3D
- Revit Structure 2008

Building Services

- MagiCAD
- AutoCAD MEP
- Bentley Building Electrical Systems
- Bentley Mechanical Systems
- DDS-CAD Electrical
- DDS HVAC

Construction

- ArchiCAD Constructor and Estimator
- DDS-CAD Building

Building material and components

- ERP systems in general

Facility Management

- Bentley Facilities
- ArchiFM
- FMDesktop
- Rambyg
- Vizelia

For downstream applications like cost estimation and planning there are a large number of actors, often with very small market share and country specific functionality.

Project management related applications

- Tocoman Quantity Management Solution
- Granlund integration tools
- NOIS Calcus

Model checkers

- Solibri model checker
- NavisWorks

Model servers

- EMS Eurostep ModelServer for IFC, Eurostep

- EPM IFC Model server, EPM Technology
- IFC Model Server, Secom

Users

In a survey in June 2007 among the international group of 5486 subscribers of the web based AECbytes, 651 persons answered how they used or evaluated BIM solutions (Khemlani, 2007). This survey was sponsored by Bentley Systems, but the questions were neutral and designed by the author of the report. Of the respondents 46% were architects, 9% engineers, and 17% CAD/IT managers. The subscribers are international and interested in BIM solutions, which might influence the results shown in Figure 3. The 3 most important criteria for choosing a BIM tool were (Khemlani, 2007):

1. *“Full support for producing construction documents so that another drafting application need not to be used,”*
2. *“Smart objects, which maintain associativity, connectivity, and relationships with other objects”*
3. *“Availability of object libraries”.*

The deliberate choice of IFC support to achieve these goals was first on the 16th place as “IFC compatibility”. The awareness of the need for an enabler for collaboration is not high.

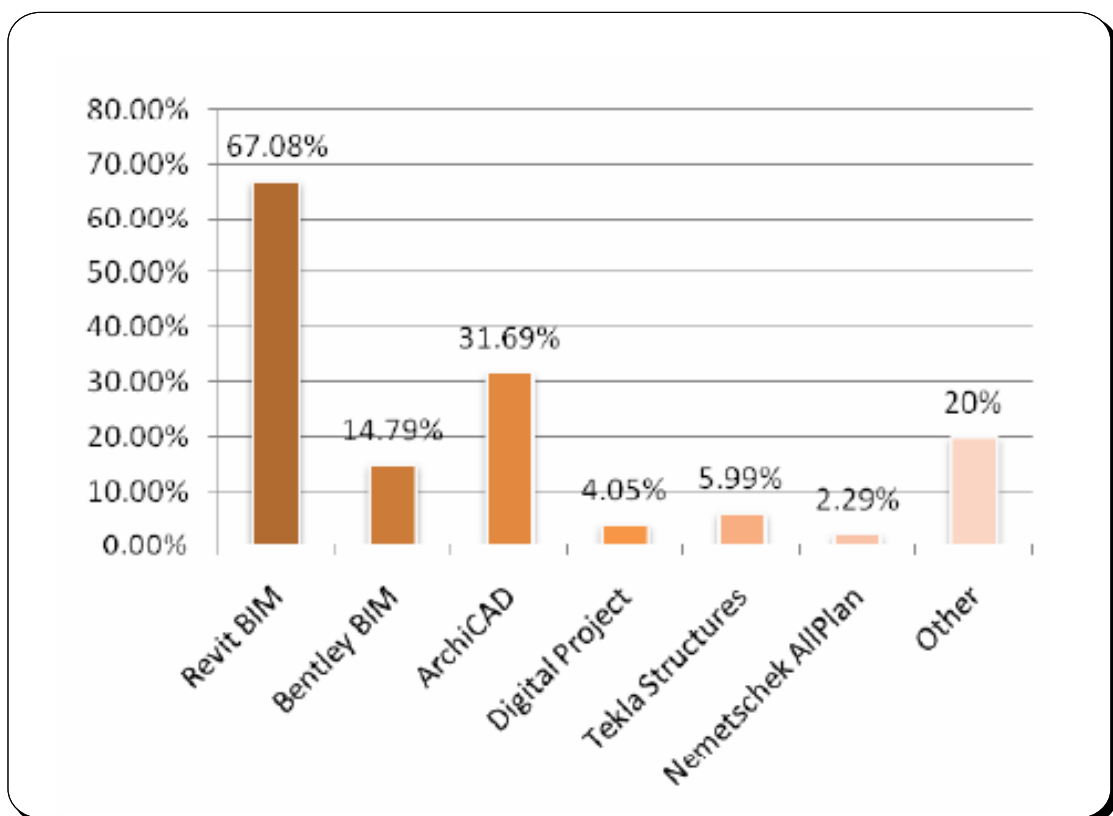


Figure 3: BIM solutions currently being used or evaluated among international subscribers of AECbytes (Khemlani, 2007)

Figure 4 illustrates the usage of BIM and IFCs as an average for all disciplines in the different Nordic countries. When adding the BIM and the IFC compliant BIM results, Finland has an average usage for all disciplines of approximately 33% related to BIM.

Among the Finnish firms responding to a web survey in January 2007 (Kiviniemi, 2007a) the volume of design work based on BIM was 33% for architects and 20% for engineers. This is very close to the result in Figure 4.

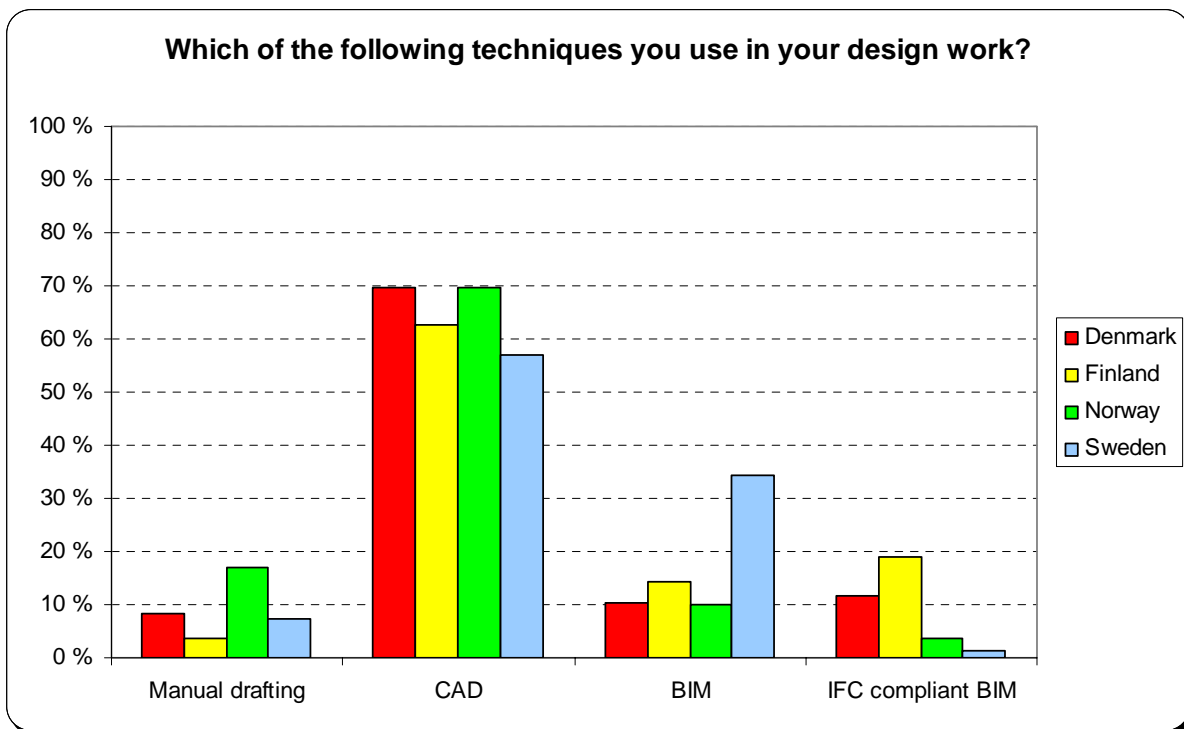


Figure 4: BIM and IFC deployment in the Nordic countries.

In Sweden, a survey, the IT-Barometer (Samuelson, 2007) was carried out during the spring 2007. The usage of BIM was approximately 28% for architects and 18% for technical consultants, see Figure 5.

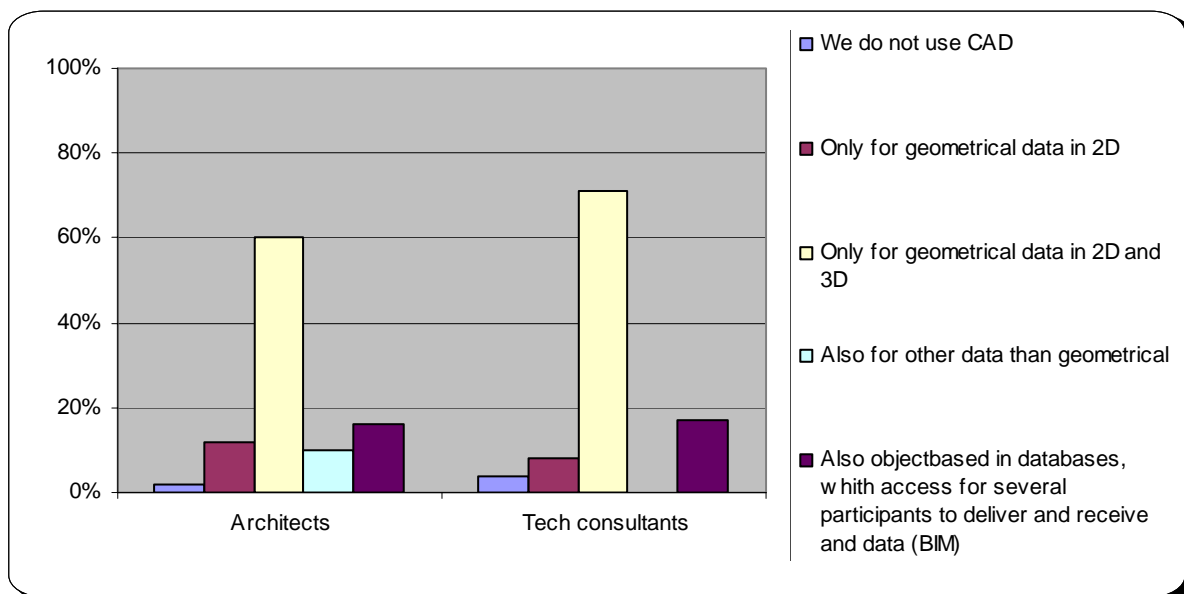


Figure 5: Proportion of usage of CAD and BIM in Sweden for architects and engineers (Samuelson, 2007)

Figure 6 illustrates the differences in usage of BIM and IFC compliant BIM between disciplines. The architects use BIM and IFC compliant BIM twice as much as the engineers. The contractors are further behind.

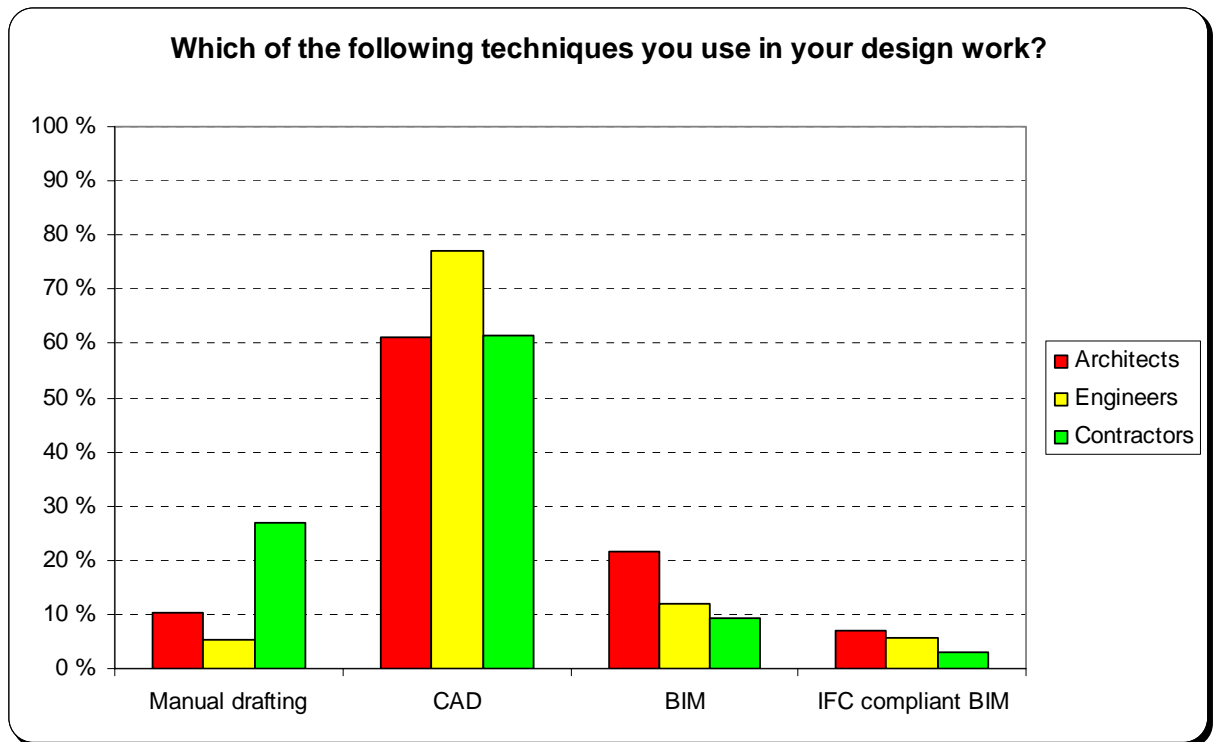


Figure 6: BIM and IFC deployment in the Nordic countries for different disciplines.

The usage of the BIM and IFC techniques based on company size is shown in Figure 7. This indicates that the smaller architectural companies are both using the new technology to a larger extent than the big ones, and at the same time are using manual techniques the most! One explanation could be that the smaller companies have shorter decision processes. They may go from sketches on paper to BIM products, without ever using the traditional CAD-products.

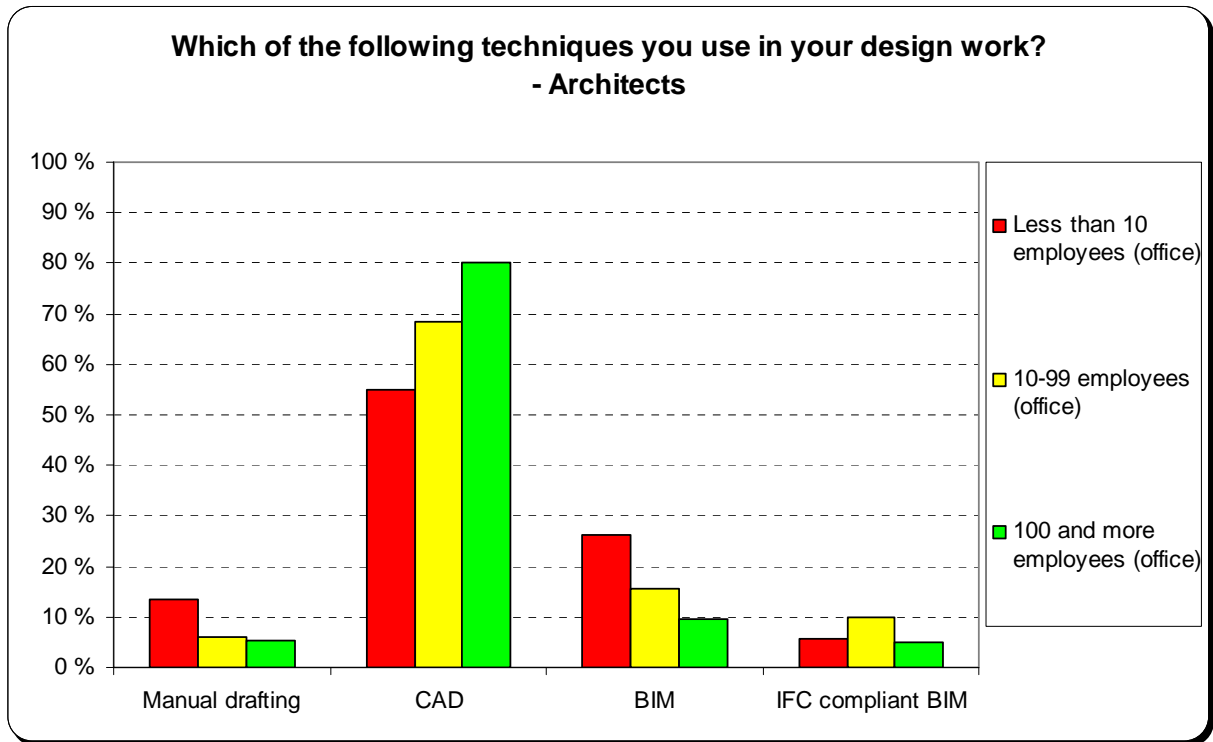


Figure 7: BIM and IFC deployment in the Nordic countries based on company size.

In Denmark a survey was carried out in the beginning of 2006 (B3D-konsortiet, 2006a). The most used BIM application among architects was ADT with approximately 35% of the firms using it, followed by Archicad, Revit and Bentley Architecture with 8 to 4% of the firms. In Figure 8 the usage of BIM in projects is shown.

Approximately 50% of the architects in Denmark are using BIM for part of some of their projects according to a survey carried out in January 2006 (B3D-konsortiet, 2006a), see Figure 8.

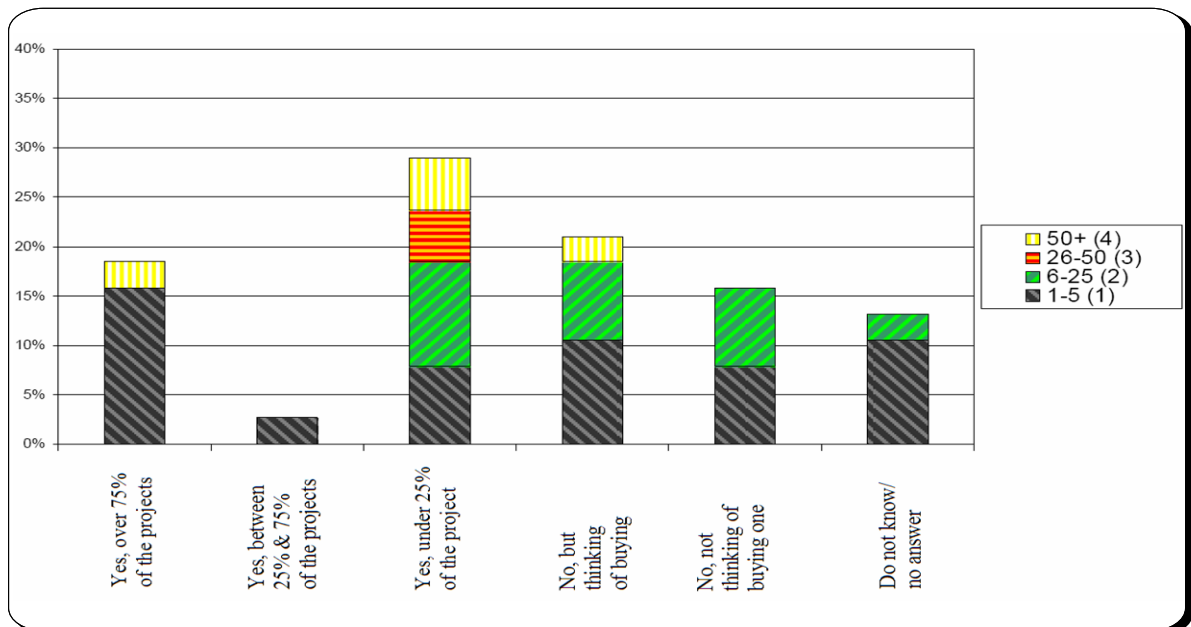


Figure 8: Is the organization (Architects in Denmark) using 3D?

Approximately 29% of the clients in Denmark are using BIM for part of some of their projects according to a survey carried out in January 2006 (B3D-konsortiet, 2006b), see Figure 9.

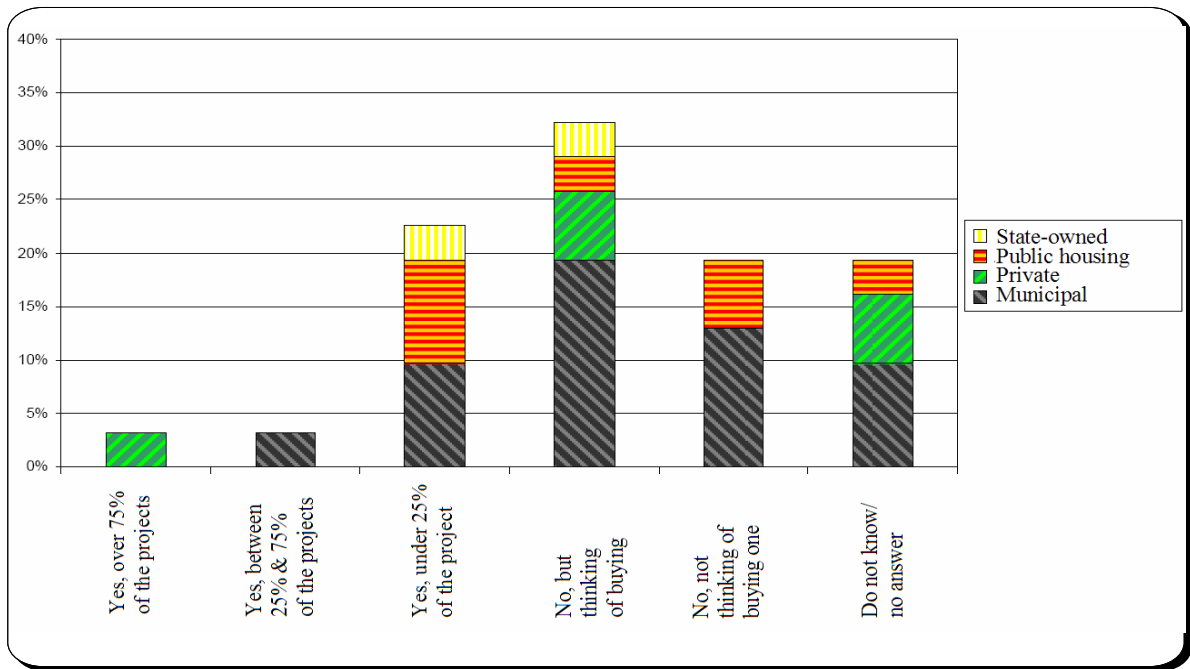


Figure 9: Is the organization (Clients in Denmark) using 3D?

Approximately 40% of the engineers in Denmark are using BIM for part of some of their projects according to a survey carried out in January 2006 (B3D-konsortiet, 2006c), see Figure 10.

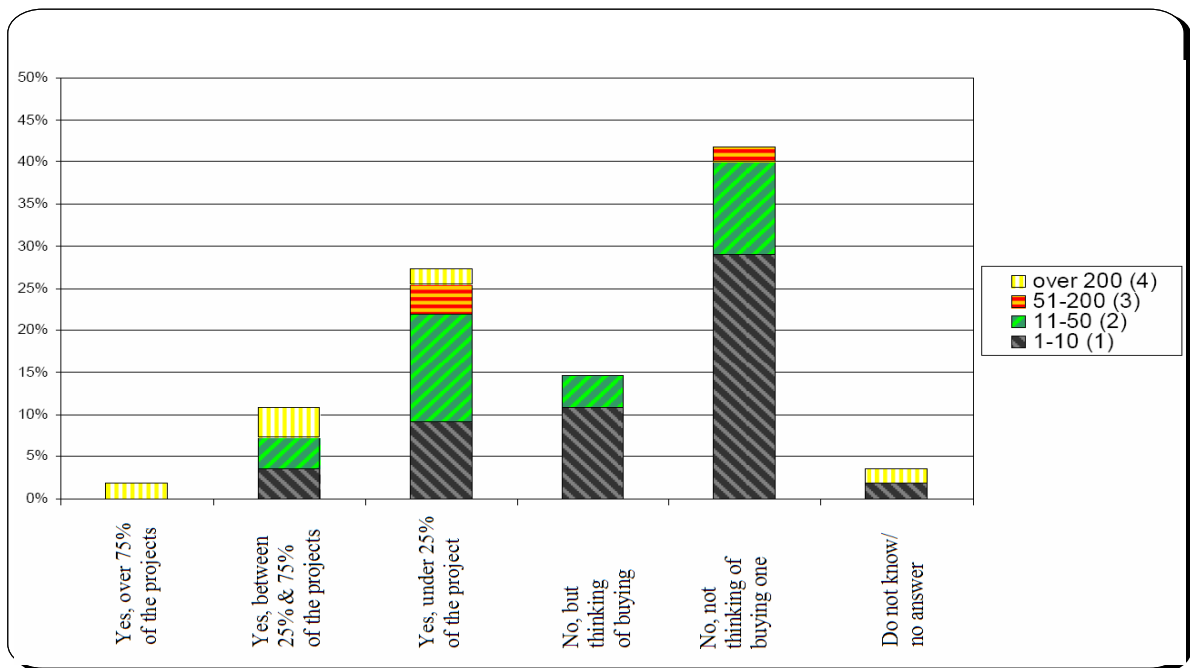


Figure 10: Is the organization (Engineers in Denmark) using 3D?

In USA the interest for BIM among architects is growing (AIA, 2006), and in 2005 approximately 10% of the companies were using BIM software in billable projects. Almost 50% of the companies with more than 50 employees used BIM in billable projects, see Figure 11.

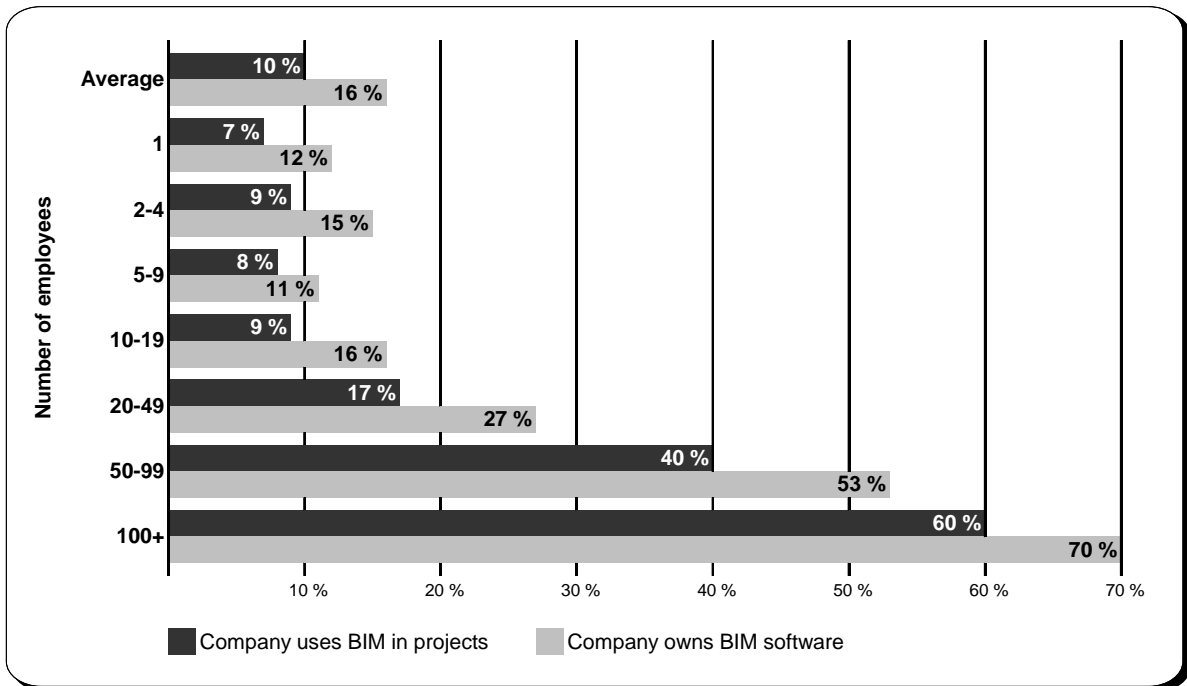


Figure 11: The usage of BIM among architects in USA categorized by company size (Data source AIA report “The Business of Architecture”, 2006).

In Finland 93% of the architect firms responding to a web survey in January 2007 (Kiviniemi, 2007a) were using BIM for some parts in their projects, see Figure 12.

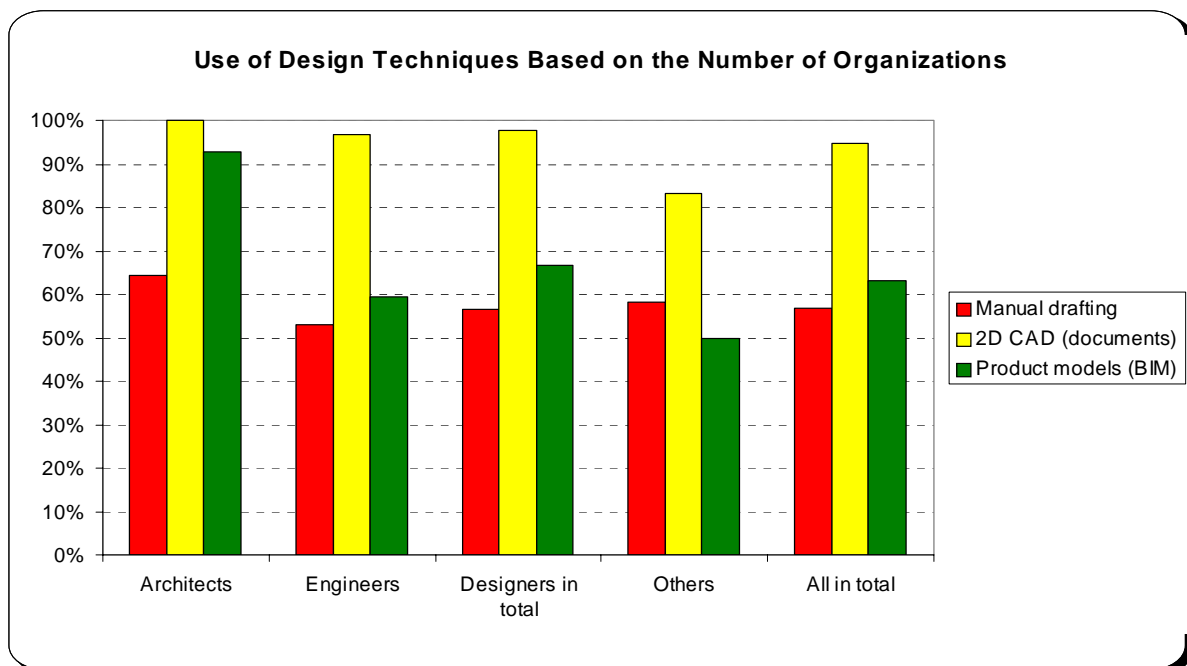


Figure 12: The usage of design techniques among architects, and engineers in Finland (Kiviniemi, 2007a).

Conclusion on the BIM awareness in industry

The industry is gradually starting to use the concept of BIM, which is seen when comparing old surveys with this one. Architects are the most adaptive to the new technology, possibly because of their tradition of working with objects and 3D for visualization. The usage also increases with the size of the company, but in the case of architects in the Nordic countries it seems that small companies are possibly more dynamic and eager to use new BIM applications. The large organizations have longer decision processes, which could explain this difference.

5.2 What is the state of art in regard of IFC compatibility?

This part of the study lists and groups existing software and software to be released in the near future, that support IFC import and/or export of the current and previous version of the IFC standard, according to the exchange specifications defined by IAI.

The current version of IFC is IFC 2x3 TC1 (Technical Corrigendum 1), but recently a technology preview has been defined, the IFC 2x3G, which is an IFC extension project within IAI. This was developed to enable a linkage between IFC and the GIS world, and also a link into reference libraries which will enable IFC based product libraries. IFC 2x3G will be the foundation for the next official release of IFC.

There are a few new entities that have to be agreed upon, and these entities are necessary for IFD (reference libraries) and the connection to GIS standards from ISO TC211.

Today's metrics for IFC exchange specifications is the view definition, which is specified by the Implementers Support Group, ISG, of IAI. This specification will in the near future expand into two parts – the IDMs which specifies the user requirements and the MVDs which specifies the technical specification of the content of an exchange.

The current certification process and the ongoing work to improve are described in the following chapters. First the certification process of today is described, and then the new one.

5.2.1 The certification process of today

Certification Workshops

A Certification Workshop only provides random examinations. More important is the preparation time before the workshop during which all available testing data has to be checked and feedback has to be provided by each participant. Therefore the effort invested into a certification has the character of quality assurance during the implementation period, rather than a quality control at one specific milestone.

With this certification method the responsibility for the quality remains at each software vendor. When accepting the certification, the vendor also assures to resolve any occurring issues in the shortest possible time frame.

The result of the certifications

The participating applications are tested against almost 250 test-cases, like the one in Figure 13 below.

Windows

19 test cases, including parametric shape representation, explicit geometry and different operation types.



Only 3 test cases (16%) passed in all applications, 5 (26%) in 8 of the 9 applications, 68% passing average.

Figure 13: Examples of windows test cases in IFC2x3 certification (Kiviniemi, 2007a)

The IFC-interfaces, i.e. import/export functions, of the tested applications are evaluated, and if they are found to reach the appropriate level of quality for starting beta-testing with data from real projects, they are accepted and will pass the 1st Step Certification. In some cases issues are detected, which are documented in the spreadsheets (Kiviniemi, 2007a).

After passing the 1st Step Certification the vendors have to commit themselves to resolve the issues as soon as possible. As a next step end-users will be invited by the software companies to test the IFC-interfaces of the participating applications under conditions of daily practice. The feedback of this beta-test will be the result of the 2nd Step Certification. This is a problem since the users do not have access to the newest versions of the IFC interfaces of the other programs being certified. Roundtrips between different software products are therefore difficult to carry out.

Implementer agreements are additional clarifications and restrictions applying to implementation of the IFC specification. The implementer agreements are defined by the relevant IAI group, the Implementer Support Group ISG and overseen by the Model Support Group MSG (also part of IAI). These agreements are today not easy to find and understand which makes them difficult to use and to influence.

5.2.2 The new certification process

The main difference between the current certification process and the new one is that the new certification process will be based on the requirements of information in an information exchange scenario, defined by IDM for that business process. These requirements are then realized by an MVD with the correct mapping to the IFC version of preference.

IDM, Information Delivery Manual - Requirements definitions

The definitions of the requirements on the information exchange are developed by the Information Delivery Manual, IDM, work which is managed by the Norwegian IAI Forum (IAI Forum Norway, 2007).

The aim of the Information Delivery Manual is to support the information exchange requirements for business processes within the building construction industry. Through IDM, the parts of the IFC model that is necessary for information exchange between identified processes can be specified.

A Process Model (PM) describes the overall process in the context of a specific domain. Examples are HVAC and Electrical engineering or Energy analysis. Business Process Modelling Notation (BPMN) is used to model the process flow for each such domain. It is however important to note that the overall process of the AEC/FM industry is not attempted to be modelled, as this is an impossible task. The aim is therefore to provide a set of Process Models which can be used, referenced or modified within a national, organizational or project scope to suit specific needs.

The following list shows all process maps identified so far:

Controls Engineering (PM) - Controls engineering deals with the overall process of planning, designing, installing, commissioning, operating and maintaining HVAC controls and automation systems for building projects.

Cost Modelling (PM) - Cost modelling is a process that attempts to bring design and price together. It has the objective of controlling costs, not just to measure them. Cost modelling therefore is defined to be the assessment and control of cost prior to the availability of knowledge of the element content of a project.

Electrical Engineering (PM) - Electrical engineering deals with the overall process of planning, designing, installing, commissioning, operating and maintaining electrical power systems for building projects. It deals with low voltage electrical installations from 12V (AC/DC) to 1000V (AC) or 1500 volts (DC) in accordance with IEC definitions. Electrical installations within scope of this process are considered to commence at a meter where the public utility supply terminates or at a transformer where voltage is stepped down to the low voltage range in scope. Incoming electrical supplies and distribution of electrical energy at higher voltages are considered to be out of scope of this process.

Energy Analysis (PM) - Energy analysis is concerned with predicting the use and cost of energy use and cost within buildings. It takes into account as input data:

Facilities Management (PM) - Facilities Management comprises many processes. For present purposes, this document is concerned with the maintenance aspect of facilities management and outlines the following processes:

- **HVAC Engineering (PM)** - HVAC engineering deals with the overall process of planning, designing, installing, commissioning, operating and maintaining heating, ventilating and air conditioning (HVAC) systems for building projects.
- **Piping Engineering (PM)** - HVAC engineering deals with the overall process of planning, designing, installing, commissioning, operating and maintaining heating, ventilating and air conditioning (HVAC) systems for building projects.
- **Structural Engineering (PM)** - Structural Engineering deals with the overall process of planning, designing, installing, commissioning, operating and maintaining structural engineering systems for building projects.

An example of the IDM documentation:

Input data for energy analysis (the use and cost of energy use and cost within buildings):

- Building layout including the layout and configuration of spaces
- Building construction including the energy performance of all construction elements including walls, floors, roofs/ceilings, windows, doors and the like
- Building usage including functional use and occupancy of spaces
- Conditioning systems including lighting, HVAC, etc.
- Utility rates provided by the user
- Weather data

Examples of output results:

- Assessment of the space and building energy performance for compliance with regulations and targets
- Overall estimate of the energy use by space and for the building and an overall estimate of the energy cost
- Time based simulation of the energy use of the building and time based estimate of utility costs
- Lifecycle estimate of the energy use by space and for the building and a lifecycle estimate of the energy cost

Examples of analysis for this process map:

- Setting comfort criteria for spaces including minimum and maximum required indoor air temperatures (summer and winter), minimum fresh air requirements
- Simple heat loss/gain calculations based on minimal data provision
- Detailed heat loss/gain calculations using well defined analytical methods
- Energy labelling calculations using analysis methods mandated by legislation
- Analysis of energy consumption in meeting the building energy demands
- Optimization of energy performance related to fuel type for lifecycle cost, environmental impact issues, comfort aspects

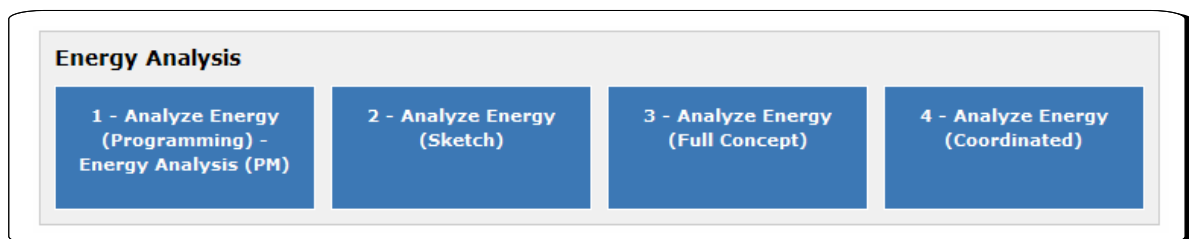


Figure 14: The process map for this high level is shown in the figure below.

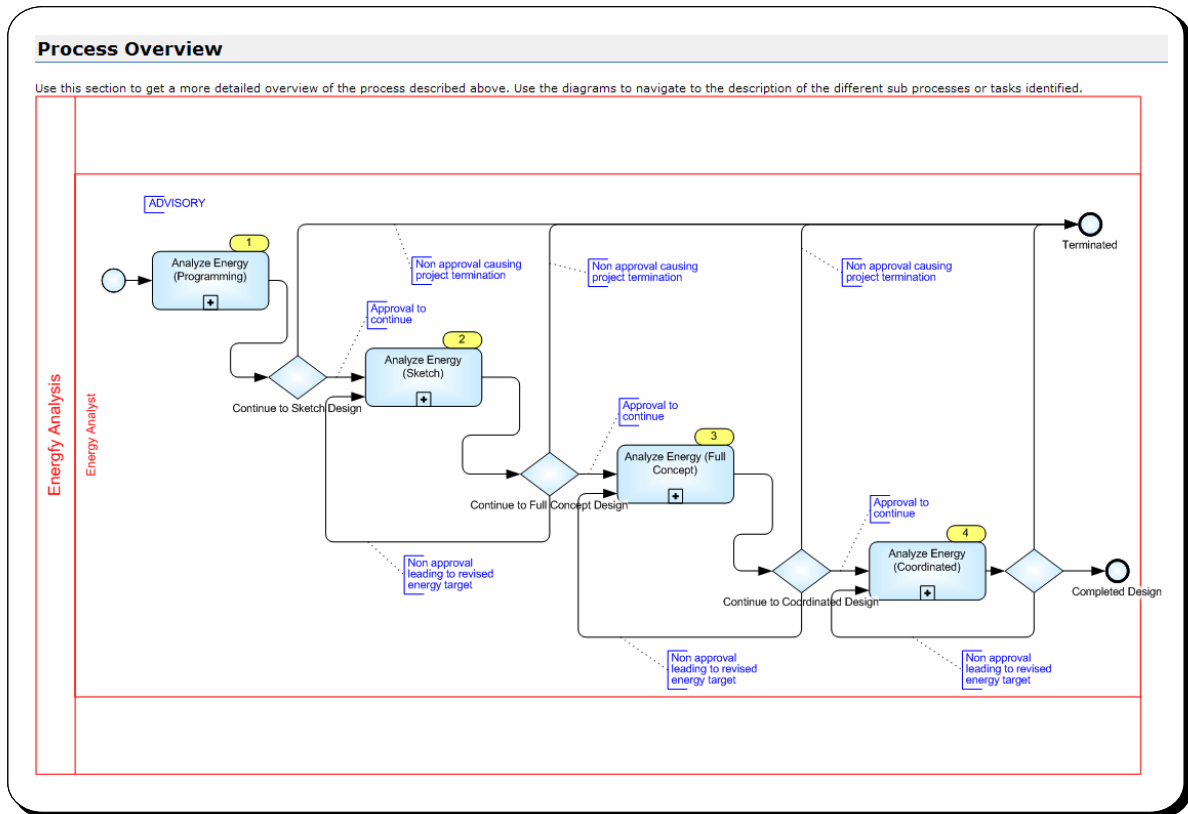


Figure 15: IDM process map.

Model View Definitions

The development of the new exchange specifications, the Model View Definitions, (IAI, 2007a), is now ongoing in collaboration with the IDM development. In the future there will be a one to one relation between the requirements on information required in a process and the technical specification for the exchange, both on the generic level and on the specific format version level, e.g. for IFC 2x3.

The ongoing work is listed below in Table 2. Today there are no official and IAI approved MVDs available.

Reference	Name	Owner	Editor
VBL-004	Architectural design to quantity take-off - level 1	Virtual Building Laboratory @ TUT	Jiri Hietanen
VBL-005	Architectural design to quantity take-off - level 2	Virtual Building Laboratory @ TUT	Jiri Hietanen
VBL-006	Architectural design to quantity take-off - level 3	Virtual Building Laboratory @ TUT	Jiri Hietanen
VBL-002	Architectural design to structural design	Virtual Building Laboratory @ TUT	Sakari Lehtinen

VBL-007	Architectural design to thermal simulation	Virtual Building Laboratory @ TUT	Jiri Hietanen
ISG-001 IAI	Extended coordination view	Implementers Support Group	Thomas Liebich
VBL-003	Extensibility	Virtual Building Laboratory @ TUT	Jiri Hietanen
GSC-001	Facility management inventory data take-over	IAI German Speaking Chapter	Thomas Liebich
GSA-001	GSA concept design submissions	US General Service Administration	Richard See
HUT_HVAC-001	Indoor climate simulation to HVAC design	HVAC-laboratory @ Helsinki University of Technology	Mika Vuolle
VBL-001	Structural design to structural analysis	Virtual Building Laboratory @ TUT	Sakari Lehtinen

Table 2: Ongoing definition and standardization of Model View Definitions within IAI (2007a).

The work with IDMs and MVDs has now merged, and there is now a common plan for the future developments.

5.2.3 Availability of IFC2x3 compliant software

The previous versions of IFCs can be accessed via the IAI International web site (IAI, 2007b). They can all be seen as development steps on the road to a stable information model, and have proved useful in their own right. The missing part has always been the exchange specifications, which are still under development, both to form and content. The IDM, Information Delivery Manual and MVD, Model View Definition initiatives are aiming at resolving this issue.

The current version is IFC 2x3 and the applications are now being certified for the “Extended Coordination View”, i.e. the today only defined view. It has a CAD oriented view on the exchange, which is geometry focused. The Implementers Support Group, ISG, has the definitions and results on <http://www.iai.fhm.edu/>.

Certified Software

The following applications, see Table 3, are expected to be on the market already or in the near future, and they have passed the IFC2x3 1st and 2nd Step Certification for the “Coordination View Definition”:

IFC 2x3 Stage 2 certification = Certified Software

Product	Discipline	Company	Exchange direction	Certification date	Organization address
ACTIVE3D v4.0	A	Archimen Groupe	Import	13.03.2007	www.active3d.net
ALLPLAN 2006.2	A	Nemetschek	Import / Export	13.03.2007	www.nemetschek.com

ArchiCAD 11	A	Graphisoft	Import / Export	13.03.2007	www.graphisoft.com
AutoCAD Architecture 2008 sp1	A	Autodesk	Import / Export	13.03.2007	www.autodesk.com
Bentley Architecture 8.9.3	A	Bentley Systems	Import / Export	13.03.2007	www.bentley.com
DDS-CAD 6.4	A	DDS	Import / Export	13.03.2007	www.dds-cad.com
Facility Online	FM	Vizelia	Import	22.05.2007	www.vizelia.com
MagiCAD	HVAC	Progman	Export	22.05.2007	www.progman.fi
Revit Architecture 2008 sp1	A	Autodesk	Import / Export	13.03.2007	www.autodesk.com
Solibri Model Checker	All	Solibri	Import	13.03.2007	www.solibri.com
TEKLA Structures 13.0	S	TEKLA Corporation	Import / Export	13.03.2007	www.tekla.com

Table 3: IFC 2x3 certified software

The certification is mainly testing IFC import. The export is limited to the test files created, and as they are not clearly documented with respect to structure nor purpose, it is possible that the cases are selected based on the known capabilities of each exporting software, and thus not testing the potential problem areas (Kiviniemi, 2007b).

The available certification documentation does not include information of property sets, and fundamental characteristics like classification, type and literal are neither specified in view definitions nor tested in the certification. The same uncertainty is valid for coordinates and units as the test cases are too isolated and limited to identify the errors. Some of the tests are evaluated only by the human eye, i.e. that the graphics look alright on the screen.

In

Figure 16, the results look good on average, but one does not know what is working and what is not working. Some test cases represent very common geometries in buildings and other represent rather unusual ones, which makes it difficult to understand the ability of one application to exchange IFC data in real projects (Kiviniemi, 2007b). The certification was done for the IFC 2x3 Extended Coordination View, the only one defined according to the old certification process.

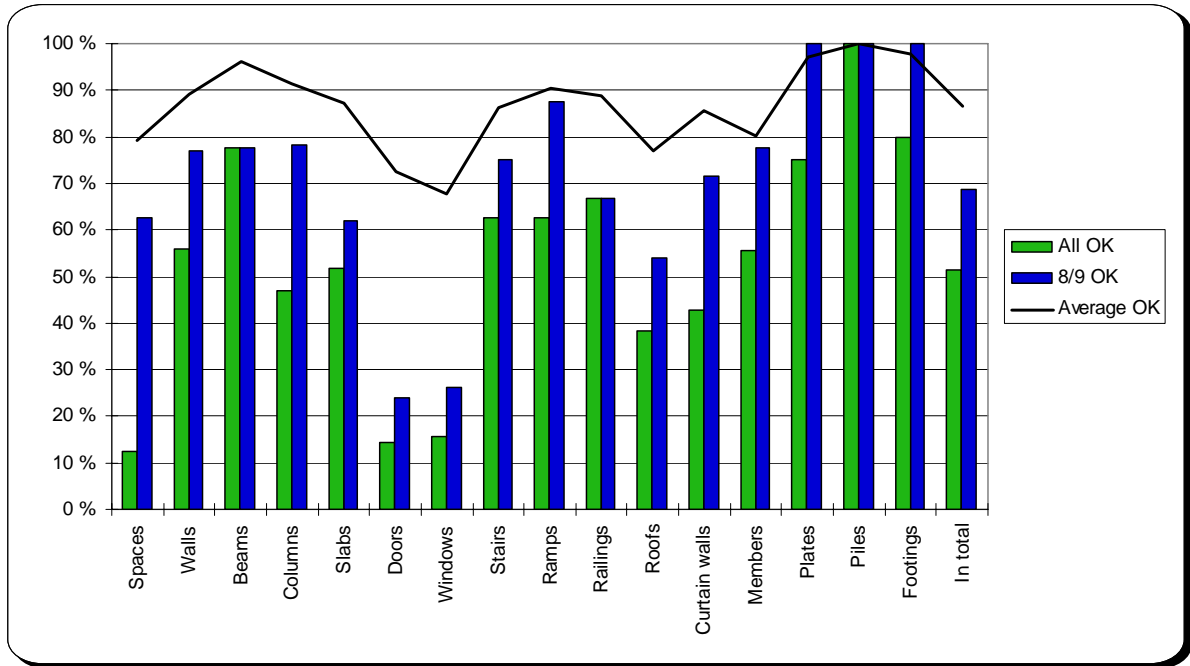


Figure 16: Results of certification by element types for the 6th certification work shop in Espoo May 2007. All OK denotes the percentage of test cases met by all the 9 applications, and 8/9 denotes the percentage of test cases which at least 8 applications have passed. Average means the average number of test cases passed in each category (Kiviniemi, 2007b).

In Figure 17 the results of how well the different applications have passed the test in average are shown. These results have improved since previous certifications, but in some of the results there are holes for one or more categories of building elements, as shown in Table 4.

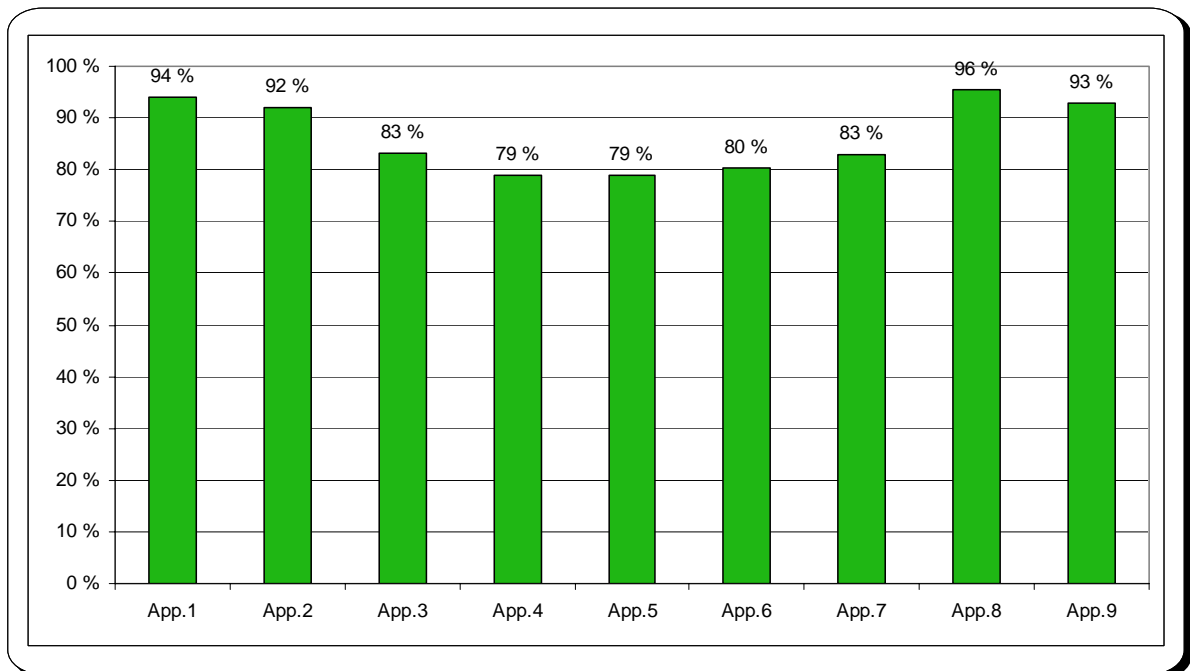


Figure 17: Average results by software – the 9 certified in March 2007 (Kiviniemi, 2007b).

For some applications there are very low figures for one or more building element categories, like spaces, doors and windows. This means that there could be great difficulties when e.g. exchanging doors between two applications with poor results in this category.

	App.1	App.2	App.3	App.4	App.5	App.6	App.7	App.8	App.9
Spaces	100 %	88 %	75 %	75 %	75 %	25 %	88 %	100 %	88 %
Walls	92 %	89 %	85 %	85 %	85 %	93 %	85 %	95 %	92 %
Beams	97 %	94 %	100 %	97 %	94 %		94 %	97 %	94 %
Columns	94 %	100 %	100 %	81 %	97 %	72 %	94 %	97 %	88 %
Slabs	100 %	100 %	79 %	76 %	76 %	86 %	86 %	93 %	90 %
Doors	90 %	90 %	71 %	43 %	43 %	52 %	67 %	100 %	95 %
Windows	74 %	84 %	63 %	58 %	32 %	53 %	58 %	95 %	95 %
Stairs	100 %	75 %	63 %	88 %	75 %	100 %	88 %	88 %	100 %
Ramps	100 %	100 %	88 %	75 %	88 %	88 %	75 %	100 %	100 %
Railings	100 %	83 %	83 %	83 %	83 %	83 %	83 %	100 %	100 %
Roofs	92 %	92 %	62 %	62 %	69 %	69 %	62 %	92 %	92 %
Curtain walls	100 %	100 %	71 %	57 %	71 %	100 %	71 %	100 %	100 %
Members	100 %	78 %	78 %	78 %	67 %	67 %	78 %	78 %	100 %
Plates	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	75 %
Piles	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %	100 %
Footings	100 %	100 %	80 %	100 %	100 %	100 %	100 %	100 %	100 %
In total	94 %	92 %	83 %	79 %	79 %	80 %	83 %	96 %	93 %

Table 4: Results by software and building element (House Partner is not certified for import).

However, it is important to emphasize that the certification of all applications was conditional. The final quality of the certified IFC 2x3 compatible software can be judged only after the shipping products are publicly available and possible corrections have been made (Kiviniemi, 2007b).

Model servers, middleware, and toolboxes

In addition to the above applications there are middleware and model servers that are working for the IFC 2x3 specification and all the previous versions, but they are not certified as certification is only done for specific views. The nature of the middleware and model servers is that they are handling the whole IFC model. The toolboxes are used to do mapping between IFC files and the applications.

IFC toolboxes (generic toolbox)

- EPM Technology AS
EDMdeveloperSeat
EDMmodelMigrator
EDMmodelConverter
- Eurostep AB
IFC Classic Toolbox
IFC Active Toolbox
- PDTEC GmbH
ECCO Toolkit
- SECOM CO., LTD
IFCsvr ActiveX Component
- STEP Tools, Inc.
ST-Developer v10

IFC toolboxes (high level API)

- Eurostep AB
SABLE Server
- Link360
B-UML 2x2 2005-Visio Edition for IFC 2x Edition 2
- Olof Granlund Oy
BSPRO COM-Server for IFC Files
- TNO Env. & Geosc.
IFC Engine DLL

• Octaga AS	Octaga Modeller RAD Kit
<i>IFC model servers</i>	
• EPM Technology AS	EDM Server EDMmodel Server for IFC
• Eurostep AB	Eurostep Model Server
<i>IFC geometry viewers</i>	
• Data Design System	DDS IfcViewer
• Forschungszentr Karlsruhe	IfcStorey View IfcViewer
• Octaga AS	Octaga Modeller
• TNO Env and Geosciences	TNO Engine Viewer
• ISPRAS, Russia	IFC/VRML Converter
<i>IFC file browsers</i>	
• STEP Tools, Inc	STEP File Browser (part of ST-Developer)
• TNO Env and Geosciences	IFC Engine Basic
<i>IFC file validators</i>	
• EPM Technology AS	EDMmodel Checker
• Express Engine Team	Express Engine
• Forschungszentr Karlsruhe	IfcObject Counter
• STEP Tools, Inc	STEP Conformance Checker (part of ST-Developer)
• ISPRAS, Russia	SemanticSTEP Checker SemanticSTEP Generator
<i>IFC schema development tools</i>	
• EPM Technology AS	EDMvisual Express
• Eurostep AB	Graphical Express Graphical Instance
• STEP Tools, Inc	EXPRESS Compiler and EXPRESS-G Tools
• PDTech GmbH	ECCO Toolkit Instance Explorer
Other IFC related tools (converter, etc.)	
• NIST	CIS/2 to IFC Translator

First step of certification

Full certification is only achieved after successful completion of stage 1 and stage 2 in the certification process. As described above stage 1 requires that the software tools can import a number of test cases, which in the coordination view are containing a set of building elements that should be tested. After the stage 1 certification a longer test period is anticipated, during which real project tests are to be carried out. In Table 5 below, the candidates for the final certifications are found.

IFC 2x3 Stage 1 certification = a test period is expected

Product	Discipline	Company	Exchange direction	Certification date	Organization address
ACTIVE3D	A	Archimen Groupe	Import	29.06.2006	www.active3d.net
ALLPLAN	A	Nemetschek	Import / Export	29.06.2006	www.nemetschek.com
ArchiCAD	A	Graphisoft	Import / Export	29.06.2006	www.graphisoft.com
AutoCAD Architecture	A	Autodesk	Import / Export	24.11.2007	www.autodesk.com
Bentley Architecture	A	Bentley Systems	Import / Export	29.06.2006	www.bentley.com
DDS-CAD	A, HVAC	DDS	Import / Export	12.03.2007	www.dds-cad.com
Facility Online	FM	Vizelia	Import	21.05.2007	www.vizelia.com
IFC for Oracle CADView-3D	A	Norconsult	Import	21.05.2007	www.norconsult.com www.oracle.com
MagiCAD	HVAC	Progman	Export	12.03.2007	www.progman.fi
Revit Architecture	A	Autodesk	Import / Export	29.06.2006	www.autodesk.com
SCIA ESA-PT	All	Nemetschek	Import	21.05.2007	www.scia-software.de
Solibri Model Checker	All	Solibri	Import	29.06.2006	www.solibri.com
TEKLA Structures	S	TEKLA Corporation	Import / Export	29.06.2006	www.tekla.com
VectorWorks	All	Nemetschek NA	Import / Export	21.05.2007	www.nemetschek.net

Table 6: IFC 2x3 stage 1 passed applications.

The previous IFC versions, still in use, are listed below in Table 7 and Table 8.

IFC 2x2 certified Software

Product	Discipline	Company	Exchange direction	Certification date	Organization address
ArchiCAD	A	Graphisoft	Import / Export	29.10.2004	www.graphisoft.com
FORNAX ePlan Checker	All	Novasprint Citynet	Import / Export	29.10.2004	www.novasprint.com
Revit Building	A	Autodesk	Export	18.11.2005	www.autodesk.com

Table 7: IFC 2x2 certified software.

IFC 2x certified Software

Product	Discipline	Company	Exchange direction	Certification date	Organization address
ACTIVE3D	A	Archimen Groupe	Import	07.05.2003	www.active3d.net
ALLPLAN	A	Nemetschek	Import / Export	07.05.2003	www.nemetschek.com
ArchiCAD	A	Graphisoft	Import / Export	07.05.2003	www.graphisoft.com
IFC2x Utility für ADT	A	Inopso	Import / Export	07.05.2003	www.inopso.de
Bentley Architecture	A	Bentley Systems	Import / Export	07.05.2003	www.bentley.com
BSPro / RIUSKA	A, HVAC	Olof Granlund	Import / Export	07.05.2003	www.granlund.fi
ElectroPartner / HVACPartner	FM	Data Design Systems	Import / Export	07.05.2003	www.dds-cad.co.uk
FORNAX ePlan Checker	HVAC	Novasprint Citynet	Import	07.05.2003	www.novasprint.com
Facility Online	A	Vizelia	Import / Export	07.05.2003	www.vizelia.com
Solibri Model Checker	All	Solibri	Import	07.05.2003	www.solibri.com

Table 8: IFC 2x certified software.**5.2.4 Free Tools**

Beside commercial software packages there are also free tools that support IFC. Tools include viewers to visualize an IFC model, often in conjunction with showing the project structure and the properties of objects, text browser to show the original IFC file for debugging, converter to convert project data from/to other file formats, and syntax checker to check the formal validity of IFC files.

Free IFC tools for visualizing, checking and translating IFC files**Data Design System**

- DDS IFC Viewer, a viewer for IFC Data.
- DDS IFC Reader, drag & drop IFC files and examine

Forschungszentrum Karlsruhe

- IfcStoreyView, a viewer for IFC Data.
- IfcViewer, a viewer for IFC Data.
- IfcWalkThrough, an application for virtually walk through IFC building models.
- IfcObjectCounter, an IFC file checker

G.E.M. Team Solutions

- IfcQuickBrowser, Text-browser for large IFC files. The IFC file is displayed in a tree structure.

Nemetschek AG

- Nemetschek IFC Viewer, free 3D IFC Viewer, supports IFC format and XML IFC Format

NIST

- CIS/2 to IFC Translator, CIS/2 is the product model for structural steel CIS/2

Solibri

- Solibri IFC Optimizer, a tool for optimizing/compressing IFC files
- Solibri Model Viewer, a viewer for IFC and Solibri Model Checker Data

TNO Building Research

- Ifc Engine Series, a set of tools for IFC Data.
- Ifc Engine Basic, a purely data viewer for IFC Data.
- Ifc Engine Viewer, a data + 3D viewer for IFC Data.
- Ifc Engine DLL, a toolbox for IFC Data
- Ifc Engine OCX, an ActiveX component with toolbox for IFC Data

5.3 What is the state of art in regard of modelling standards/ guides in different countries which enables exchange of BIM in consensus?

Several countries are working on national BIM standards, and this study lists and describes the most important ones. One observation is that they are on different levels both on object level and stage. Some of them require IFC models, but do not say anything about the content.

USA - nBIMs

The National BIM Standard project by National Institute for Building Sciences (NIBS, 2007).

Reference standards in the NBIM Standard provide the underlying computer-independent definitions of those entities, properties, relationships, and categorizations critical to express the rich language of the building industry. The reference standards selected by the NBIMS are international standards that have reached a critical mass in terms of capability to share the contents of complex design and construction projects. The NBIM standard includes two candidate reference standards; the IAI Industry Foundation Classes (IFC) and OmniClass™.

The IFC data model consists of definitions, rules, and protocols that uniquely define data set which describe capital facilities throughout their lifecycle. These definitions allow industry software developers to write IFC interfaces to their software that enable exchange and sharing of the same data in the same format with other software applications, regardless of individual software application's internal data structure. Software applications that have IFC interfaces are able to exchange and share data with other application that also have IFC interfaces.

The OmniClass Construction Classification System (known as OmniClass or OCCS) is a multi table faceted classification system designed for use by the capital facilities industry and includes some of the most commonly used taxonomies in use in that industry. OmniClass is applicable for organizing many different forms of information important to the NBIM Standard, both electronic and hard copy, and can be used in the preparation of many types of project information as well as for communicating exchange information, cost information, specification information, and other information that is generated during the services carried out through the facility lifecycle.

Norway – BIM manual with experiences from the HIBO Statsbygg project

Statsbygg has started the work on a BIM manual based on the experiences from the HIBO (Bodø) project up to today. The plan is to have a 0.9 alpha version at the end of 2007. The BIM manual is to be delimited to the new Norwegian standard NS8353 CAD manual, and possibly coordinated with the developing nBIM standard in USA. This will in the first stage be a manual for Statsbygg and then for Norway.

Finland - Guidelines

The ProIT-project (an R&D project between years 2003 – 2006 with wide industry basis) developed a number of guidelines on product modelling. Later on the work was organised into a co-operative committee under the Building Information Foundation (RTS).

The guideline publications of ProIT include:

- Product modelling in construction projects – General principles (in Finnish)
- Product modelling in architectural design (in Finnish)
- Product modelling in structural design (in Finnish)
- Product modelling in building services design (in Finnish; in the process of publication).

The ProIT guidelines provide introduction to product modelling, in general but also applied to a specific discipline, and provide some general guidelines on how to do modelling. However, the guidelines don't define detailed data exchange specifications.

Germany - BIM/IFC user guide (IFC Anwenderhandbuch - written in German)

Describing the use of Building Information Models in the area of architecture and building services (including test files) (buildingSMART Germany , 2007)

The German user guide has defined the lowest level of information exchange for Architecture, HVAC and Facility Management. It specifies which properties are mandatory, optional or project possible. The properties are explained and also specified to domain and other restrictions.

USA - Building Information Modelling - Virtual Design & Construction

The Associated General Contractors of America (AGC, 2007.)

The future of the design and construction industry is going to be driven by the use of technology. The best example emerging today is the use of three-dimensional, intelligent design information, commonly referred to as Building Information Modelling (BIM). BIM is expected to drive the construction industry toward a "Model Based" process and gradually move the industry away from a "2D Based" process. This "Model Based" process where buildings will be built virtually before they get built out in the field is also referred to as Virtual Design and Construction (VDC). "The Contractors' Guide to BIM: Edition 1" generally introduces the subject of Building Information Modelling (BIM). As this guide identifies, BIM is a tool that enables our industry to more efficiently operate in new and increasingly expeditious ways. Regardless of the extent to which you decide to participate in BIM, simply getting started and understanding the topic will keep you in touch with a subject that is probably the most revolutionizing tool to come into the design and construction industry in recent times.

Denmark - Guidelines for Working with 3D CAD Applications

As a result of the Digital Construction program, initiated by the Danish Enterprise and Construction Authority, a suite of guidelines regarding 3D have been developed. There are both guidelines concerning setting up requirements and how to fulfil the requirements in file and database based CAD/BIM applications. Four guidelines are available in English: 3D CAD Manual 2006, 3D Working Method, 3D Working Methods – print guidelines and Layer- and Object Structures 2006.

The full English versions are available at www.detdigitalebyggeri.dk (under "Digital Construction in English", where a general introduction and reflection on "Digital Construction" can also be found). Furthermore a short English summary is available at IAI Forum Denmark.

Singapore

Singapore has since 1997 been promoting and later on also requiring the use of BIM for various kinds of approvals like building plan approvals and fire safety certificates (AECbytes, 2005). The CORENET e-PlanCheck defines Singapore's Automated Code Checking System and several authorities in Singapore are participating in the e-submission system, which requires the use of BIM and IFC. The BIM Guideline "Integrated plan checking" is now in its final definition phase.

Korea

Researchers at a major Korean University are working on national BIM Guidelines.

Guidelines on IFC capabilities of commercial software systems

- Reference Guide for the ArchiCAD IFC support
- ArchiCAD IFC Guide - version1 (In Swedish – draft version)
- Documentation for the IFC-Utility 2x for ADT developed by Inopso
- BIM/IFC Guideline (Leitfaden - written in German) for ALLPLAN IFC support

5.4 How many major clients demand object modelling in 3D in a significant part of their construction works and what is their (approximate) market share?

There are two categories of clients, those who have defined requirements and those who will do it soon.

The first category includes clients like GSA in the US, Senate Properties in Finland, Statsbygg in Norway and Public works in Denmark, that are already in the process to publicly state their BIM requirements, and also more specific IFC requirements, for certain phases of the building, construction and FM processes.

Finland - Senate Properties

Senate Properties has assessed product model technology to be sufficiently ready for putting to use in ordinary project work, and the company has decided to require models meeting the IFC standard in its projects as of 1st October 2007 (Senate Properties, 2007).

Senate Properties will draw up detailed modelling guidelines by 1 September 2007. The guidelines will specify the data content requirements for models to the participants in the project at each stage of the design. The guidelines will comply with the main lines specified in the ProIT project, applied to decisions to be made in Senate Properties' investment process. In the first phase, all design software packages which have passed IFC 2x3 certification may be used for modelling.

Denmark - Governmental projects

"Byggherrekravene" is a set of requirements for the governmental sector (Det Digitale Byggeri, 2007).

Starting January 2007, the architects and other designers as well as the contractors participating in governmental construction projects, are able to manage a series of new digital routines, methods and tools. More construction projects will in the coming years have to comply to requirements according to the definitions of "Det Digitale Byggeri" (the digital construction).

One part of the requirements is related to a new common classification system, but it is so far up to the clients to decide whether the system should be used or not. (Det Digitale Byggeri, 2006)

During the Digital Construction program a number of reports and guidelines have been developed in order to make it easier for the industry to fulfill the requirements and in general adopt the technology. In general BIPs has adopted the results from the Digital Construction project and are promoting the new working methods to all companies in the Danish Construction Industry.

3D models – For projects above 5.5 million € 3D models in the design have to fulfill a number of requirements regarding content, information levels for the various phases, which are to be defined by the client for the individual project. The models have to be exchanged using the IFC format, if nothing else is decided.

In Denmark some municipalities and private clients are demanding object based modelling, but the volume is small compared to the total construction market in Denmark.

Norway – Statsbygg

Statsbygg has decided to use BIM for the whole life-cycle of their buildings (Statsbygg, 2007). In 2007 at least 5 projects will have to use BIM. In 2010 all the projects will use IFC/IFD based BIM.

USA – GSA, General Services Administration

All new and major modernization projects in Fiscal Year (FY) 2007 and beyond that receive design funding are required to submit a spatial program BIM for Final Concept Approval (GSA, 2007).

At a minimum, architects and engineers are required to have the following objects in a valid 3D geometry representation:

- Wall objects
 - Openings
 - Door objects
 - Window objects
- Slab objects
- Column objects
- Beam objects

In addition, spaces must include the following information for Space objects over 9 square feet:

- GSA BIM Area (formerly GSA Net Area in previous versions)
- Space Name (in accordance with approved space names in appendix C)
- Space Number
- Occupant Organization Name
 - GSA STAR Space Type
 - Full-Floor Space

In addition to these requirements on individual space objects, architects and engineers must also create a full building floor space (with a space name and number) for every floor that represents the GSA Design Gross Area.

There may be additional zone requirements, depending upon the type of project (e.g., courthouses, historic buildings). Architects and engineers must consult with the GSA project

team to determine if additional requirements are necessary. They are also encouraged to provide additional information above the minimum requirements.

The BIM deliverables required in the Preliminary and Final Concept submission include:

- A single BIM file in IFC 2x2 format (preferred) or IFC 2x format.
- BIM file(s) in the native format of the BIM-authoring application(s).

USA – US Coast guard

Web-Enabled BIM projects

5.5 How many clients demand IFC exchange in their construction works, and what is their (approximate) market share?

Finland

One leading actor is now demanding IFC.

- Senate Properties
 - 2006 – 308 million Euro investment in new projects and investments – total portfolio 5.6 billion Euros, revenue 578 million Euros

Denmark

Governmental projects have only a small parts of the total property area. The impact on the market created by the requirements on IFC is however big.

- The Palaces and Properties Agency
 - The agency provides the Danish state with attractive offices in flexible buildings. The portfolio of office properties includes some 550,000 m2 worth a total of DKK 4.3 billion. Another approx. 450,000 m2 are leased and administered by the agency on behalf of the state.
- The Danish University and Property Agency
 - The agency portfolio consists of 1.640.773 m2 buildings in 2006
- Defence Construction Service
 - The agency portfolio consists of 2.900.000 m2 of buildings in 2007
- Gentofte Municipality, others Municipalities are adopting the requirements from the Digital Construction project in Denmark.
- KLP Ejendomme

Norway

- Statsbygg

USA

- GSA, General Services Administration

Sweden

Today there is no IFC demand from clients.

The Netherlands

Today there is very little IFC demand from clients.

5.6 How many clients prescribe specific modelling standards / guidelines in their construction works?

Several major clients like GSA in the USA, Senate Properties in Finland and Statsbygg in Norway are right now defining their first modelling standards/guidelines.

In Denmark the public clients have already stated their requirements and some of them are part of the law.

Finland

- Senate Properties

Denmark - Governmental projects

- The Palaces and Properties Agency
- The Danish University and Property Agency
- Defence Construction Service

Norway

- Statsbygg

USA

- GSA, General Services Administration

Sweden

No requirements from clients.

The Netherlands

No requirements from clients.

5.7 To what degree do universities and other public teaching facilities educate people in BIM technology

The on-going pioneering multidiscipline courses in Australia are now spreading to other countries. Several modelling courses are also given on a regular basis at the major universities in US (e.g. Stanford), Germany (Munich), Denmark, Finland and Sweden (Luleå Technical University) and many other countries. Also several public teaching facilities are giving shorter courses in this field. Modelling courses are relatively common while training in exchange scenarios by using IFC is still not common. This study lists the most BIM and IFC related courses out of all these courses and trainings on offer.

University Courses on Building Information Models

Table 9 is based on a list from Peter Scuderi from November 2006 (Scuderi , 2006).

Country	University	Key academic staff	Course Name and Description	Comments
Australia	University of New South Wales	Jim Plume	Computers & Information Technology (introduces concept of BIM/product modelling and interoperability)	Year 1 general intro to computing for all disciplines in the Faculty
			Computer Aided Design (CAD is taught as a BIM process: building a 3D model and extracting the 2D drawings)	Year 2 course for architecture and interior architecture.

Erabuild

			Design Collaboration using BIM (around 10 different IFC compliant applications are used to support up to four multidisciplinary design teams working on a building project)	Senior cross-disciplinary elective course
			Object Based CAD Modelling (postgraduate coursework course on the principles of BIM and interoperability using IFC)	Mainly postgraduate students.
			There is also some coverage of BIM and IFC concepts in advanced computing courses in the Building Construction Management programs at both UG and PG level.	
	Queensland University of Technology	Debbie Smit	Computer Studies	compulsory subject for Year 2 students
Current Construction Issues			an elective subject for Year 4 students	
These subjects are part of the Construction Management course. They focus on interoperability in the construction industry, and it's relationship to construction management.				
Denmark	Aalborg University	Kaj A. Jørgensen, Thomas Ditlev Petersen, Svend Hvid Nielsen	Product Modelling and Product Configuration (1 ects) (Currently in Danish)	
			Product Data and Product Models (2 ects) (Currently in Danish)	
	Copenhagen University College of Engineering	Ass. Prof. Søren Wind Ass. Prof. Lisbeth Lindbo Larsen	Digital building design, 5 ECTS (in Danish): Projectweb, BIM, IFC, digital invitation for bids.	
			Process planning under building construction, 10 ECTS (in Danish): Projectweb, BIM, IFC, Lean construction, product data, Facility Management	
Finland	Tampere University of Technology / Dept of Civil engineering	Prof. Jarmo Laitinen	Information Models in the Construction Industry	Some other modelling software courses exist also
	Helsinki University of technology / Dept. of Civil and environmental engineering	Prof. Juhani Kiiras	Information technology in construction	
	Helsinki University of technology / Dept of architecture	Architect Marko Rajala	Information management for architect	
Norway	Norwegian University of Science and Technology (NTNU)	Prof. Knut Einar Larsen, Ass. Prof. Birgit Sudbø, Prof. Tore Haavaldsen	Prefabrication of buildings based on digital models	A section of the course includes topics related to BIM and IFC
			Virtual Building	Issues related to digital 3D models in architectural design and analysis.
			Design of Buildings and Infrastructures	Introduces BIM and IFC in planning and design.
Sweden	Luleå University of Technology	Prof. Thomas Olofsson Dr. Rogier Jongeling	Virtual Construction in collaboration with the ITC Euromaster program. The course provides an overview of planning and virtual design methods for construction, with a special focus on simulations with 4D CAD technology (3D CAD + time). IFC is covered by the course.	The course is in the ITC Euromaster program for the final year at the university.

Singapore	National University of Singapore	Dr TEO Ai Lin, Evelyn	Introductory lesson on IFC Bachelor of Science (Building) Measurement I, Measurement III	
			New Bachelor of Science (Project Management & Facilities Management) Measurement (Building Works) Measurement (Specialist Works) Safety, Health & Environmental Management	

Table 9: University Courses on Building Information Models

5.8 To what degree have the private construction companies (incl. building material companies) adopted BIM technology in their line of business

The major construction companies in the Nordic countries have all adopted BIM technology. The level and detail of adoption is varying from company to company. Within the individual company it also varies from department to department. There are more BIM oriented adoptions in construction companies around the world.

This study presents the most important and largest adoptions of high level BIM technology in the Nordic countries.

The Nordic countries

All the listed companies are involved in BIM related development. Most of them have their own development of in house systems and models as the basis for BIM, but they also follow the IFC development in the Nordic region.

- NCC - using internal BIM for a new industrialized construction process
- Skanska – using 3D and 4D in Finland
- PEAB – developing their own internal BIM for concrete element based processes
- YIT – using BIM for pre-cast element management
- Selvaag – implementing IFC based BIM

Several of the architectural and engineering offices in the Nordic countries have adopted the BIM concept and are working with process improvements and adding their tools to cover the BIM paradigm.

5.9 Deployment of BIM and IFC today

What is the current deployment of BIMs and IFCs in the different user categories like designers, construction companies, building owners and software vendors? In the questionnaire we got the following answers, shown in the Figure 18 and Figure 19 below. The use of BIM and IFC is shown for a number of different purposes, with an average of approximately 15% for BIM and 5% for BIM in IFC format.

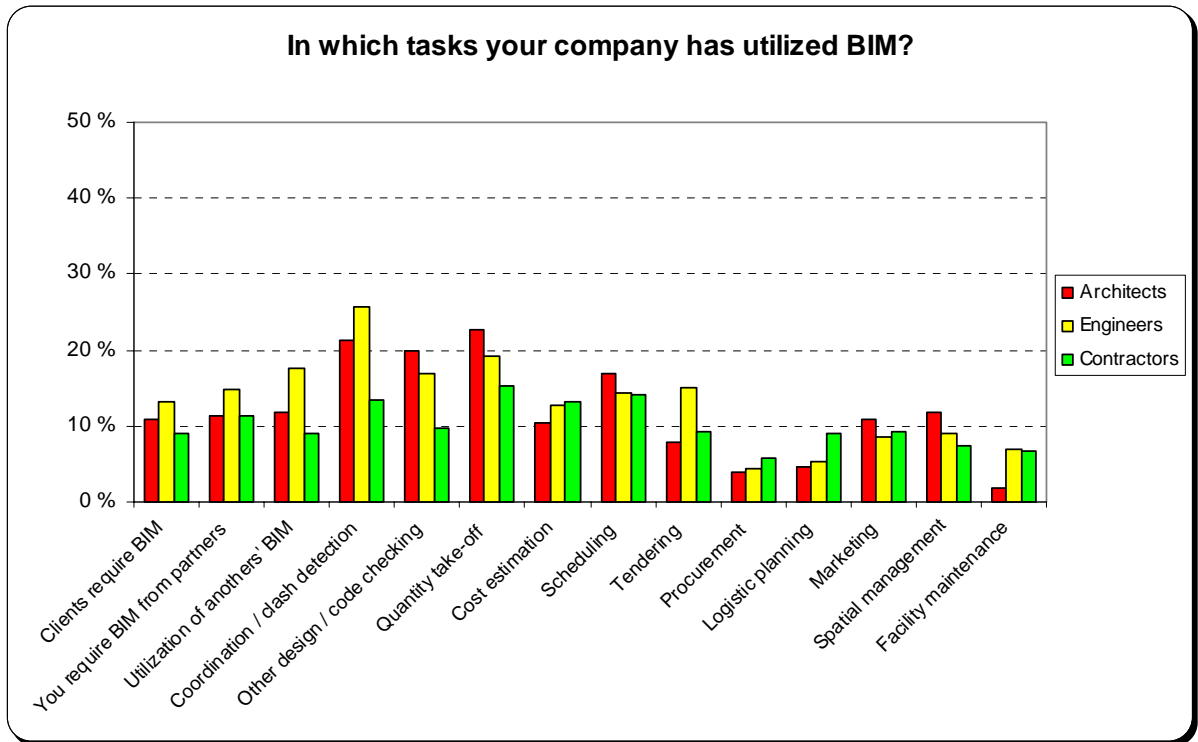


Figure 18: The use of BIM for specific tasks in the Nordic construction sector.

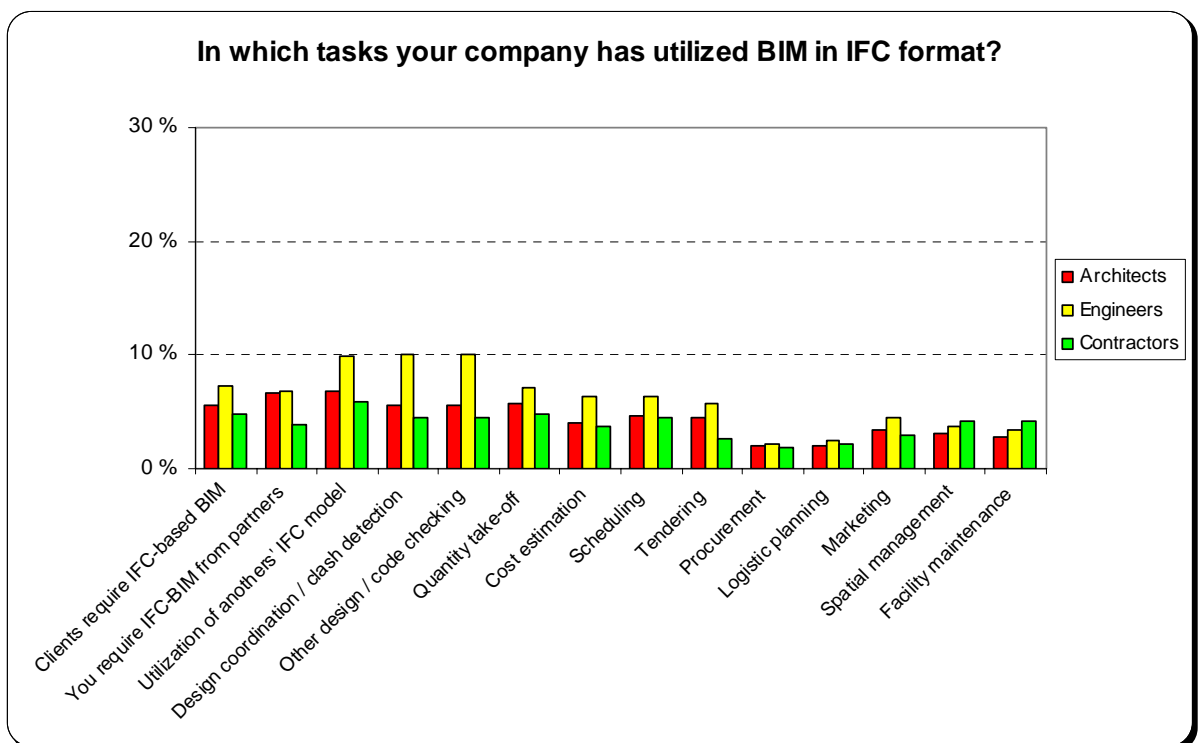


Figure 19: The use of IFC for specific tasks in the Nordic construction sector.

6 Area 2 - Lessons learned on the process of development and implementation of BIM and IFC

The lessons learned regarding development, implementation and deployment of BIM and IFC are viewed from a technical and drivers/obstacles perspective. The reason for this distinction is that regardless of technical quality or capabilities it is necessary to have strong drivers that insure deployment actually takes place.

The technical perspective tries to identify the overall conclusions of what have been learned during the last decade regarding BIM and IFC - primary in the Western Europe and secondary in USA and Australasia. In addition to written reports input have been collected from conversations and interviews with domain experts (Karlshøj, 2007).

Regarding the drivers and obstacles it should be mentioned that competition and fear often are forcing the drivers to push for a change. The following is an example of how a driver can be created and how the power can be repositioned so the underdog turns into the driving force.

When the large Danish engineering firms more than 20 years ago decided to implement CAD software they were the first to adopt the technology in the industry. By implementing CAD software in their services they more or less forced the small companies to join forces and establish an organisation to take care of their needs in order to implement CAD in small offices. A software company implemented their needs and the small companies deployed the results. Due to the large number companies in the organisation they became a driver in the industry that the large companies had to take seriously and join to influence.

6.1 BIM seen from a Technical perspective

The concept behind BIM was developed decades ago, and led to prototypes at universities and deployment at early adopters in the construction industry. At that time the acronym BIM was not used, but different names, acronyms and terms have been used during the years to describe more or less the same concept, e.g. virtual models, product models, building product model, building information model, building and object oriented modelling.

From a theoretical point of view all disciplines in the design, construction, use and maintenance of a facility could benefit from the BIM approach, but for many reasons the adoption have been slow looking at the last 20 years up until around 2005. During the last two to four years deployment of building information modelling have increased significantly. Despite the slow adoption of BIM in the industry a group of interested people identified the need for interoperable solutions. These people formed the backbone of interoperability development that has taken place within ISO, Eureka, IAI and other similar organisations. They identified a need which has been neglected by most people for decades, but today has become visible also for the more advanced users of ICT in the AEC/FM industry.

The existence of the BIM concept, availability of powerful hardware, software providers and costumers in a competitive marked has led to development of better software products in the BIM area. A significant part, but not the majority, of the industry are using BIM tools today and the adoption seems to be increasing rapidly.

6.1.1 BIM technical findings

As the industry gradually has adopted the BIM products some findings can be identified:

- Database based BIM tools are becoming more popular, probably because of the shortcomings in the file based software products. File based systems are in general very flexible and allows the user to create what is needed. Unfortunately file based systems force the user to get involved in non value added issues related to data management. Database based systems let the user focus on design whereas tasks related to data management and flexible multi-user access are handled by the software. Some of the file based systems are starting to allow simultaneous multi user access to files, which makes them less different to database based systems.
- The ability to have reliable and efficient data exchange between different applications is becoming increasingly important. Data exchange based on pure geometry elements is not seen as the long term solution. The interest in interoperability has started to rise in the industry, which leads to different ways of solving the problem. This can be accomplished in different ways e.g.: Product Suites, direct links between independent applications and use of neutral and proprietary files formats. So far the product suites, direct links or proprietary formats have been able to show the best results.
- Creating and merging cross domain models is a challenge today. There are barriers in order to use BIM in a coordinated way during the whole lifecycle in standard BIM products. Tools can and are used today to produce benefits for the user e.g. more consistent drawing production. The ability to handle scalability, levels of abstractions, consistency in a total BIM model, which contains information from different disciplines like design, construction, product manufactures, operation, is still not possible yet. This includes the issues regarding how to handle change management in a multi actor environment.
- Detailed modelling of buildings is often not possible with the BIM tools available today in commercial construction projects. Today's tools are normally either overall cross domain tools or tools for making very detailed modelling within only one area.
- It is common to improve or add information to documents that are automatically produced from BIM models in order to create the traditional construction documents. This problem can be solved in different ways. One solution could be improvements in the BIM tools to produce the traditional construction documents, another solution could be to update and standardise the traditional documents in order to make drawing production from BIM easier. A third and more radical solution would be to reconsider the structure and need for traditional documents in the construction industry (Khemlani 2007).
- There seem to be some diversity in the BIM tools used by the AEC/FM industry. This helps the software vendors to be competitive, but it also puts pressure on the need for interoperability as different tools use different file formats or databases.
- Since most, if not all BIM tools, give the user a certain degree of freedom in terms of usage, it may lead to non-compatible solutions in construction projects. As users have started to realise this, a need for neutral and product specific guidelines has become apparent. This has led to development of project, company or national guidelines, which, in principle do not differ very much from each other, though they are not compatible at a detailed level. Some guidelines are based on the use of BIM whereas others are limited to the use of 3D CAD objects. As many design companies, contactors, product manufactures, owners of facilities companies and software companies are acting in the

global economy, harmonisation of guidelines would make business easier and more efficient.

- Companies working in several countries would probably prefer to have common standards that can be used cross borders.
- The terminology regarding BIM is not consistent. Some people see BIM as the next generation of CAD tools that are working with objects, while others only will use the term BIM if all information regarding a building is fully integrated and accessible for all relevant participants. Fully integrated could be seen as a system that is able to handle geometry, properties, specifications, extractions (drawings), quantity take-off, processes etc.
- Very advanced use of BIM is rare today, which means that most of the specifications, analysis and simulations made today are done independently of the BIM or at least only done by loosely coupled systems.
- Regardless of whether IFC is used or not for transferring data between the BIM applications or other types of ICT tools, the lack of a common terminology for properties, relations etc. prevents computer to computer communication. Local agreements between manufactures and specific software producers are possible, but since most projects are solved by project specific organisations the local isolated solution is not sufficient at the AEC/FM level.
- It is a prerequisite to have modelling standards in order to really benefit from the exchange of objects between parties in the AEC/FM industry. The guidelines should cover the case where different parties come from different countries, which in modern projects is mostly the case. Extensive exchange of object properties will require strong centralized coordination via IFD (or something similar), alternatively, parties have to agree on an ad hoc setup or well establish business networks.
- Since the IFC specifications covers many business processes it is necessary to limit the scope of an exchange scenario in software products by the MVD approach
- IDMs are necessary in order to specify the needed information for the receiving body in an exchange

6.1.2 Conclusions regarding the technical aspect of BIM

On the development side much has been achieved during the last decade, and the commercial interest in BIM will most likely force the development to continue.

There are still many open issues regarding the more advanced merging of models, ability to handle high levels of details, detailed modelling etc.

Among the most advanced users the need for integrated or interoperable solutions is increasing. A few construction offices have adopted the highly parametrical products used by other industries. Guidelines to help users have been developed, but coordination between guidelines is still lacking.

6.2 Drives for BIM and main obstacles

The AEC/FM has to a certain degree adopted the BIM tools, and has just started to change their business processes to get the full benefit of BIM. Many companies have seen the benefits of BIM, which can be verified by interviews, surveys and the general interest for BIM.

BIM tools are used for different purposes depending on the role of the company, which means that designers concentrate on consistence between drawings, reuse of data to visualisation and improved possibility for communication with other participants in a project, whereas contractors see benefits in quantity take-off and marketing if they are also project developers in projects.

6.2.1 Drivers for BIM

Adoption of BIM needs a driver that is forcing or encouraging a change:

- National initiatives have promoted the use of BIM which may have led to acceleration in the adoption of BIM. Based on our own survey, there is no clear indication between the national initiatives and the level of use of ICT among architects and engineering in the Nordic countries. The utilisation of BIM produced by other participants is, according to our survey, higher in Finland than in the other Nordic countries, which may be related to a continuous support from Tekes in Finland to promote the potential of BIM.
- The adoption of BIM has differed from country to country. In Sweden the major contractors are playing an important role in the construction sector, and have most likely influenced the use BIM in Sweden. In Finland the continuous support from Tekes has encouraged the industry to adopt the BIM concept. The Association of Finnish Contractors has focused on implementing BIM in the industry, and the state client has followed the same path but added the need for open standards. In Denmark a user driven organisation bips has had strong influence in the use of IT in the Danish construction industry. The mandatory demands on BIM from the Danish state clients in 2007 have moved the use of BIM to a higher level in Denmark. In Norway the civil state client has influenced the use of BIM during the last 3-4 years. The Norwegian Homebuilders Association has encouraged the industry to adopt BIM and IFC. Several Norwegian contractors have invested and implemented BIM systems in order to have integrated ICT support for their production of apartments and houses. In the Netherlands the use of BIM may have been influenced by the limited willingness to share digital data cross company boarders, but BIM is being implemented in order to gain benefits at the company level.
- Professional organisations in some countries are helping the deployment of BIM by promoting the idea and opportunities. Several professional organisations in Nordic countries are encouraging their member companies to adopt the BIM concept.
- For business reasons, some companies have found an interest of their own in BIM and adopted the BIM concept. They have thus enforced the use of BIM to their subcontractors e.g. architects working for main contractors. Some product suppliers may also have invested in BIM to make themselves attractive to architects or engineers, because they have invested in BIM tools.
- According to our survey, very few companies saw the possibility to develop a new business as a reason for investing in ICT, so this turned out to be a weak driver. But investments are in general considered as improving competitiveness and boosting technical work. According the to a mainly US based survey carried out by AECbytes (Khemlani, 2007) the most important stand alone criteria for the users of BIM is the ability to produce final construction documents within the BIM tool itself, while other issues regarding integration, 4D and IFC were lower. BIM can be used to improve the traditional processes whereas more radical process improvements are less important today.

- Investment in IFC compliant BIM got the highest score in our survey regarding future investments, in (Christensen, 2007) it is shown that the use of 3D is expected to increase during the coming year.

6.2.2 Obstacles for adopting BIM

The following reasons have been identified as the main obstacles that are preventing the adoption of BIM:

- Lack of flexibility in the modelling capabilities, at least in older versions of BIM tools, has caused concern about the use of BIM among architects because the tools could limit their architectural and artistic freedom.
- Investment and cost for training are according to our survey, preventing adoption of BIM in many companies. Despite the answers from our survey it should be mentioned that the relative cost for hardware and software is probably lower than ever before.
- Balance between the cost for modelling buildings in BIM tools and the expected benefits for other participants in a project may prevent companies to start modelling.
- The use of BIM in the design phases makes it possible to monitor change during the design process. This can be seen as an advantage for some parties in the AEC/FM industry because it is easy to track changes, while others may feel this as limiting their ability to make changes during the design process.
- There is a general concern among some people that the size of a company is related to its ability to adopt BIM. The assumption is that in general it should be easier for bigger companies to adopt BIM and ICT. A fact that is confirmed by our survey, but the result also shows that there are many companies not following this trend.
- In the Nordic countries there seems to be a positive attitude towards sharing digital material in the AEC/FM industry, whereas in other countries the willingness seems lower (based on our interviews).
- A concern for lack of handling digital material from a legal or contractual viewpoint may also prevent people to adopt and especially share BIM models with other participants.
- Seen from the industry's side, lack of interoperability is an obstacle in order for adopting BIM, and for the clients' point of view to demand BIM data from their consultants, since they either had to demand data in a specific format or manage all the interoperability issues themselves.
- A significant obstacle for using BIM in general is the need to redefine the work processes and roles that each player must have in a future environment in AEC/FM, where BIM is fully integrated in all the relevant processes.

6.2.3 Conclusions regarding drivers and main obstacles

The use of BIM is increasing in the western world. All around the world and especially in Europe, the use of BIM is commonly defined as using CAD-orientated systems. Despite the growth it is still a minority of the work in the AEC/FM that benefits from BIM.

According to our survey, traditional parameters like constant software upgrading, costs and education are main obstacles preventing a higher level of usage of ICT, including BIM.

The general debate in some countries regarding the potential division of the society in an “A” and “B” team also exists regarding BIM. The companies who decide not to adopt the BIM concept may in the long run exclude themselves for doing business in some areas. A strong division in A and B teams will also have impact on the mobility of the workforce.

6.3 IFC seen from a Technical Perspective

Industry Foundation Classes can be viewed from a technical perspective in several separate ways. There are many different levels of technical issues that influence the final output, when using IFC to transfer data between applications. It starts with the specification and the methodology behind the development of these, and continues with the implementation of the specification in software programs and how the user has defined the data in his application.

6.3.1 IFC technical findings

- All parts of the IFC specifications have been developed to support processes defined by people from the industry and with commitment from software vendors to implement the functionality in their products. The lesson learned from this methodology is lack of review of the specifications and that the specifications only are partly implemented. The gap between information modellers and the AEC/FM industry should ideally have been narrower.
- Despite the shortcoming on funding, the current IFC specification is in general considered to be of high quality and the only specification having a scope covering the whole lifecycle for buildings. IFC 2x is accepted by the ISO as a publicly available specification and can become a real standard without modifications. (ISO, 2005).
- The ongoing development of the specifications has led to development of views. Views are parts of the IFC specifications that must be implemented in order to participate in the certification process. There is an approach in progress to make a more robust and well documented methodology by making a coherent framework containing IFC specifications, information delivery manuals, model view definitions and certification. A result of the constant development of the IFC specifications is that the level of complexity has increased during the years. There seems to be no obvious correlation between the size of the software vendor and its ability to implement IFC. This is because smaller companies are making software of at least the same quality as the big vendors. (Amor, 2007).
- Using IFC compliant software products in a research environment and in real projects has often led to dissatisfaction. In order to compensate for this problem the International Alliance for Interoperability (IAI) has set up a procedure for a self certification process, monitored by IAI. Unfortunately there are still significant problems in order to achieve high quality in the IFC interfaces. (Kiviniemi, 2007), (Amor, 2007).
- Even though a software product has been certified, there is no guarantee that the user can access the certified version as it is released months after the certification was given.
- Another important issue is performance during import and export of medium sized and realistic buildings in IFC format in both certified software and non-certified software.
- The structure of the IFC specifications and the used technology produces IFC files that are tenths or hundreds of megabytes, which again influence the time for data transfer and required amount of memory in computers to map the IFC structure to the native structure.

- A solution to the problem regarding large files and the need for merging data from different actors in the AEC/FM industry has led to development of model servers. This is an interesting development, but the lesson learned so far is that the technology is not mature for professional use yet. (Jørgensen, 2007) and (Haug, 2006). By the use of model servers it will be possible to improve the capabilities to monitored and manageable transactions among many participants and still maintain an integrated and consistent information model of the building. Model servers will lead to reduction of the amount of data that have to be transferred in order to make a transaction or inquiry.
- The constant development of the IFC specifications has led to different releases of the specifications. Although they are based on the same basic technology this easily leads to incompatibility because the specifications are published in a single schema. Since different software products may support different versions of the IFC specification, the users would prefer to have seamless transition between IFC versions which they do not have today (Ferries, 2007), (Grobler 2007).
- Related to the issues regarding the single schema approach, there is a concern among the software vendors caused by lack of stability/single schema problem which may lead to changes in the specifications (Grobler, 2007).
- According to the IFC2x3 release of the specification, the current certified view fulfils the requirements for certain tasks, while many other tasks are not supported. I 2007 additional views are being defined for structural work, thermal analysis, quantity take-off and facility management. Others may be added. If the views are implemented, a significant higher number of tasks will be supported, but it will also make it more complex for the users to get an overview of the combination of IFC releases, view and certified software.
- From a users point of view, mandatory and consistent implementation support for classification and type information, would have improved the number of processes that could be supported by IFC already today.
- There is a lack of information to users on how, when and for what purpose IFC can be used to day with the current available software.
- The current IFC specifications do not support parametric data, which may not generally be a problem, but if product manufacturers should be encouraged to use IFC for distributing product data and specifications, then, in addition to IFD, there will be a need for parametric data support, in order to reduce the number of products in product families that have to be modelled explicitly.
- During the last 3-4 years it has become obvious that the gap between the IFC specifications and the users in real construction projects has to be better supported. Development of an Information Delivery Manual is meant to overcome this problem. Since the development phase of the work still is in progress, it is too early to know whether this work will solve the problem. Some national or even product specific guidelines have already been developed or are in progress. There seems to be a need for coordination in the area.
- New business demands based on a need for interoperability in areas not supported by the IFCs, will lead to extension projects, funded efforts to expand the IFC specification. This in turn will lead to a new release of the IFC standard, forcing software vendors through the certification procedure again. Business needs may require a constant stream of new IFC versions, while software vendors would like to avoid as few versions as possible.

6.3.2 Conclusions regarding technical aspect of IFC

A well funded process with strong involvement from the AEC/FM would probably have led to a more harmonised data model and a greater balance between the requirements from the AEC/FM, software companies and research. Nevertheless it is clear that the IFC specifications are capable of handling large amount of information from the AEC and FM industries.

What could be learned regarding the development of the views is that there should have been a stronger involvement of people from AEC/FM to set priorities and people with domain knowledge to define views.

A single based express schema is and will become an increasing problem.

Regarding implementation it was clear that the effort of making software solutions of high quality within the existing framework required more work than what was put into it. Confidence in the existing certification process should be improved by strengthening the demands, the procedures and enforcement. There is an increasing need for software vendors and/or the developers of the IFC specifications to make transition between different IFC releases seamless.

The lesson learned regarding deployment is that IFC is only used by a small minority of the organisations in the AEC/FM industry, and a potential increase in use is heavily depending on, from a technical point of view, that the results from conversions are fast, reliable and predictable. As use accelerates, lack of handling compatibility between different releases of IFC can become an increasing problem.

Promoting the capabilities in the IFC specifications have given cause for much higher expectations, than what can be achieved with today's software. So regardless of which software solution that is presented for solving real day-to-day problems, it will not live up to people's expectations.

6.4 Drives for IFC and main obstacles

Seen from a commercial point of view there is always a risk when changing from one paradigm to another, that new or existing players can get a greater share of the new market. On the other hand newcomers or competitors see an opportunity in changes. This is one of the major challenges a wide spread use of IFC has had.

Another important condition is that there was no existing general practise to harmonise, since the development of IFC has occurred at the same time as the BIM tools seriously have been adopted by the industry.

6.4.1 Drivers for IFC

The following groups are seen as the most important to make impact on the use of IFC:

- The first IFC specifications were developed by a closed group of companies that were connected to Autodesk. Some people from the academic world participated in the work from the beginning. When the initiative was made known to other companies, academics and public organisations joined. Some of the people who were looking for profit within a short period of time left the organisation or reduced their contributed work to IAI. That left IAI with people accepting that the development and implementation would take years. Due to that change, IAI could easily be seen as a group of evangelists, who

concentrated on creating the specifications without much notice from the rest of the AEC/FM industry.

- Only a few countries and some committed companies and academics stood behind the development of the specifications. That led to some frustration among the evangelists. Lack of influence led to modest interest from most companies, which only produced prototypes rather than including the IFC interfaces in the ordinary products. A “wait and see” attitude made it difficult to raise funding for the development work, and to move from prototypes to real products and application in concrete projects.
- As more organisations have started to request, demand or raise expectations that IFC will be mandatory for certain clients, in most cases public clients, the awareness of IFC have improved among the software vendors, professional organisations, private companies and private and public clients. (US Coast Guard, Senate Properties in Finland, Statsbygg in Norway, GSA in the US, Singapore Building and Construction Authority, The Palaces and Properties Agency, The Danish University and Property Agency, Defence Construction Service, PSIBouw Netherlands have pushed for IFC).
- The push for IFC from public clients has made a change since the major vendors have increased their interest in IFC, and are including support for IFC in more products.
- There is still no serious interest or demand for IFC from a wide range of organisations in the AEC/FM industry. This is because the concept of BIM has not yet made a full marked penetration, and reuse of data from BIM models is low. The majority of the companies in the AEC/FM industry do not consider model based integration as important. They are maintaining project material manually.

6.4.2 Obstacles for adopting IFC

There are many obstacles for adopting IFC:

- The lack of IFC compliant software products has lead to a minimal use of IFC in the AEC/FM world. While the demands for IFC compliant software are negligible, most software vendors hesitate to invest in development for IFC compatibility.
- With a high focus on CAD in IAI for some time, there is a lack of IFC compliant software products outside the traditional CAD products.
- Lack of robust IFC interfaces in the available software products with IFC interfaces have and are major obstacles for a wider and voluntary use of IFC as the preferred protocol for exchange of data related to buildings.
- Lack of information on how and when IFC can be used is hindering the use.
- Contrary to the goal that the level of expertise about IFC does not need to be very high, there is still a considerable need for expertise. At present, expert knowledge is necessary, since only some areas of the IFC specifications are supported by software products, and the quality of the software is forcing the user to be aware of the shortcomings and finally because the software products have to be used in a certain way in order to get the import/export to work.
- Lack of trained employees and access to training. People with knowledge on BIM and IFC are a limited resource.
- In some countries there seem to be a willingness to share digital data among the AEC/FM industry, while in other countries transfer of digital information is seen as a transfer of proprietary knowledge. In this case it is not the problem related to IFC itself that is

hindering data exchange, but common goals for the industry to change the ways of sharing information and knowledge.

- There is an uncertainty among organisations about how the legal situation is in relation to BIM and exchange of data between organisations. The general impression is that the area should be investigated further and that the outcome should be transformed into regulations and procedures to be incorporated into contracts etc.
- Organisations that for several reasons have chosen not to recommend the use of IFC because of its shortcomings (for good reasons), are delaying the process as there is no pressure on the software companies to make IFC interfaces of high quality, if they are not going to be used anyway.
- In general there is a want for clear requirements of how data should be delivered to the clients. Work has started in this area, but so far only at a national level, which makes it difficult for companies providing cross boarder services. On the other hand it can be looked at as a starting point for international standardisation.
- Some software vendors are supporting the idea behind IFC, while others are promoting proprietary solutions. This is providing the industry with an unclear message regarding IFC. This leads to the question who should they believe in.
- Problems related to the exchange of object information are mainly related to the use of different software solutions. Only in the case of exchanging pure geometric model information is the method of modelling the biggest obstacle.

6.4.3 Conclusions regarding drivers and main obstacles for IFC

A change needs a driver and in respect to IFC, it looks like it is the public clients that would be the driver. Perspectives about the future benefits for the industry from a number of evangelists are not enough in order to make a change happen, since few companies or individuals have adopted the idea so far. A bigger change worldwide towards greater adoption of IFC needs big players willing to go first. Based on the results from our survey it looks like IFC is at a tipping point, since expectations to investment in IFC based BIM will increase during the coming 2 years.

The reason why IFC compatible BIMs are not yet identified as a solution to the problem of meaningful data exchange between agents in the construction sector is because the fragmented industry has not been able to agree upon the use of IFC. This is mainly due to competitive issues, lack of understanding of the positive consequences, and because of poor quality in the IFC interfaces. There seem to be no real interest in the industry to change its business processes. Another reason is the chicken and the egg paradox: The software industry is waiting for the software industry to take action, and the software industry is waiting for the AEC/FM industry to demand a solution.

7 Area 3 - Necessary future steps to move towards the use of integrated BIM processes

This chapter concentrates on the possible means to overcome the problems, obstacles and shortcomings in the current technology and business processes, which have delayed the adoption of IFC compliant, integrated BIM. The conclusions and recommendations represent the views of the authoring group, and are based on long and active involvement in the work of IAI and other product model and BIM development, implementation and deployment activities. However, these choices and recommendations are not facts but personal interpretations of facts and intended to serve as basis for readers to make their own interpretations of the same facts.

7.1 Basic problem and drivers

7.1.1 Basic dilemma

The basic dilemma in the deployment of integrated BIM can be described as a paradoxical loop; there is not enough market demand for integrated BIM, because there is not enough measured evidence of benefits of the integrated BIM, because there are no adequate software tools to use integrated BIM in real projects (Figure 20).

This paradox is typical for systemic innovation in a complex supply network where changes in one player's processes affect the business of other players (Taylor and Levitt, 2004a). Typically most players either passively wait what is going to happen or actively try to prevent the change as a potential threat. Only very few companies see the change as an opportunity and are willing to take an active role in driving for it. However, their affect in the market is limited until the critical mass has developed. Thus, the change usually takes a long time. At the moment it seems that integrated BIM is gradually achieving the critical mass, at least in some countries, as pointed out in sections 5.5, 5.7, 6.2.1 and 6.4.1.

In the case of integrated BIM the best solution to speed up the deployment is to create demand and supply at the same time or at least within a reasonable timeframe to enable lucrative market for software vendors and adequate tools and profitable business for AEC/FM companies. The most efficient way seems to be significant national effort which can create a critical mass in relatively short period of time (6.2.1).

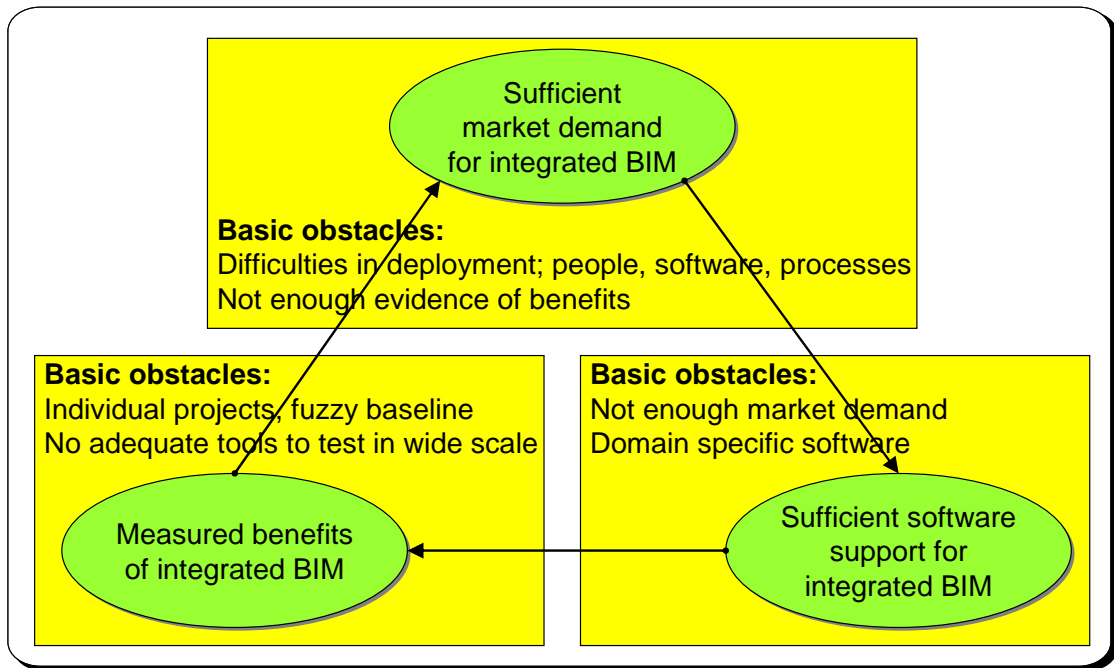


Figure 20: Paradoxical loop of integrated BIM (Source: Arto Kiviniemi, VTT 2007).

7.1.2 Effects of public and private interest and funding

As described in 7.1.1 the development, implementation and deployment of integrated BIM is a complex issue depending on the co-existing demand and supply. There are practically infinite number of factors influencing the path and speed on how this development could happen; will there be any key-players who want to actively promote the change, which role they have, which parts of the development they see as a creation of a competitive advantage, do they want to participate in the creation of a “new infrastructure” – collaboration platform for AEC/FM – is the public funding available or is the development based on private funding, etc.? In practise the issue is too complex to be handled in detail in this study. Thus, it needs to be simplified heavily to identify some of the key elements of different scenarios. Figure 21 tries to identify four main scenarios, how strong or weak public or private interest could affect the development, implementation and deployment of integrated BIM.

The right and left columns are not necessarily dependent of each other, although strong interest on either side will most probably influence the other in some timeframe.

If the goal is to actively improve the deployment of integrated BIM, the best scenario is naturally strong public and private interest and funding. In that case, the open questions are related to the needed actions and their timing, which are discussed in 7.3.

Likewise, the worst scenario is weak public and private interest and funding, which is the case currently in most countries. In this case, the drivers for development, implementation and deployment are practically missing and the changes in the industry are slow and limited. From the viewpoint of this study, this is not an interesting scenario since there are no means or target groups to influence.

The challenging scenarios are the two diagonal cases; either public interest and funding, or private interest and funding are strong, which means different development paths; “Infrastructure’ for integrated BIM” or “BIM in core of companies’ strategy”. Both cases are

discussed in 7.3. In practice the situation is never so “black-and-white”. Experiences of the major public support have always generated significant private interest in integrated BIM; good examples are Denmark, Finland and Norway where very different public policies have created strong response in the AEC/FM industry. The main driver has so far been the activities of public building owners and agencies.

Strong	Potential direct impacts: 'Infrastructure' for integrated BIM <ul style="list-style-type: none"> • Legal requirements for BIM • New RECC agreements • Robust, official certification • Coordinated new education programmes • Active research and development of integrated BIM 	Potential direct impacts: BIM in core of companies' strategy <ul style="list-style-type: none"> • New business processes • Partnership & other collaboration models based on ability to work in the new environment • Strong commercial incentive to develop software products and deploy integrated BIM
	Potential direct impacts: Market driven integrated BIM <ul style="list-style-type: none"> • Deployment speed difficult to predict and influence • Education development based on individuals (universities, departments, professors) • Limited research and development of integrated BIM • Potential push from private side 	Potential direct impacts: Slow deployment of integrated BIM <ul style="list-style-type: none"> • Weak incentive for companies to deploy integrated BIM; focus in internal business processes - increasing fragmentation of RECC • Weak commercial incentive to develop software products • Potential push from public side
Weak	Public interest and funding	Private interest and funding

Figure 21: Four main scenarios; public and private interest in integrated BIM.

7.1.3 Drivers for development, implementation and deployment of integrated BIM

Usually development of ICT tools has started from automation of the manual processes rather than from re-thinking the processes. Then the development can go gradually through informational transition towards transformational change (Figure 22).

This applies to the development and deployment of ICT-based design tools also. The first step was automation of drafting which still is the dominating working method in the AEC/FM industry. First BIM applications have inherited their technological basis from these drafting tools and are mostly used just as the repository from which the designer can generate drawings, i.e. still in the automational level of the development. However, in most cases this step already justifies the necessary investments in moving from 2D drafting into use of BIM, and thus is a reasonably simple step for individual companies.

The development and implementation of IFC specification into the current BIM-based tools represents a step to the informational level by enabling an information management platform among the different AEC/FM shareholders. Most AEC/FM companies cover only one domain and thus cannot benefit from integrated BIM unless at least some other players in their business network adopt the interoperable tools simultaneously. However, if the processes stay the same

as in the document-based environment, the change has only limited impact to the business environment.

The third step means that the potential of BIM is used in the development of business processes. For example, simulations and analysis tools are often used in the early phases to compare alternative solutions instead of the current verification at certain milestones of the process. Changing the processes will affect the roles and responsibilities of the players, thus also changing contractual relations in AEC/FM.

The current business models and fragmentation of the AEC/FM industry do not support the transformational change well. Different shareholders have different, sometimes even conflicting, business drivers and this has slowed down the adoption of integrated BIM. In the current process all project participants – owners, construction companies, project managers, architects, engineers, manufacturing industry, facility managers, and software vendors – try to sub-optimize their own business and there is no obvious owner for the interoperability in the AEC/FM industry. Thus, nobody has the motivation or power to implement a new model of collaboration for the whole project. Then the best solution on industry level seems to be step-by-step development of current tools to improve communication and data sharing. This can happen either so that each participant will get adequate benefits of the new technology in each step or so that some key players will more or less force others to the change. Even this development needs several drivers as identified in section 6.2.1; national technology programs or legal requirements can speed up the deployment significantly.

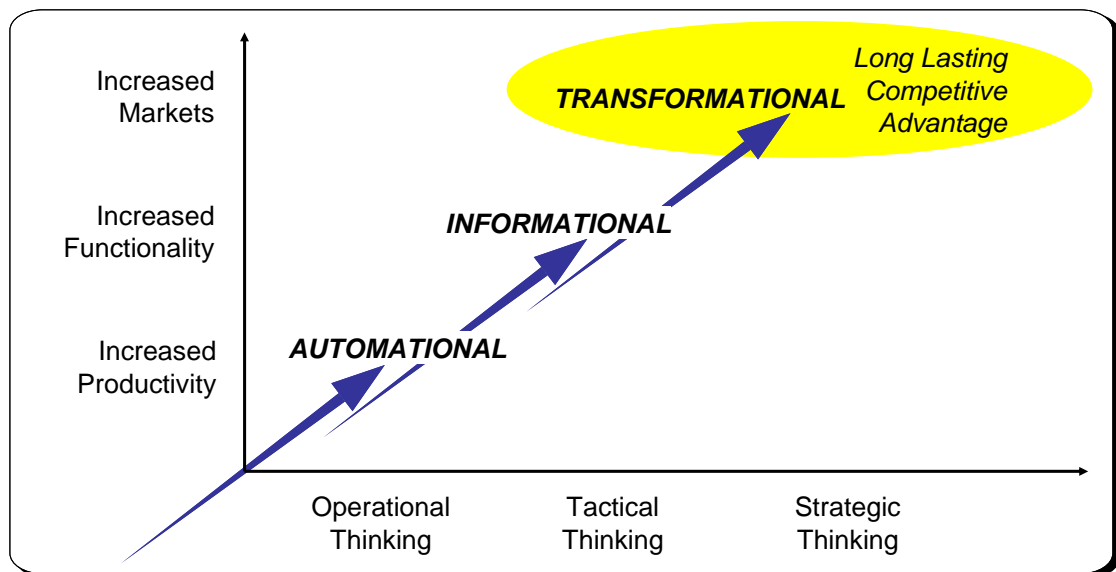


Figure 22: Adoption levels of new technology (Source: VBE II project, Stephen Fox, VTT 2006).

The different business drivers have not been adequately recognized in the development and implementation of IFC specification. In addition, the driver for the development of the specification has been rather the technology push of the “evangelisers” than the existing market demand (6.4.1). However, these business drivers are a necessity for demand and that is a necessity for extensive and robust implementation of interoperability.

7.1.4 Business Drivers

In general, the business driver for all companies is Return on Investment (ROI); the amount and time of payback for the necessary investments in adopting new technology, such as BIM, and

changing the business processes. The acceptable level of ROI and the required payback time depends naturally on the company and its business model. Thus, the following categorization of assumed benefits of the use of BIM is only a framework which is not necessarily valid on the company level.

For end-users of the buildings (community) the main interest areas are:

- improved quality-cost ratio (higher quality with the same costs or the same quality with lower costs); buildings are a significant resource and cost for the end-users organizations
- improved understanding of the expected end-result; visualizations and virtual prototypes based on analysis and simulations
- improved safety, security by and sustainability analysis and simulations of virtual prototypes

For building owners and investors the main interest areas are:

- investment costs; lower costs and better predictability
- life-cycle costs; lower costs and better predictability
- improved quality-cost ratio; analysis and simulations supported decision making
- improved marketing by better communication and service for clients
- improved safety, security by and sustainability analysis and simulations of virtual prototypes

For facility managers the main interest areas are:

- life-cycle costs; lower costs and better predictability
- improved quality-cost ratio; accurate and up-to-date as-built and maintenance information
- improved safety, security by and sustainability analysis and simulations of virtual prototypes

For contractors the main interest areas are:

- improved productivity by efficient information processes within and between different tasks; bidding, cost estimation, scheduling, procurement, site activities, etc.
- improved quality-cost ratio; better productivity and less errors
- improved marketing by better communication and service for clients

For designers and engineers the main interest areas are:

- improved productivity; less re-work because of changes and contradicting documents
- improved quality-cost ratio; better coordination of different disciplines
- improved marketing by better communication and service for clients

For manufacturing industry the main interest areas are:

- improved marketing by better communication and service for clients

- improved productivity and quality-cost ratio by streamlining the information flows between product development, design configuration, manufacturing and logistics

For software industry the main interest area is:

- improved sales with reasonable development costs. Integrated BIM competes with any other development needs and unless the expected ROI is at least as good as in other functionalities, it will not be a primary issue for software vendors.

7.2 Existing obstacles and actions needed

7.2.1 Technical issues and functionalities of integrated BIM

Integrated BIM and interoperability are issues which have been addressed also as a part of other wider R&D roadmaps for the AEC/FM industries (

Figure 23 and

Figure 24).

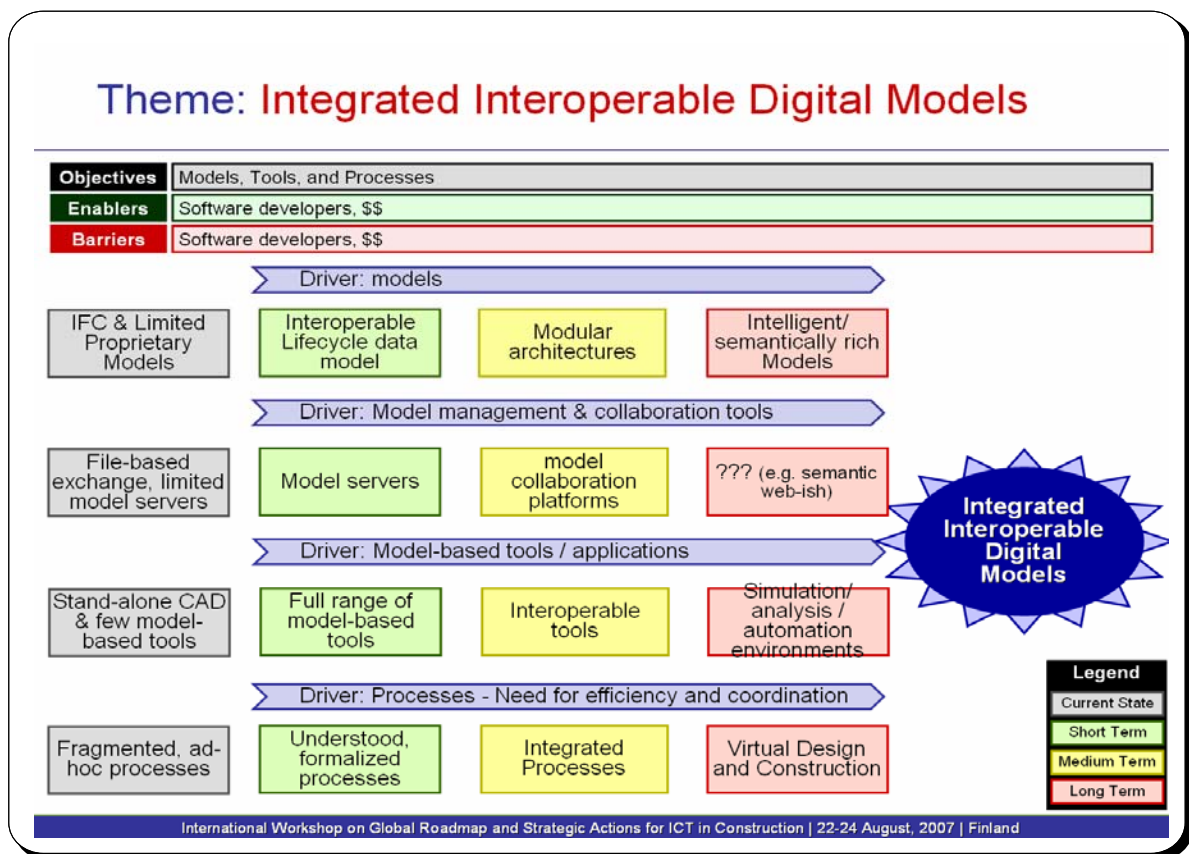


Figure 23: Integrated interoperable digital models theme in the Strat-CON & Fiotech roadmap (source Strat-CON-Fiotech roadmap workshop, August 22-24, 2007).

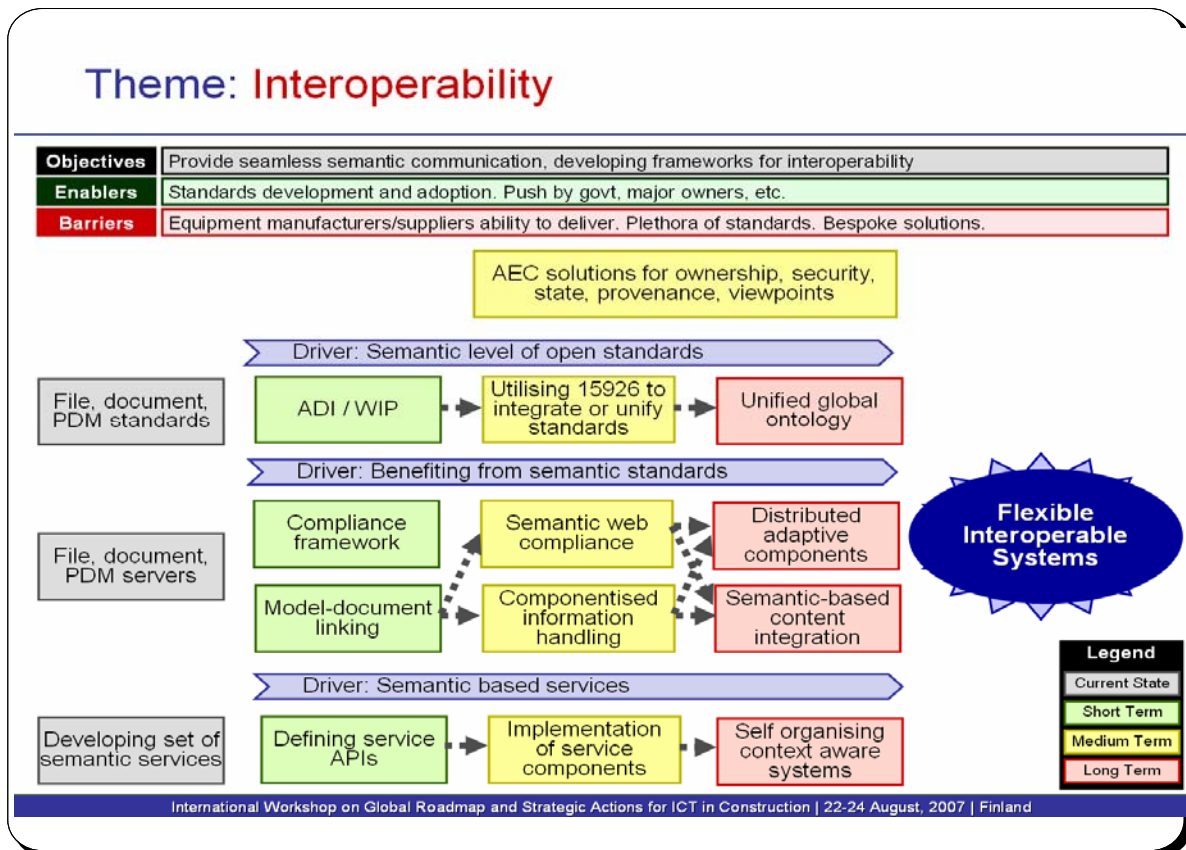


Figure 24: Interoperability theme in the Strat-CON & Fiotech roadmap (source Strat-CON-Fiotech roadmap workshop, August 22-24, 2007).

7.2.1.1 Coverage and quality of the IFC specification

The current IFC specification is significantly wider than any of its implementations, except some model servers and software toolboxes which can cover the whole IFC schema (5.2.3). One of the main reasons for the situation is the development of current software tools from domain specific, or even drafting, viewpoint (7.1.2). Thus, the current tools do not contain internal objects and structures for many of the IFC objects. In general, the quality of the current IFC specification is considered to be good (6.3.1), but nevertheless some minor corrections will be needed when the implementation efforts will continue and cover larger part of the specification.

Although IFC specification is already wider than its implementation it does not cover all needs in the AEC/FM industry. Thus, further development of the specification will be necessary in the future, but it is a low priority at the moment since it will take years to implement the current potential of the IFC specifications even without any additions. The development of extensions for IFC specification should be addressed and funded by the parties which see the need for such additions.

One reason for the difficulty and slow progress of the IFC implementations is the complexity of the IFC specification. Its implementation requires significant effort and without sufficient market demand it is not lucrative for the software vendors. To improve the situation IAI has already discussed about improving the structure of IFC specification. One of the proposed solutions is a clearer modularization of the specification into smaller sub-schemas (6.3.2, ITM 2007). Another need which has been discussed in IAI is the improved support for model servers, especially simpler representation for geometry which could increase the performance of the servers.

Recommendations for actions:

- Type of action:* Development of open, non-commercial standard. Possibly some research issues related to the modularization and simpler structure of future IFC specification.
- Action priority:* High for necessary corrections needed for immediate implementation, medium for modularization and low for further extensions of the IFC specification. In general, this action belongs in phase 2 in the development roadmaps (Figure 31, Figure 33 and Figure 35).
- Needed actors:* Global effort. International Alliance for Interoperability developing the IFC specification, AEC/FM industry defining its needs, and software companies testing the implementability of the specification.
- Funding:* Development of IFC specification is the foundation of integrated BIM and it does not create immediate business value to any actor either in AEC/FM or software industry. Thus, at least partial public funding is needed for major improvements, such as the modularization. Immediate corrections can be funded by IAI's current organization and extensions should be funded by the interested parties.

7.2.1.2 IFC certification and development of IDM and MVD

The current IFC certification process is inadequate since it does not ensure that the certified products can be used in real projects without major technical problems (6.3.1). In addition, the certification is not based on a well-defined use-case and thus its content is not clear; even if the IFC export functions it is almost impossible for an average end-user to find out what information will be exported or imported (6.3.1).

The IDM (Information Delivery Manual) and MVD (Model View Definition) processes have been developed to address the questions of content in specific use-cases (5.1.1). The methodology and even some use-cases exist, but they have not been implemented since the current certification is not based on their use.

One of the mandatory requirements for a reliable certification process is that it must be managed by a party who has no vested interest in the results, i.e. the activities should be separated from the IAI and software vendors. It is also crucial that the requirements and possible limitations of each certified use-case are documented in detail and in a way which the end-users of the software can understand. Such information is totally missing from the current IFC certification processes.

Recommendations for actions:

- Type of action:* Establishment of an independent IFC certification body, need for public funding at least in the beginning.
- Action priority:* High. The quality problems of the IFC implementations are by far the biggest obstacle for the deployment of integrated BIM; unless the use of data exchange is reliable it cannot be used in real projects. This action belongs in phase 1 in the development roadmaps (Figure 30, Figure 32 and Figure 34).
- Needed actors:* Global effort. A neutral organization or consortium to establish and manage certification for IFC compliant BIM software in collaboration with software

vendors and AEC/FM. Potentially, for example, a group of universities or other research organizations preferably from more than one country.

Funding: Development of a robust and reliable certification process demands significant resources and technical knowledge. This means that also the costs would be significant and, at least in short term, cannot be covered by the certification fees since the market demand for IFC compliance is not yet sufficient. Thus, at least partial funding from public sources is a necessity to start the activities.

7.2.1.3 Additional BIM functionalities and tools

Integrated BIM will increase the possibilities to add functionalities to existing BIM-based tools and create totally new tools. The so-called down-stream applications, applications utilizing the information created in authoring applications (5.1.4), have the largest development potential. Some existing examples in this category are checking, simulation and analysis tools using IFC files as the input. The development of new tools or additional functionalities is mainly commercial software development, but can also include research activities. The potential application area is very wide and difficult to define in exact terms, thus only four priority themes are documented in the next sections. In general, all these actions belong in phase 2 in the development roadmaps (Figures 19, 21 and 23).

7.2.1.3.1 IFC compliant model servers

One already identified important area is the IFC model server technology, which seems to be one of the key elements in efficient data sharing. Current file-based exchange is not an adequate long-term solution for integrated BIM since it does not enable partial exchange; files containing the whole building in IFC format are huge and not practical in situations where only small part of the building has changed (6.1.1). In addition, file exchange does not support version control and efficient information management. The existing commercial IFC model servers (5.2.3 and 6.3.1) add real value to customers today. However, there is still need for both research and development in this area. Research is needed especially related to, for example, synchronization issues, project management, partial model exchange, and software interfaces. One of the research questions is if other industries already have adequate technical solutions for model servers, which could be applied to IFC structures.

Recommendations for actions:

Type of action: Both research and commercial development.

Action priority: High within phase 2. IFC model servers will be one of the key elements in deployment of IFC compliant BIM.

Needed actors: Global, EU, regional, national and company efforts possible. Universities and other research institutes in research, software vendors in product development.

Funding: AEC/FM and public funding for research. Product development funding mainly from software vendors, possibly some public development funding.

7.2.1.3.2 Product libraries

True as-built and maintenance models are dependent on manufacturing information. In addition, the manufacturing information is needed in the design and construction processes. Prerequisites for the use of manufacturing information as a part of integrated BIM are the standards for product libraries and the availability of the information in IFC compliant format. There has been several research projects investigating product libraries; latest and most complete project in this area is development of IFD (International Framework of Dictionaries) in Norway. However, there has not been any serious effort to produce real product libraries for the AEC/FM industry. The further development will still require some additional research, but the main

question is the real demand for such information, and it can be created only by the extensive use of integrated BIM in design, construction and facility management activities.

Recommendations for actions:

Type of action: Both research and implementation.

Action priority: Within phase 2, high for research, medium for implementation. It is feasible to implement product libraries in wide scale only when the integrated BIM is commonly used in the AEC/FM.

Needed actors: Global, EU, regional, national and company efforts possible. Universities and other research institutes in research. Manufacturing industry, information brokers and software services in implementation.

Funding: Manufacturing industry and public funding for research. Manufacturing industry for implementation.

7.2.1.3.3 Sustainability and environmental issues

Sustainability and environmental issues are becoming increasingly important for all shareholders in AEC/FM. Integrated BIM is an excellent platform to develop software tools for analysing different environmental aspects of project alternatives. The prerequisite is to link environmental and lifecycle data with design models which is similar to the link between cost databases and design models. Some research on this area has already been done (Häkkinen 2007, Tucer et al 2003), but more research and actual tool development is still needed. Commercial implementation has the same challenge as the product libraries; it requires interest of the manufacturing industry and critical mass of BIM users (Figure 25).

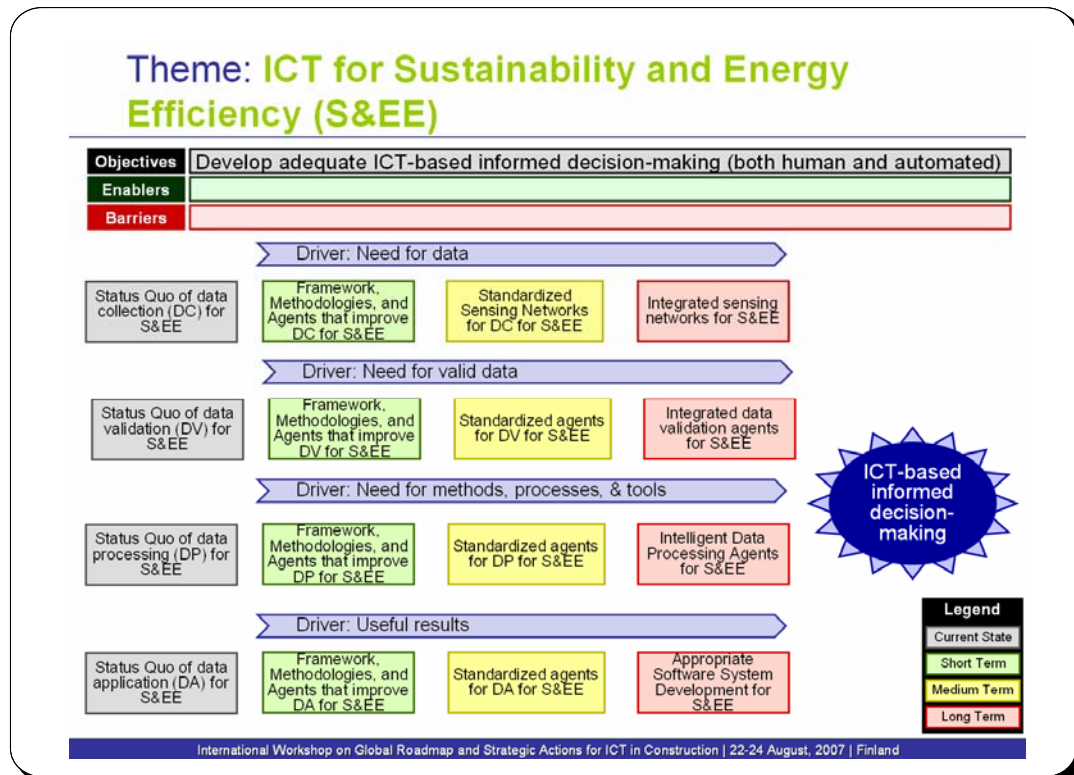


Figure 25: Sustainability and energy efficiency theme in the Strat-CON & Fiatech roadmap (source Strat-CON-Fiatch roadmap workshop, August 22-24, 2007).

Recommendations for actions:

- Type of action:* Both research and implementation.
- Action priority:* Within phase 2, high for research, medium for implementation. It is feasible to implement environmental and lifecycle databases in wide scale only when the integrated BIM is commonly used in the AEC/FM.
- Needed actors:* Global, EU, regional, national and company efforts possible. Universities and other research institutes in research. Manufacturing industry, information brokers and software services in implementation.
- Funding:* Manufacturing industry and public funding for research. Manufacturing industry for implementation.

7.2.1.3.4 Security and safety

The importance of safety and security is rapidly growing on the global level, and this has generated new R&D initiatives, for example, on EU and national levels (EU FP7 2007-2013, Tekes 2007-2013). This development has a strong connection to buildings and built environment and thus also relates to integrated BIM, which can provide both platform for safety and security analysis and advanced user interface for emergency situations (PARK 2007).

Recommendations for actions:

- Type of action:* Both research and implementation.
- Action priority:* Medium within phase 2.
- Needed actors:* Global, EU, regional, national and company efforts possible. In research universities and other research institutes. In implementation security, service and software companies.
- Funding:* Can be part of existing or new R&D programmes.

7.2.1.3.5 Knowledge management in integrated BIM environment

Recent and expected advances in ICT tools offer significant potential to improve collaboration and knowledge sharing within industry, companies and project teams and improve their performance in meeting quality, safety, sustainability, schedule, and cost objectives. Market forces in many segments and locations are demanding improved project results related to each type of objective.

Many types of obstacles create substantial difficulties in realizing the potential of BIM to improve collaboration and project results; for example, knowledge content for tool development and implementation of advanced tools. The knowledge to share for effective collaboration includes many diverse types, some of which are difficult to capture, represent, and retrieve. The types of implementation obstacles include market, competitive, contractual, organizational, social, personal skill, language, incompatibility of tools, and lack of standards.

For knowledge content, the major challenges are to model process knowledge and translate technical information and knowledge for use in multiple languages. Overcoming gaps concerning implementation of advanced ICT tools for collaboration will require increased understanding of related economic, contractual, and motivational factors.

A prerequisite for effective knowledge sharing and collaboration support is seamless and instant access to the right information and knowledge at the right time and at any place. This will

require advances in knowledge capture and representation, along with removal of contextual and individual obstacles to provide user-centric ICT services.

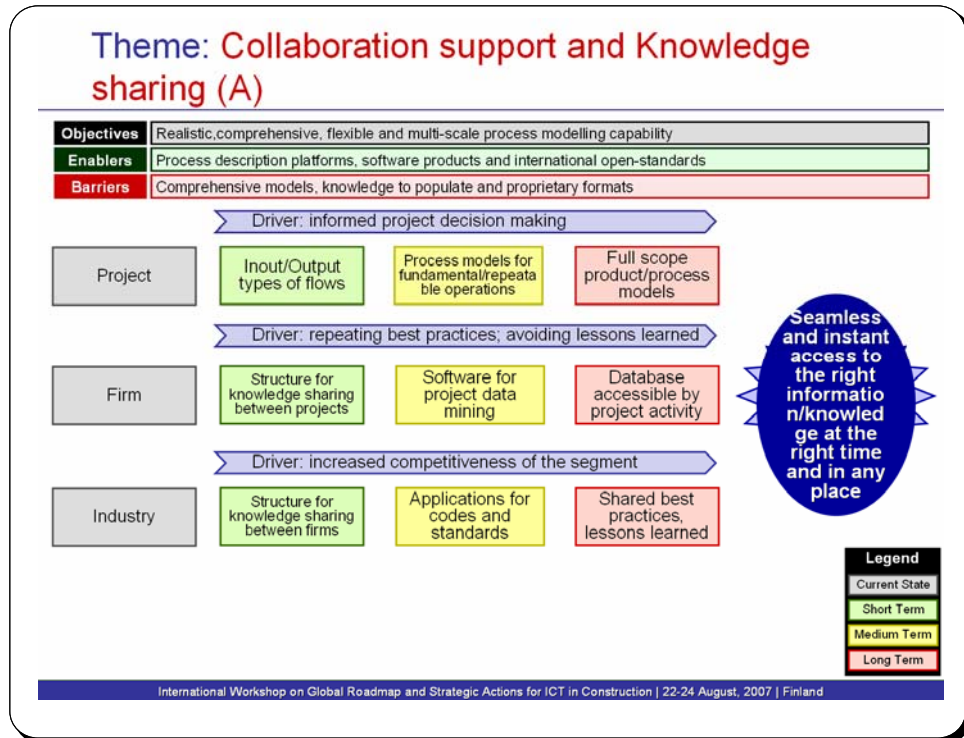


Figure 26: Collaboration support and knowledge sharing theme A (Process Modelling) in the Strat-CON & Fiatech Roadmap (source Strat-CON-Fiatch roadmap workshop, August 22-24, 2007).

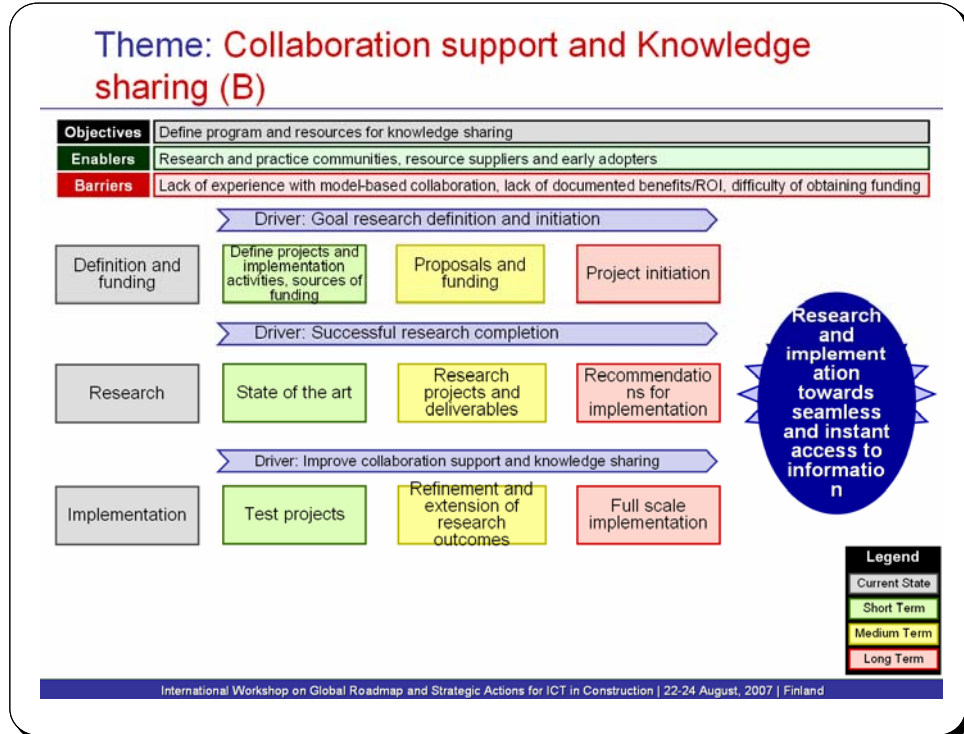


Figure 27: Collaboration support and knowledge sharing theme B (Program and Resources) in the Strat-CON & Fiatech Roadmap (source Strat-CON-Fiatch roadmap workshop, August 22-24, 2007).

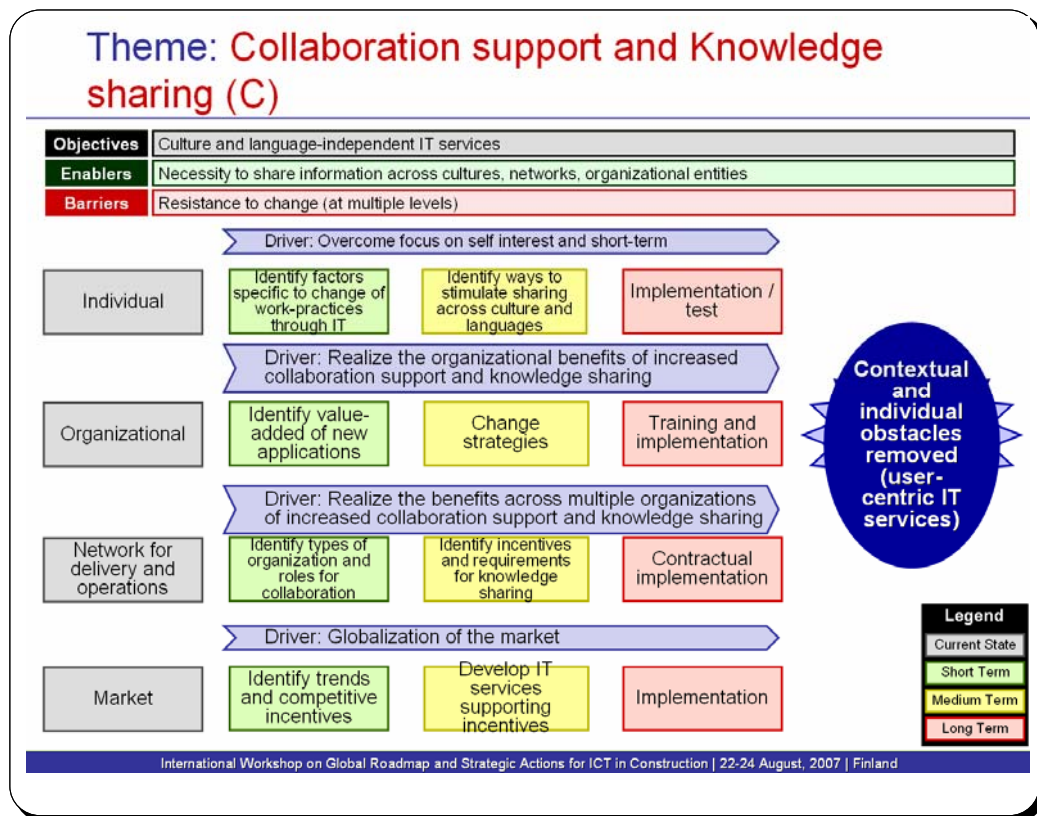


Figure 28: Collaboration support and knowledge sharing theme C (Culture and Language Independent Services) in the Strat-CON & Fiatech Roadmap (source Strat-CON-Fiatech roadmap workshop, August 22-24, 2007).

Recommendations for actions:

Type of action: Both research and implementation.

Action priority: Medium within phase 2.

Needed actors: Global, EU, regional, national and company efforts possible. In research universities and other research institutes. In implementation software companies.

Funding: Can be part of existing or new R&D programmes and product development.

7.2.1.3.6 Procurement and logistics in integrated BIM environment

Several earlier European and national research projects have studied the use of BIM-based information in the procurement process. The main conclusions from the earlier research are that the basic idea is possible and applicable, but there are also several technical and human issues which must be solved before the method can be deployed in the practice. Some of the main obstacles are (1) impacts of the new process into the business models of different actors, (2) the quantification of the benefits and possible problems, and (3) necessary information content of the BIM. Unless the business implications can be identified and quantified reasonably accurately, the industry is not willing to start the necessary actions which would enable the change.

Recommendations for actions:

Type of action: Both research and implementation.

Action priority: Medium within phase 2.

Needed actors: Global, EU, regional, national and company efforts possible. In research universities and other research institutes. In implementation service and software companies.

Funding: Can be part of existing or new R&D programmes and product development.

7.2.2 Process and contractual issues of integrated BIM

Technology is not the only issue related to the deployment of IFC compliant BIM. As already stated in section 7.1.2, most AEC/FM companies have no incentives to use integrated BIM or data sharing to optimize the whole project. This requires tangible evidence of benefits and also the new business models and contracts.

7.2.2.1 Evidence of benefits of integrated BIM

As stated in section 6.2 many companies have seen the benefits of BIM, which can be verified by interviews, surveys and the general interest for BIM. However, as stated in 7.1.1 there is very little measured evidence of the benefits. The objective measurement is difficult for several reasons; fuzzy baseline because of the one of a kind products and difficulty to identify the reasons for success or failure because multiple factors affect in the end-results and are difficult to standardize in the measurements. Another issue is that the benefits are not equal to the AEC/FM companies. The impacts of the use of integrated BIM can vary significantly depending on the domain and company's business model.

However, measured evidence is important for the industry to be able to evaluate the profitability of the investments in integrated BIM. Some efforts on this area have been done (for example, CIFE 2007, VBE II 2007), but the results are mostly anecdotal information on how companies see the results. More research of the topic is absolutely needed.

Recommendations for actions:

Type of action: Research and publications of the business impacts of integrated BIM.

Action priority: High, but difficult to make in phase 1 since there are so few real projects. Thus, moved into phase 2 in the roadmaps (Figures 19, 21 and 23).

Needed actors: Global, EU, regional and national efforts possible. Universities and other research institutes. Data is needed from the AEC/FM industry.

Funding: Public research funding.

7.2.2.2 Modelling guidelines for integrated BIM

The integrated BIM-based processes are significantly different compared to the traditional document-based AEC/FM processes. This has already created a need to develop practical process and modelling guidelines, and such development is on-going in several countries (5.4), sometimes even on company level with little if any collaboration. However, having several slightly different guidelines in the future would be confusing for the industry. Thus, international collaboration in defining modelling guidelines is an important action item in deploying integrated BIM.

Some of the major building owners and other public authorities (GSA and USCG in USA, Danish Enterprise and Construction Authority in Denmark, Senate Properties in Finland, Statsbygg in Norway and PSIBouw in the Netherlands) have already agreed on collaboration and prepared a Memory of Understanding. In addition Senate Properties (Finland) has already started to

translate their BIM guidelines in English and Statsbygg (Norway) will do the same after their guidelines have been finalized. The next discussions about the collaboration will be held in connection to the International buildingSMART conference in November 2007 in Brisbane, Australia. Queensland Government will act as the host and possibly join the group.

Recommendations for actions:

- Type of action:* Definition of detailed modelling methods, information content and deliverables at different project stages.
- Action priority:* High, and already done or on-going in several places. This action belongs in phase 1 in the development roadmaps (Figure 30, Figure 32 and Figure 34).
- Needed actors:* Global, EU, regional and national efforts possible. Owners, other AEC/FM companies and consultants, possibly also universities and other research institutes.
- Funding:* AEC/FM, currently mainly large institutional building owners. International collaboration may need some additional public funding if seen as an important action.

7.2.2.3 Process development for integrated BIM

While the modelling guidelines address specific needs and possibilities using current IFC compliant software, the process development has also a wider perspective. Current implementations are based on the document-based paradigm processes and thus not necessarily optimal for integrated BIM processes; which would be the optimized processes if they are re-engineered without the old limitations? The thorough process re-engineering is mainly a research issue, but immediate practical process development must be done on the company or professional association level.

Recommendations for actions:

- Type of action:* Research of optimal integrated BIM processes.
- Action priority:* High for the development of processes to benefit from integrated BIM, and already done or on-going in several places. This action belongs in phase 1 in the development roadmaps (Figure 30, Figure 32 and Figure 34). The full re-engineering requires significant time and effort and will continue also in phase 2.
- Needed actors:* Global, EU, regional and national efforts possible. AEC/FM companies and/or professional associations developing their internal, supply chain or domain processes. Universities and other research institutes for the full re-engineered processes.
- Funding:* AEC/FM companies and public research funding to the respective parts of development.

7.2.2.4 Contractual models

Moving into integrated BIM processes will raise questions of contractual issues, such as, task definitions, binding order and validity of different documents and BIM, IPR, use of the models for different purposes, libraries by third parties if delivered as a part of a mode, etc. These issues must be addressed before the wide utilizations of BIM.

Recommendations for actions:

- Type of action:* Development of new contract models
- Action priority:* High. This action belongs in phase 1 in the development roadmaps (Figure 30, Figure 32 and Figure 34).
- Needed actors:* Global, EU, regional and national efforts possible.
- Funding:* Professional AEC/FM associations and construction clients.

7.2.3 Human issues of integrated BIM**7.2.3.1 Education of integrated BIM**

Most of the current AEC/FM education in the universities and other educational institutes is based on the traditional document-based processes, even if they teach how to use modelling software. There is an immediate need for education on the usage of the new tools and processes for the current AEC/FM professionals. In the longer term there is a need to change the AEC/FM curricula. Only a handful of universities provide education based on integrated BIM processes (5.8). In addition to these universities, CIB (International Council for Research and Innovation in Building and Construction) has recently recognized this need and integrated BIM education is one of the key elements in CIB's new focus area "Integrated Design Solutions" (IDS), which just started its work in June 2007. Sharing educational and research ideas, information and material among the interested institutes are crucial elements needed to speed up the development of courses to meet the future requirements of the industry. CIB IDS could serve as a global platform for these activities.

Recommendations for actions:

- Type of action:* Education of the new tools and processes for current AEC/FM professionals and development of integrated BIM curricula for AEC/FM education.
- Action priority:* High. Education of the current professionals belongs in phase 1 in the development roadmaps (Figure 30, Figure 32 and Figure 34). Development of the new curricula belongs in phase 2 in the roadmaps (Figures 19, 21 and 23).
- Needed actors:* Global, EU, regional, national and organizational efforts possible. Universities and other educational institutes are the crucial actors, research institutes and AEC/FM companies can help in providing material and other help.
- Funding:* Part of educational system, in Nordic countries, public funding.

7.2.3.2 Promotion and collaborative efforts of integrated BIM

Currently AEC/FM companies are clearly interested in BIM and IFC compatibility, especially in Nordic countries based on the results of the questionnaire (Appendix - own survey). Among the most active collaborative initiatives at the moment are, for example, buildingSMART in Norway and NBIMS in USA. In Denmark the IFC compliant model requirement for public building projects was defined by a law in the beginning of 2007, and in Finland Senate Properties requires extensive use of models in their projects starting after October 1st, 2007. The basis for Finnish activities related to integrated BIM were created already in the VERA programme in 1997-2002 and the public support continued in the SARA programme in 2003-2007.

Based on the results of the questionnaire in this study, the nation-wide efforts have influenced the market, but obviously with relatively long delay which is visible when comparing use of IFC compliant BIM in Finland and in Norway (5.1.4).

The next step should be moving from national focus towards larger efforts; Nordic, EU and global collaboration in defining R&D agendas and industry requirements as well as doing actual R&D collaboration. An example of such collaboration is the proposed collaboration of large building owners in defining next generation BIM guidelines (7.2.2.2).

Recommendations for actions:

- Type of action:* International collaboration in defining R&D agendas and industry requirements. Joint international R&D projects.
- Action priority:* High in those countries where it is not yet done or on-going. This belongs in phase 1 in the development roadmaps (Figure 30, Figure 32 and Figure 34).
- Needed actors:* Global, EU, regional and national efforts possible. Focus should be in large international efforts
- Funding:* EU, regional and national funding agencies and international AEC/FM companies.

7.3 Prioritized steps - some potential roadmaps towards integrated BIM processes

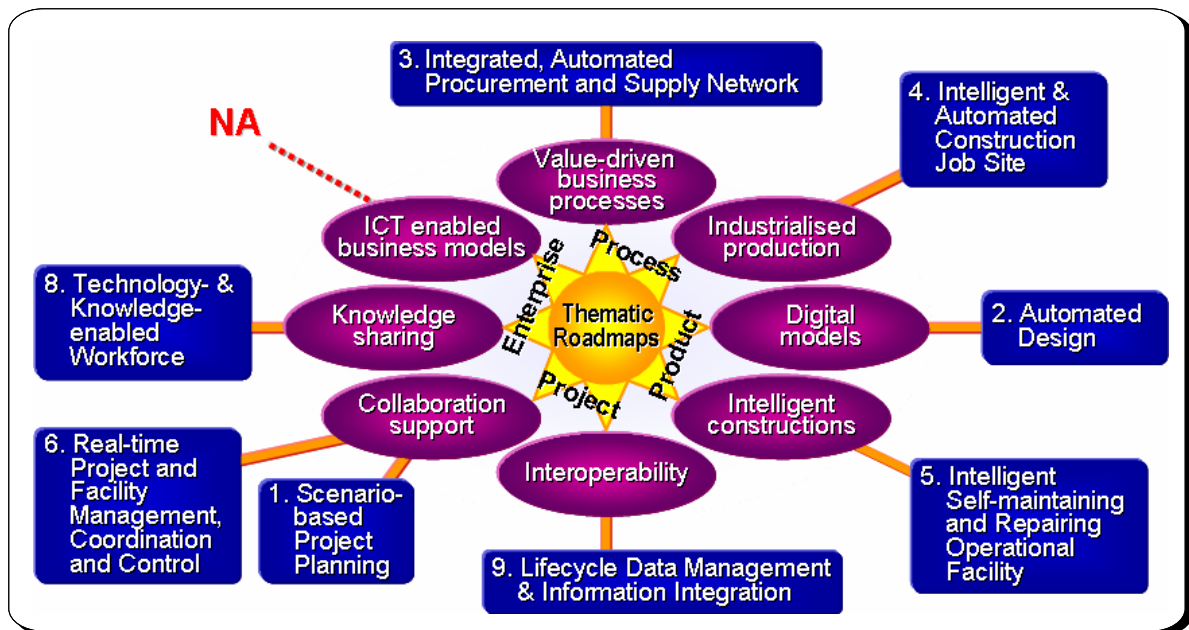


Figure 29: Mapping between the Strat-CON and Fiotech Roadmaps (source Strat-CON-Fiotech roadmap workshop, August 22-24, 2007).

Integrated BIM is a small part of the total R&D roadmap for AEC/FM industries. However, it affects several areas in the wider roadmaps, for example, in the Strat-CON roadmap it relates directly to at least to 5 of the 8 areas: Digital models, Interoperability, Collaboration support, Knowledge sharing and ICT enabled business models (Figure 29). The development path and speed will depend on the priorities, resources and activities of the different parties: building owners, contractors, designers and engineers, facility managers, building component

manufacturing industry, software vendors, universities and other research institutes, research funding bodies, etc. As described in 7.1.2 there are almost infinite number of factors influencing into the path and speed how this development could happen and this study discusses only three simplified options: strong private or/and public interest. The proposed time frames are naturally very rough and based on an optimistic scenario; the actual speed can vary depending on the amount of available funding and human resources.

All scenarios are divided into two phases. All issues in phase 1 are high priorities for adoption of the existing integrated BIM. The issues in phase 2 have lower priority or are possible only after phase 1 with relatively wide adoption of existing integrated BIM.

7.3.1 Strong private demand: Integrated BIM in the core of companies' strategy

As described in 7.1.1 the adoption of systemic innovations, such as integrated BIM, is slow and difficult to implement since it affects the business environment of several individual companies. If only private drivers exist without any public support and funding the change can take a very long time. In the subject of this study this is clearly visible; the use of IFC compliant BIM in projects is much higher in Finland than in other Nordic countries (see Figure 4), but the development changed rapidly in Norway and Denmark immediately when the public interest and support emerged.

However, the situation of IFC compliant BIM is very different than it was 1997 when the VERA programme started in Finland, and the following roadmap sketches (Figure 34 and Figure 35) are based on the current state-of-the-art.

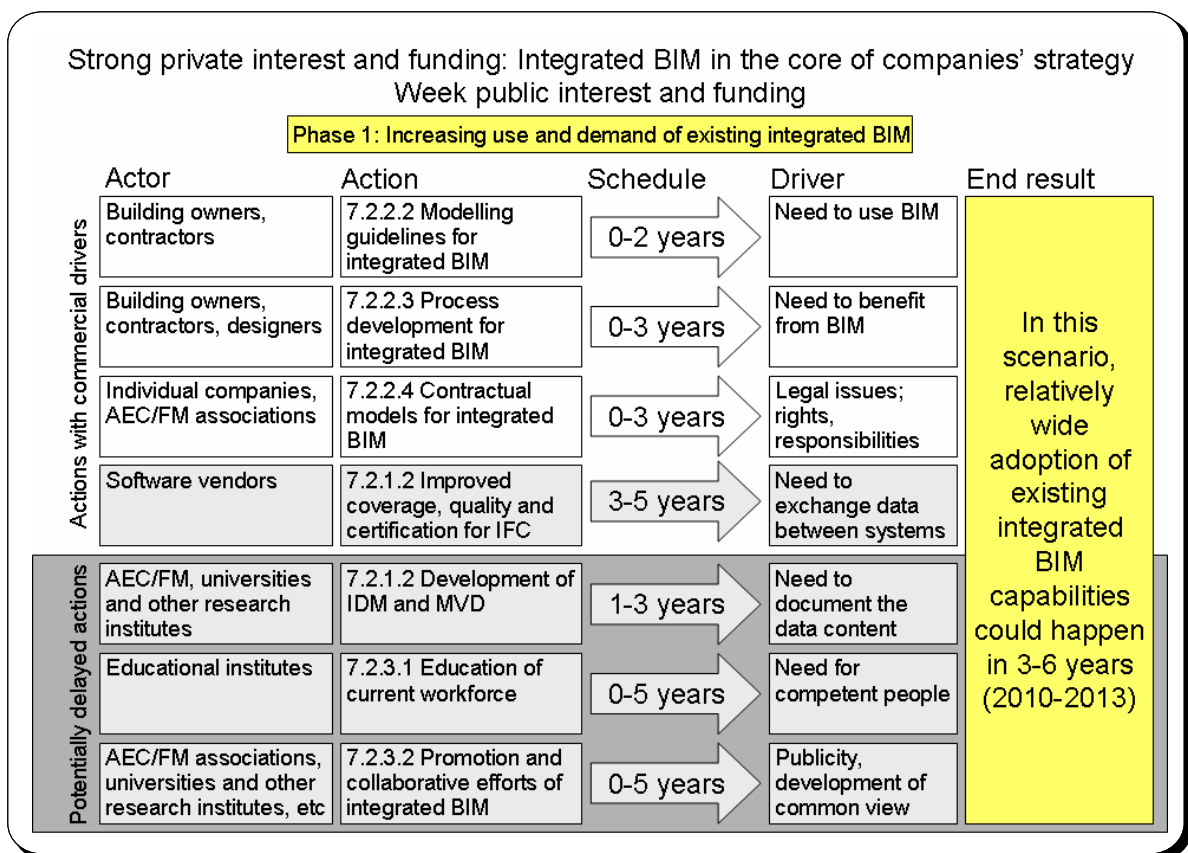


Figure 30: Phase 1 in private driver scenario.

Some owners and contractors have already started to use integrated BIM in their processes, but very seldom based on IFCs because of the insufficient quality of IFC implementations. In any case, on company level, supply chain level or project consortium level it is possible to use integrated BIM based on some compliant software products. Thus, the timeframe to implement modelling guidelines, develop processes and new contract models is possible within 0-3 years. Actually several companies have already done this on some level.

The implementation of high quality IFC support is a commercial issue; it must be a business case for vendors and it has been the biggest bottleneck in the past and in our opinion will continue to be that without sufficient investment into robust quality assurance and certification process. It seems very unlikely that this will happen based on sole private demand since sufficient commercial demand will not emerge without good implementation quality as stated in 7.1.1. Thus, the estimation, 3-5 years can be very optimistic (Figure 30). It may be more likely, that different proprietary systems will emerge and dominate market instead of open international standards.

In addition, development of data exchange use cases (IDM and MVD), educational programmes and promotional efforts of integrated BIM based on sole private demand and funding can be very difficult. There are already some efforts in that area, but not enough to create the critical mass. It is likely, that without some public support these areas will not develop as needed to support the adoption of integrated BIM.

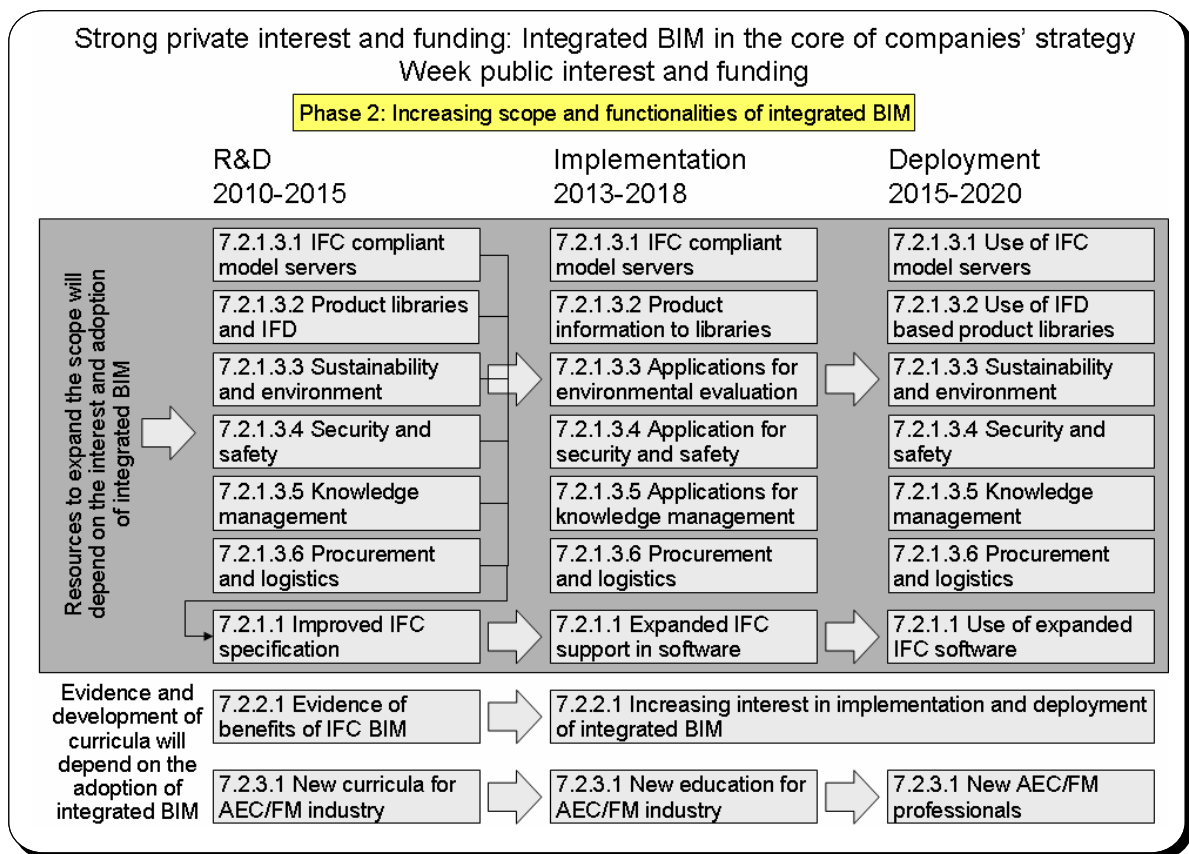


Figure 31: Phase 2 in private driver scenario.

Figure 31 illustrates one potential scenario of phase 2 with private interest only. The timing for expanded scope and functionalities of IFC compliant BIM is hypothetical since it will depend on the adoption of the existing integrated BIM (Figure 30). In addition, development of the new

features based on sole private funding is very unlikely. Likewise, the new curricula for AEC/FM professionals in universities and other educational institutes based on sole private funding without significant public support is not easy to implement. Thus, the timeframe to deploy any of the new features extensively in the industry will inevitably take long time in this scenario.

7.3.2 Strong public demand: 'Infrastructure' for integrated BIM

This scenario is a "mirror" of the previous one; strong public interest without private support. Based on the experiences, this scenario seems rather theoretical; in Finland, Norway and Denmark the public interest and support has rapidly generated interest and support in the private side as well. Thus, the timeframe of this scenario in Figure 32 is probably pessimistic. The reason this scenario is discussed is to high-light some characteristic differences of the public and private support.

Public support can easily generate publicity, promotion of ideas, educational programmes and different standards for data exchange (IDM and MVD). However, it cannot easily generate sufficient market for IFC compliant software – especially on small markets such as the Nordic countries. Thus, the robust tools can be missing and thus the deployment of integrated BIM based on open standards, such as IFC, can be delayed. One way to influence the market is the demand of the use of IFC compliant BIM in projects owned by public building owners, which has already started in Finland and Denmark and is happening in Norway. This effect can be fortified by the collaboration of public owners, which is already happening.

Public support can also create a robust certification process for IFC compliance, and thus strengthen the market demand for an open standard by providing reliable tools based on it.

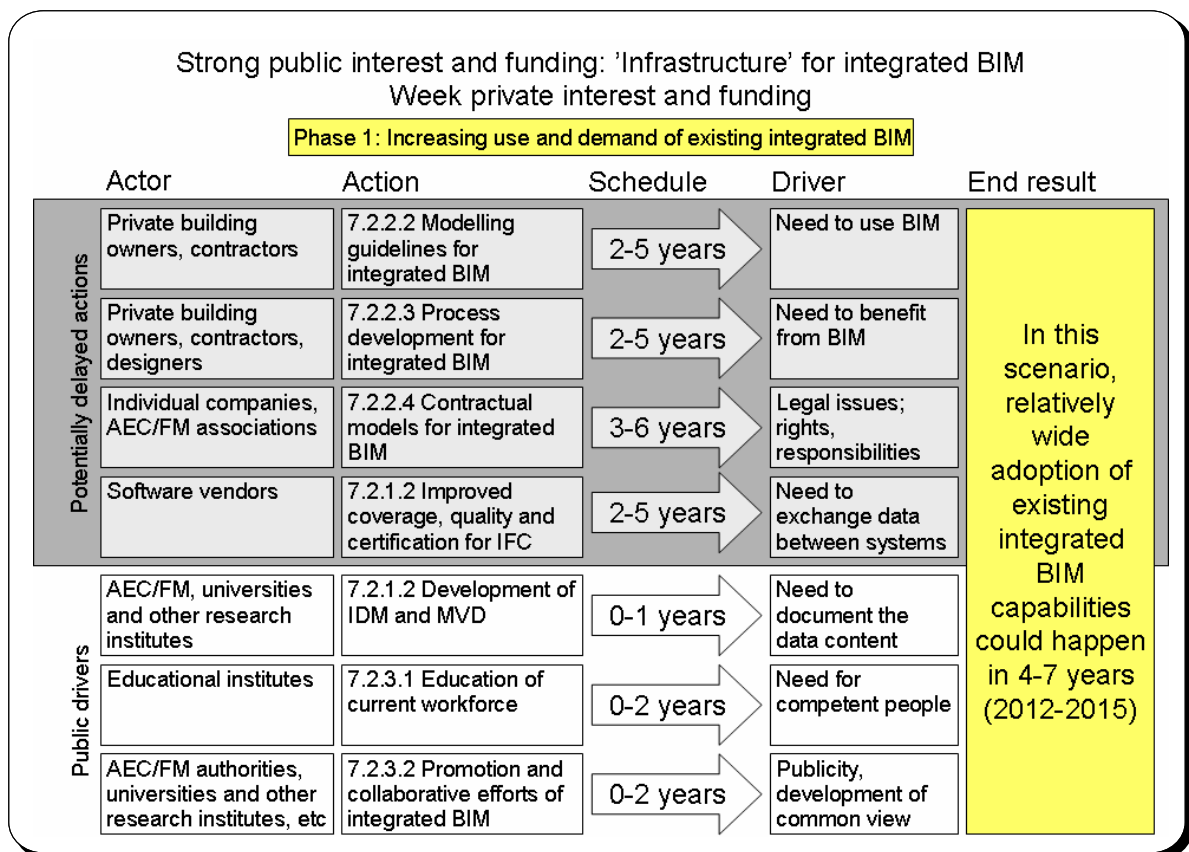


Figure 32: Phase 1 in public driver scenario.

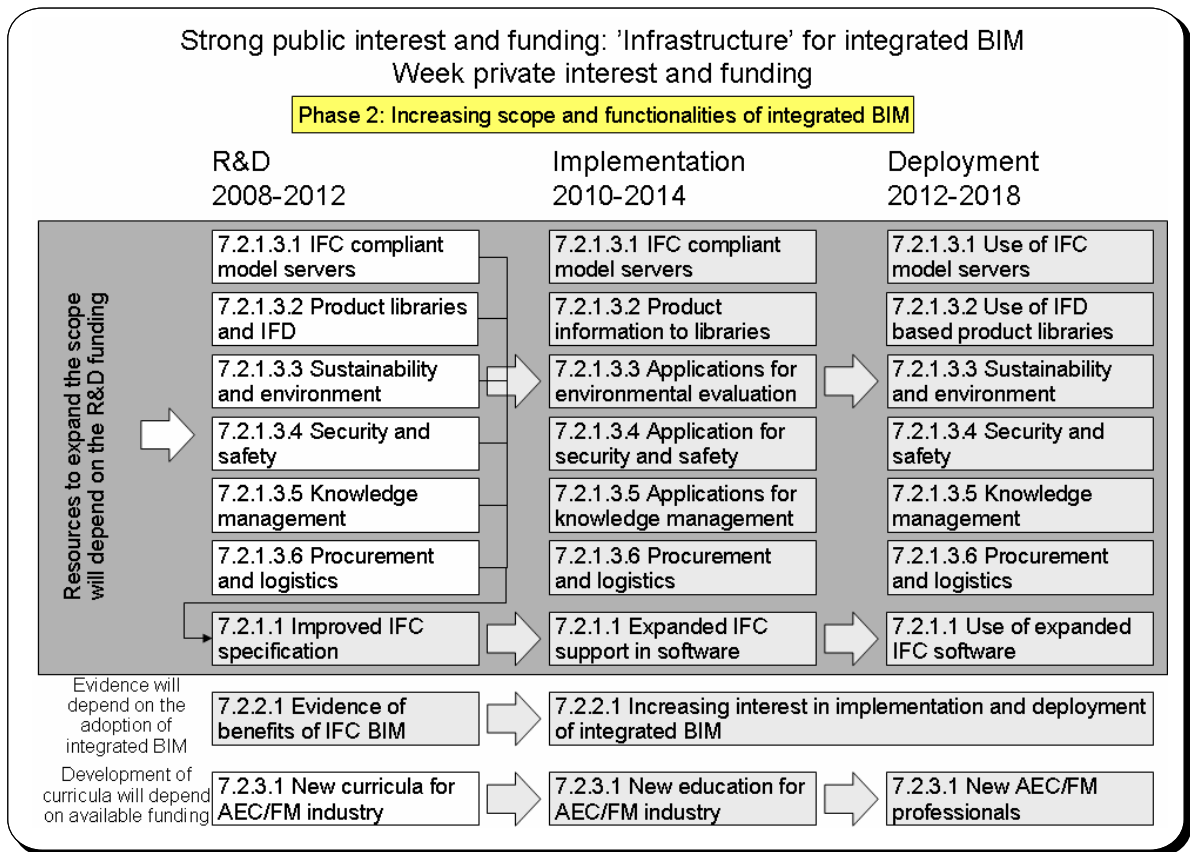


Figure 33: Phase 2 in public driver scenario.

When looking at phase 2 (Figure 33) the difference of public drivers compared to private drivers is clearly visible; development of increased scope and functionalities as well as integration of these features in the IFC specification can start already before the market has fully adopted integrated BIM. This means that the implementation and deployment of these technologies can happen immediately after adoption of the existing integrated BIM without such delay as in Figure 31 based on the sole private support.

7.3.3 Strong public and private interest and funding for integrated BIM

Obviously the combination of public and private interest and funding is the most effective one; private demand creates the market and public support helps to fill the “voids”; common development needs which are necessary but not easy to fund in the private side.

Looking at the current IFC compliant BIM state-of-the-art, it is possible to move into relatively wide adoption of integrated BIM in the Nordic countries and the Netherlands within 1-2 years. However, this demands active R&D policy by private companies and public actors (Figure 34).

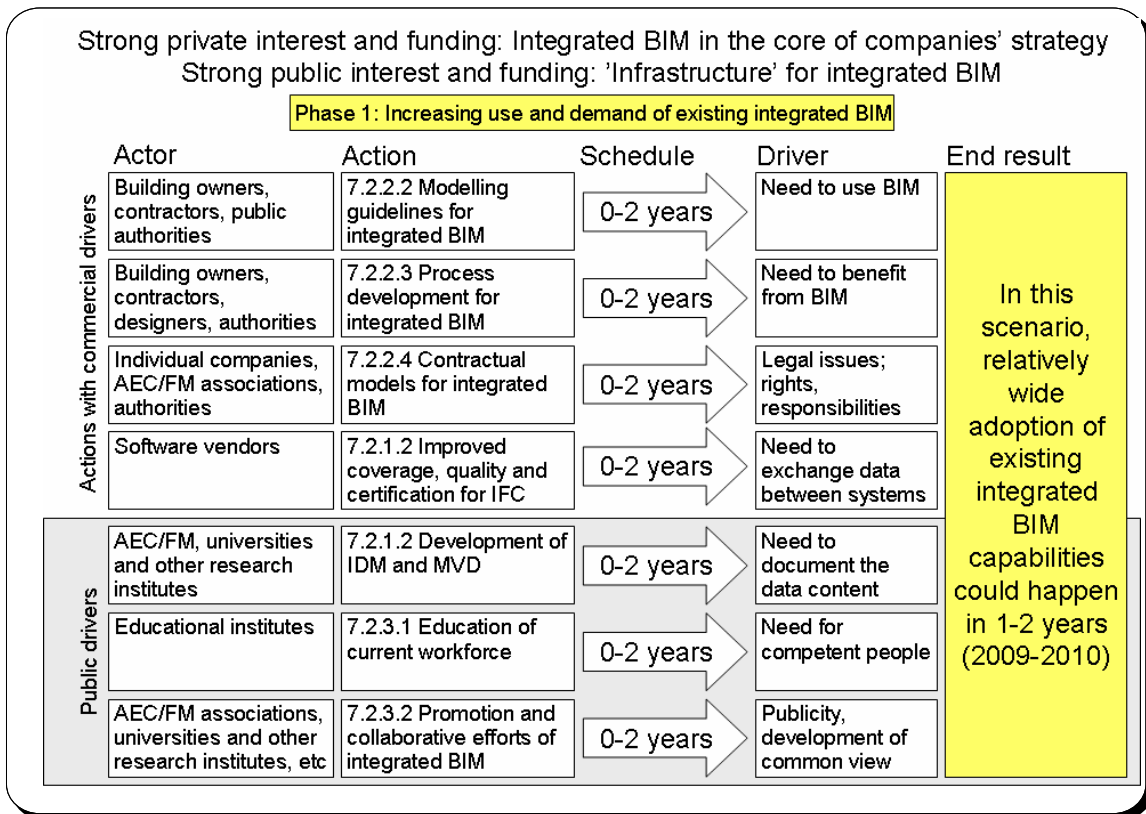


Figure 34: Phase 1 in public and private driver scenario.

Similarly, strong public and private interest makes phase 2 faster and more feasible by speeding up the research processes and reducing the uncertainties of commercial implementation and deployment (Figure 35).

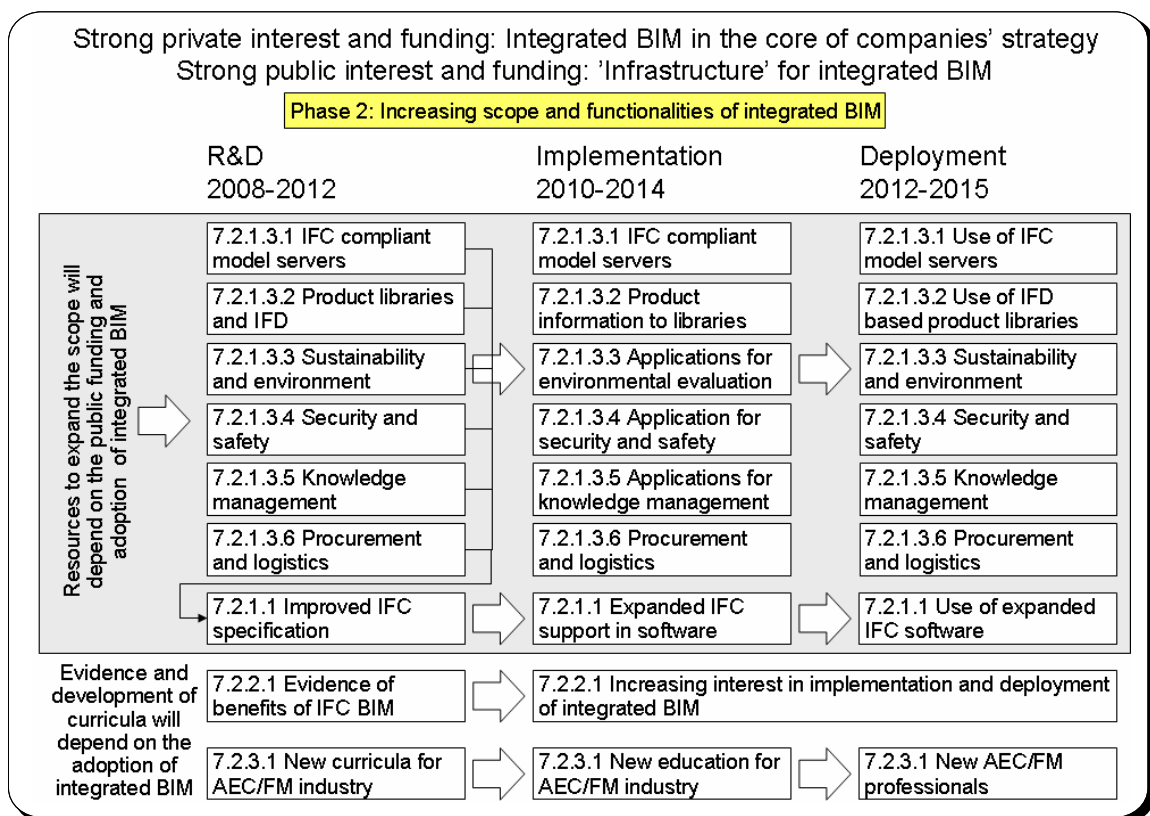


Figure 35: Phase 2 in public and private driver scenario.

7.4 Conclusions of Area 3: Necessary future steps to move towards the use of integrated BIM processes

Deploying new technology, such as integrated BIM, is a challenging task when done on the level of an industry cluster, such as AEC/FM. One possible solution is to leave the issue to the markets to decide; the feasible solutions will prevail in the long run. However, it is a slow and unpredictable path forward. If there is a will to influence actively in the development of the technology and processes, we must identify the key factors and try to influence through them.

The biggest obstacle for the deployment of integrated BIM is clearly the lack of robust and reliable software support for IFC data exchange and sharing. Thus, creating enough market demand to make the implementation effort tempting for software companies and creation of reliable certification process are the highest short-term priorities. Similar, short term necessity is establishing standard processes and contractual models for the use of integrated BIM in the same way as AEC/FM has had standard procedures for the document-based processes.

In longer term, need for efficient collaboration platforms (IFC model servers), education for new processes, improved analysis and simulation tools and improved and expanded IFC specification are obvious. Facilitating the implementation of IFC support and improving the performance of the models by reducing the complexity are important parts of the next generation IFC specifications.

Nordic countries (in this context including the Netherlands with very similar culture) have a significant advantage in adopting new technologies; the small population, intense networks and flexible, goal oriented working methods combined to low litigation risk enable testing and adopting new technologies much faster than in large market areas, such as USA or UK; alignment of innovations in the networks can be much faster (Taylor and Levitt 2004b). This fact among the other potential Nordic strengths was also identified in the recent press release by the Finnish Ministry of Trade and Industry (MTI 2007), which as the result of a Nordic meeting proposed intensifying the Nordic innovation collaboration and creation of joint Nordic "Innovation Embassies" especially in the Asian market. Integrated BIM combined with the Nordic environmental and energy know-how could be one focus area in such collaboration.

8 Conclusion

8.1 Current Status and Lessons Learned

The IFC standard is generally agreed to be of high quality and is widely implemented in software. However, the certification process allows poor quality implementations to be certified and essentially renders the certified software useless for any practical usage with IFC. The IFD Library is also generally seen to have the potential to solve many real world problems. However no implementation support in off the shelf software exists at the moment. As for IDM/MVD, the standards are still under development, and although certain proofs of concepts exist, it is not yet ready for implementation in off the shelf software.

The academic institutions have started programs around these new opportunities but should increase their activities to meet real demand in the industry. Drivers for development and deployment appear to be large public clients and public funding. The issues with certification and better implementation of Integrated BIM must be addressed through these drivers.

Through the results of our survey we show that CAD is still the major form of technique used in design work (over 60%) while BIM is used in around 20% of projects for architects and in around 10% of projects for engineers and contractors. IFC compliant BIM is actually used less than manual drafting for architects and contractors, and show about the same usage for engineers.

8.2 Necessary Future Steps

We recommend a set of steps to improve the deployment and usage of Integrated BIM, which depends on the three open international standards, IFC, IFD and IDM/MVD, and their implementation in software and business processes. Furthermore, we show that strong public interest and funding lead to strong private interest and funding in the same field, and combined these drivers yield the fastest development track towards the buildingSMART vision.

8.2.1 Technical Recommendations

- Continued incremental improvement of the IFC specification with predictable release cycles is necessary. The improvements should be user driven, dictated from business needs. The specification should move towards a modular base, enabling focused improvements with less overall impact of existing implementations
- Implementation of IFD in real usage scenarios should be started, preferably with software in the early phase of the building process, and continue with other software as the process demands. Continued efforts to improve the technical aspects of the IFD Library must be ensured. Standard IFD based Product Libraries should be developed
- Production of software ready IDM/MVDs and implementation of these is necessary in real project scenarios. This should be done in parallel with the standard specification of IDM/MVD
- An Integrated BIM depends upon ability to merge models from various sources, efforts to develop open technology to improve this process is called for

8.2.2 Process Recommendations

- The software certification process for IFC is currently insufficient to ensure dependable software in real world projects. This must be improved, and using IDM/MVDs to build a new certification process looks promising. Similar care must be taken when developing certification for IFD related software
- USA, Finland, Norway, Denmark, Germany, Singapore and Korea are all currently working on BIM Guidelines. It is important to ensure that continued high quality efforts goes into this work, and that proper funding can be secured for an international BIM Guideline
- Integrated BIM will have impact on contractual and process issues in the AEC/FM Industry. Continued collaborative efforts to study this impact and suggest solution to challenges presented is important and must be secured
- Studies to demonstrate the business impact of implemented buildingSMART technology in the AEC/FM Industry should be carried out

8.2.3 Political Recommendations

- Large public clients should be early adapters and set proper demands in the market to drive the implementation and development of buildingSMART technology forward. Public authorities must follow up with significant funding to ensure the proper long term development and implementation speed. We acknowledge that a free market approach will not suffice to ensure the necessary open standards based foundation. However, when sufficient demand in the market is created, a free market approach is desired for further development. This is in agreement with similar earlier efforts, like the development of the Internet
- Further stimulation and support to academic institutions to ensure long term research and educational programs in this field is important
- Finally, continued and increased international collaboration is important to ensure the full potential of these open international standards

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10 Appendix 1 - Own Survey

The project has carried out an own survey distributed in Denmark, Finland, Norway, Sweden and the Netherlands. This appendix captures some detailed results of the survey. The survey questions were designed by the project team based on their knowledge. The questionnaire, as it was presented to the respondents, is at the back of the appendix.

10.1 Target groups and responses

The target groups for this survey were main actors in the building value chain.

The questionnaires were sent out in June, July and August 2007, with some reminders. In the Netherlands the questionnaires were sent out in the middle of September. The requests were distributed by e-mail with information and a link to the database at VTT in Finland. The questions were performed both in English and Danish.

The total response was to some extent influenced by the vacation period in the summer.

Denmark

The questionnaires were distributed to:

- Members of IAI Forum Denmark
- Implementeringsnetværket (implementation of the Digital Construction)
- bips: construction - IT - productivity - cooperation (large user organization)
- IT group within The Danish Association of Construction Clients
- All Engineering offices member of the Danish Association of Consulting Engineers
- IT group from The Danish Construction Association
- Danish Association of Architectural Firms
- Asked The Confederation of Danish Industries and the Unions - not sure about the outcome.

The survey includes 51 respondents from Denmark, with good response from architects and multidisciplinary engineering companies.

Finland

The Finnish distribution of the questionnaire:

- The Association of Finnish Architects' Offices (ATL)
- The Finnish Association of Consulting Firms SKOL
- SARA technology program network
- buildingSMART Finland network
- Finnish Association of Architects (overlaps strongly with ATL)

The request was sent also to the following associations:

- RAKLI - The Finnish Association of Building Owners and Construction Clients
- The Association of Finnish Construction Engineers and Architects RIA

The survey includes 58 respondents from Finland, with good response from architects and acceptable among engineering companies.

Norway

The Norwegian distribution was carried out in cooperation with:

- Rådgivende Ingeniørers Forening / Association of Consulting Engineers
- Tekniske Entreprenørers Forening / Technical Contractors' Association
- Boligprodusentene / Norwegian Homebuilders Association
- BuildingSMART / IAI Norway
- People related to some IFC / BIM research projects

The survey includes 198 respondents from Norway, with good response from all main domains in the target groups.

Sweden

The questionnaires were distributed in cooperation with:

- Representatives for professional associations (client owners, architects, structural and civil engineers, and mechanical engineers)
- Contractors' research organization
- Members of Swedish IAI Forum

The survey includes 64 respondents from Sweden, with good response from architects and acceptable from engineers.

Netherlands

The questionnaires were distributed from STABU in September with a reminder in October.

The survey includes 20 respondents from Netherlands, which is too low presenting the situation in the country. The answers from Netherlands are included in the totals.

Total

Table 10 shows total respondents and the domains which they represent. Architects and the "engineering group" are the predominant disciplines, but there is also sizable proportion especially from the main contractors.

The category "Other" includes software developers and providers, project managers, universities, research institutes, organisations, public services, financing, market information providers, government etc.

Responses	Denmark	Finland	Norway	Sweden	Netherlands	Total
Architect	13	24	40	35	1	113
Multidisciplinary Engineering	17	1	28	8	1	55
Structural Engineer	2	9	21	4	1	37
Building Services Engineer (both HVAC and Electrical)	2	3	3	1		9
HVAC Engineer		1	7			8
Electrical Engineer	1		6			7
Facility Management	3	1		3		7
Owner	2	1	6	2		11
Main Contractor	2	3	34	3	6	48
Building Services Contractor (both HVAC and Electrical)		1	4			5
HVAC Contractor			5			5
Electrical Contractor			11			11
Building material or component manufacturer		2	12			14
Other	9	12	21	8	11	61
	51	58	198	64	20	391

Table 10 Total respondents and domains.

Some figures present the total from Denmark, Finland, Norway and Sweden. Table 11 shows the main domain distribution within these countries.

Responses	Denmark	Finland	Norway	Sweden	Total
Architects	13	24	40	35	112
Engineers	22	14	65	13	114
Contractors	2	4	54	3	63
All others	14	16	39	13	82
	51	58	198	64	371

Table 11 Respondents and main domains in the Nordic countries

This appendix will present results and distinguish between:

- All in total
- Architects
- Engineers
- Contractors
- Architects in Denmark
- Architects in Finland
- Architects in Norway
- Architects in Sweden
- Engineers in Denmark
- Engineers in Finland
- Engineers in Norway
- Engineers in Sweden
- Contractors in Norway
- Manufacturers in Norway

Generally every respondent is equally weighted in this presentation of results. Some of the bigger companies are represented by respondents from different departments. To some extent this will compensate for the fact that bigger companies sometimes should have a higher weight than smaller companies.

In the introductory section the respondents were asked about their relations with buildingSMART and IAI (International Alliance for Interoperability) see Figure 36. Even though most of the respondents probably work in projects and in environments where BIM and IFC are part of the common language, the major part has not participated directly in the work so far. On the other hand the knowledge and experiences of working with BIM are increasing.

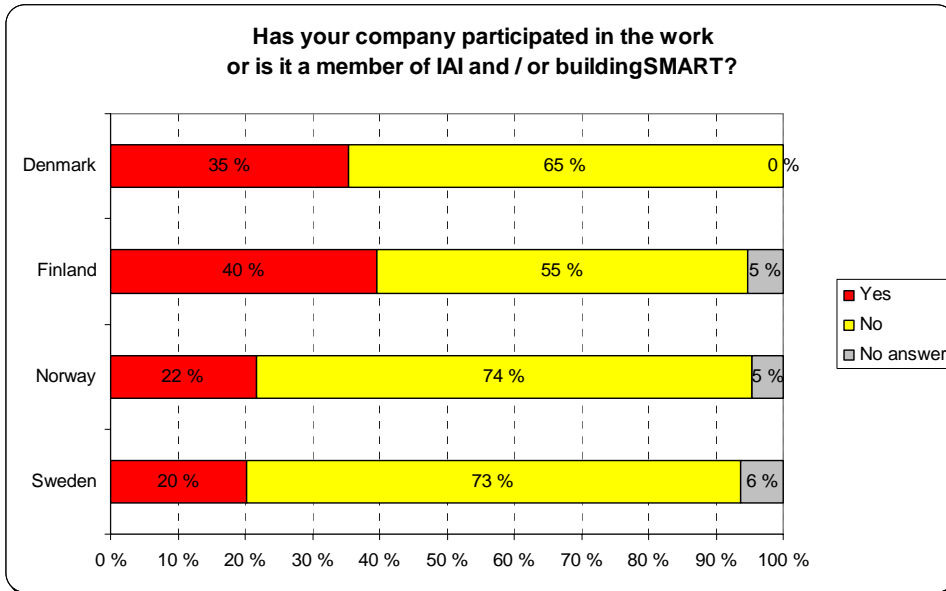


Figure 36: Respondents related to IAI or buildingSMART.

10.2 Techniques in design work and level of computerization

The first part captures techniques in design work and levels of computerization in general. Figure 37 shows the main techniques used in the design work. Traditional CAD (Computer Aided Drafting) is still the most used techniques for the main disciplines. The architects seem to keep ahead compared to engineers and contractors when it comes to using BIM.

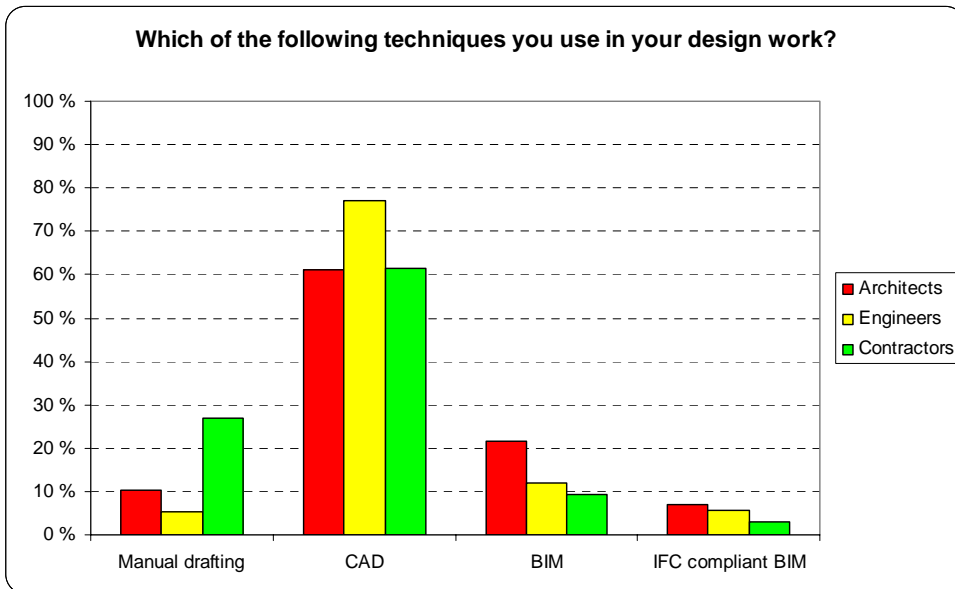


Figure 37: Techniques used in design work - main domains.

In Figure 38 the same issue is visualized when comparing the Nordic countries. Note that the use of BIM in Sweden in this figure seems to be unexpected high. When studying Table 11, Figure 37 and Figure 38 we see that the reason for this is due to the relatively part of architects among the Swedish respondents. The result for using BIM in Sweden would have been a little lower in Figure 38, when weighting with respect to disciplines or company sizes. Figure 39 shows the same issue among architects in the Nordic countries.

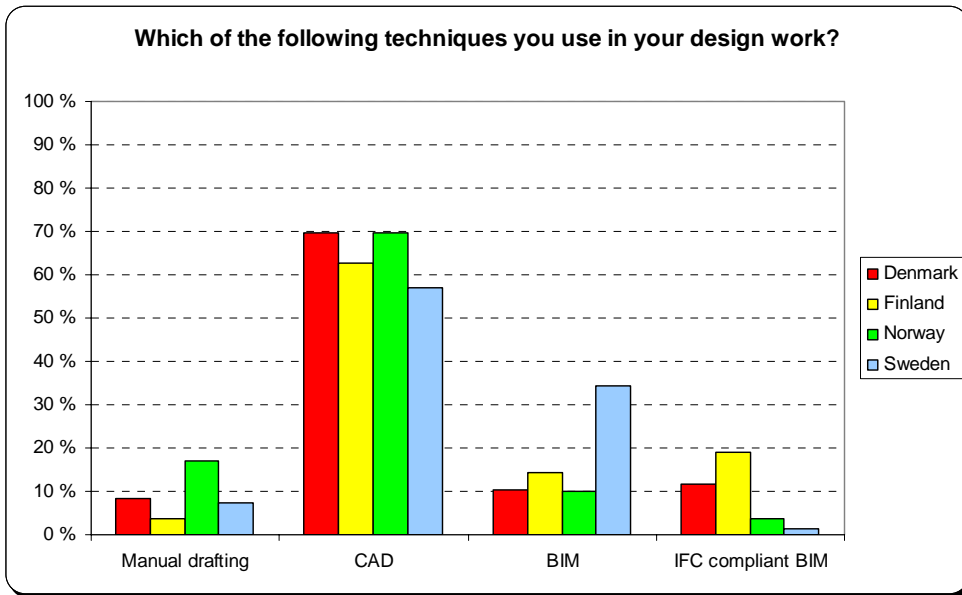


Figure 38: Techniques used in design work - countries.

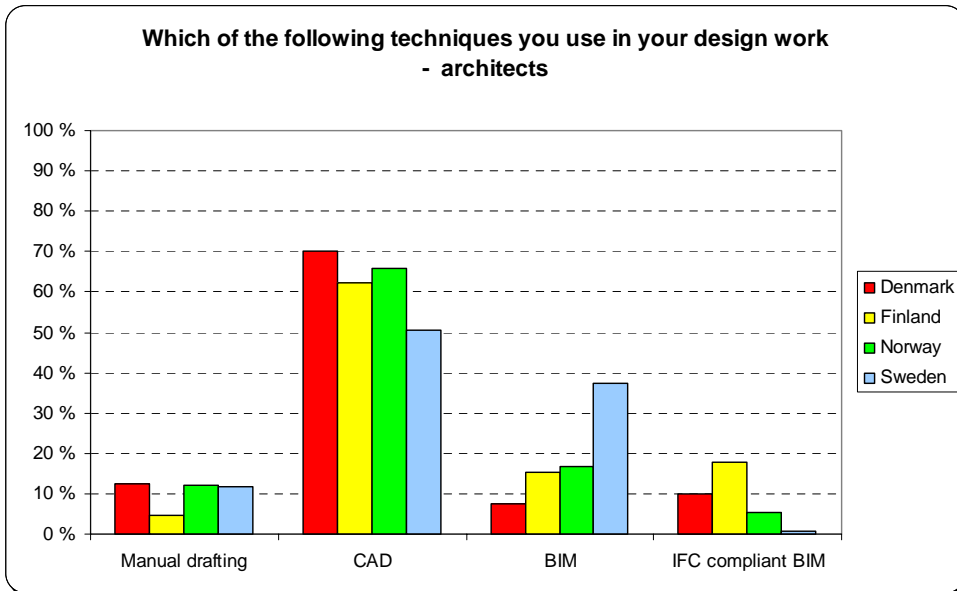


Figure 39: Techniques used in design work - architects / countries.

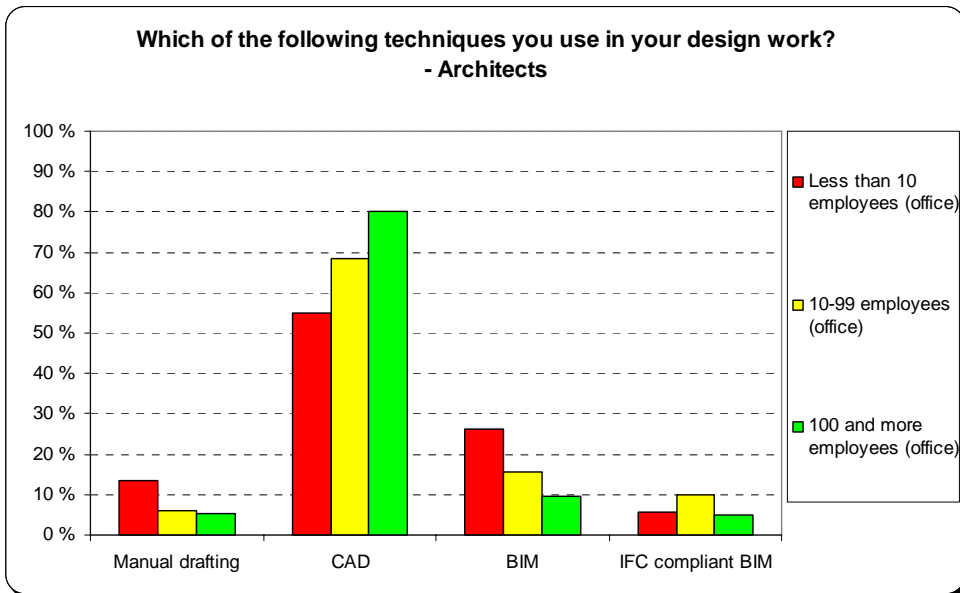


Figure 40 Techniques used in design work - architects with different company sizes.

Figure 40 shows the architect companies with three different groups of size; 1) Less than 10 employees, 2) 10-90 employees and 3) 100 and more employees.

What about the changes during the last years? In Figure 41 the respondents express changes in the last two years. Even though many actors have no opinion about BIM, one third claims they have increased use of BIM.

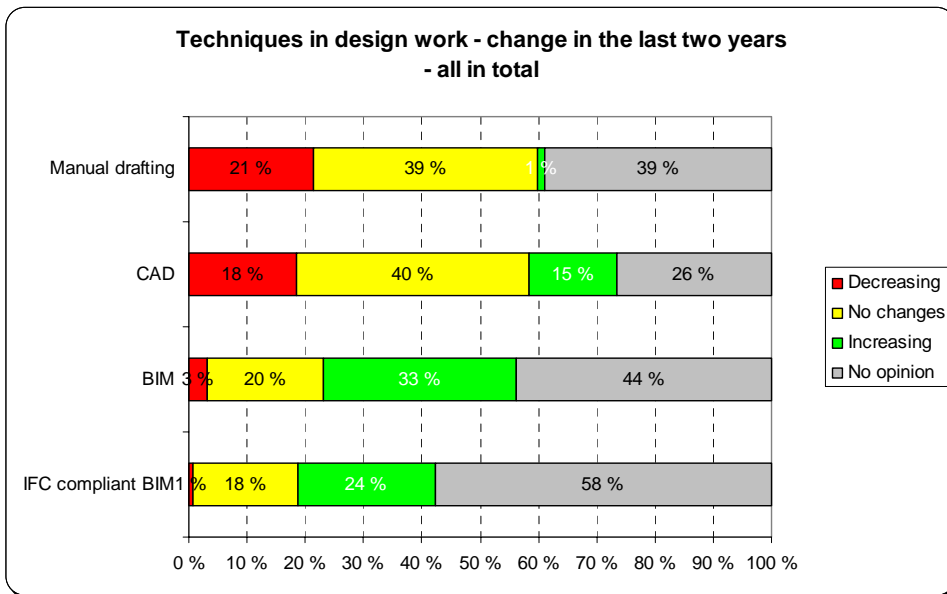


Figure 41: Changes in techniques used in design work - all in total.

Change in use of techniques is of great interest. It seems obvious that BIM and IFC compliant BIM has increased at the expense of manual drafting and CAD. Figure 42 to Figure 48 show the same topic for different disciplines and countries.

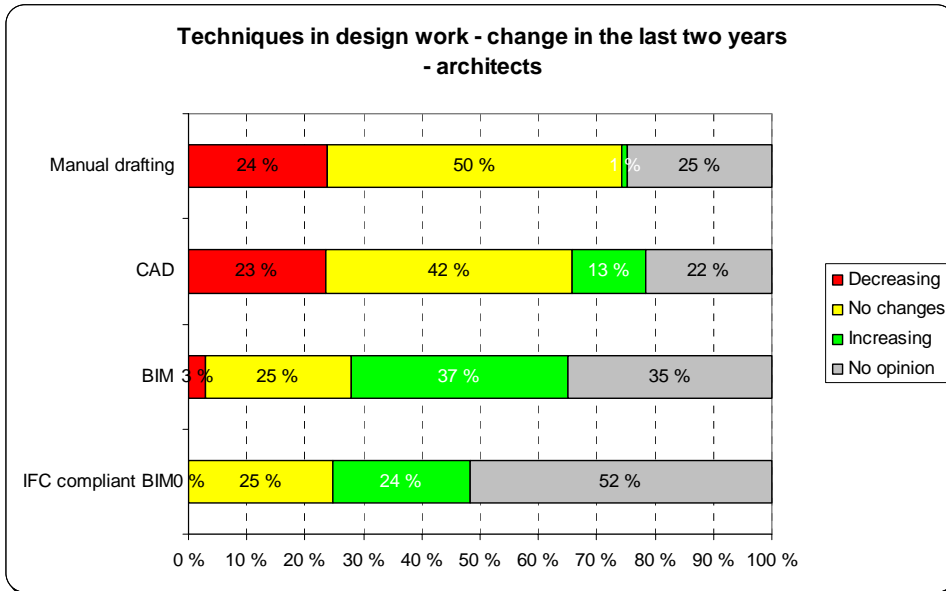


Figure 42: Changes in techniques used in design work - architects.

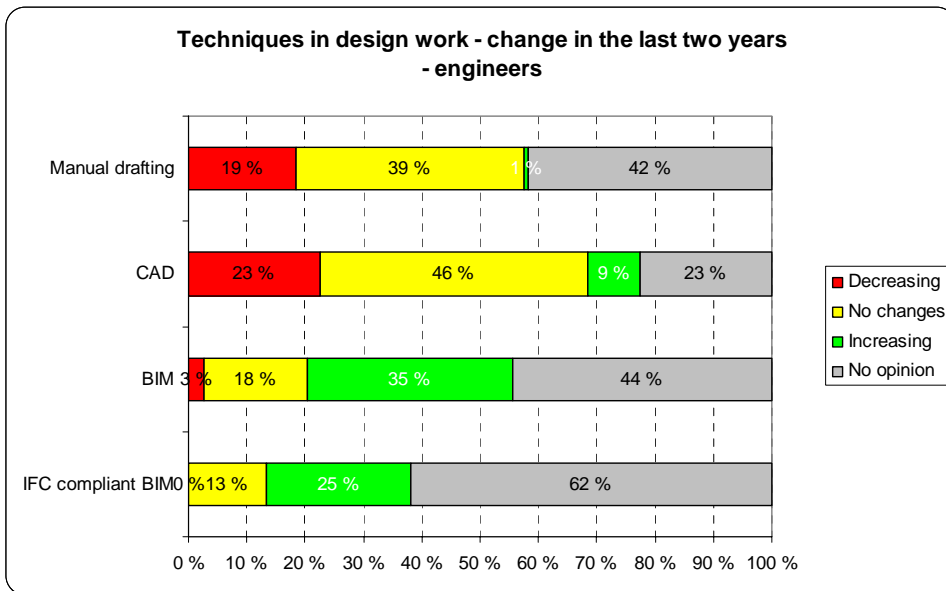


Figure 43: Changes in techniques used in design work - engineers.

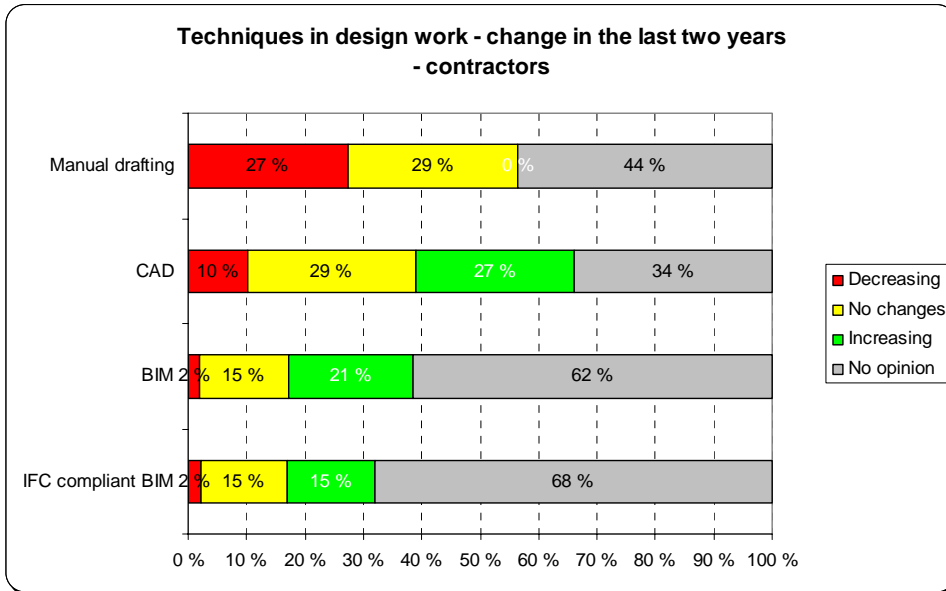


Figure 44: Changes in techniques used in design work - contractors.

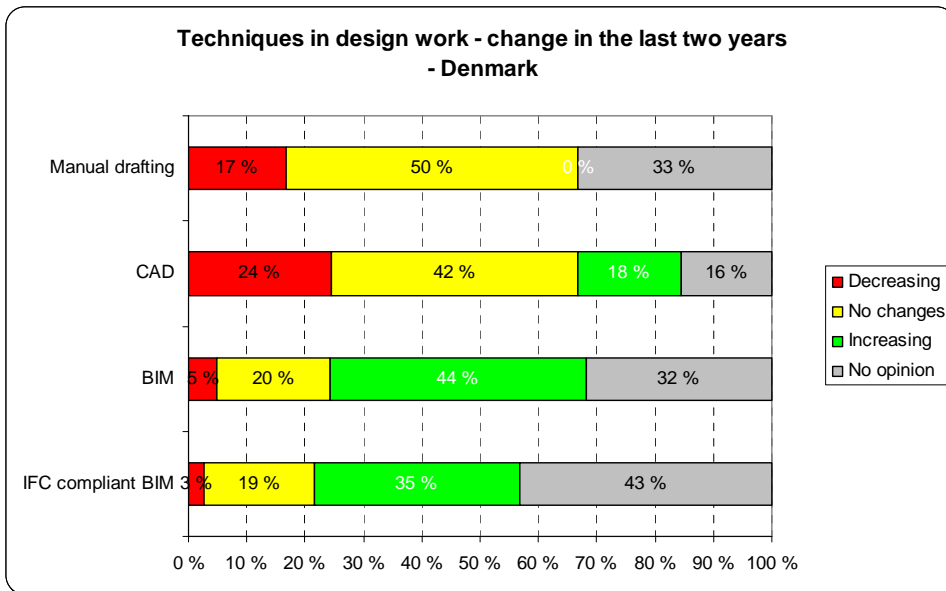


Figure 45: Changes in techniques used in design work - Denmark.

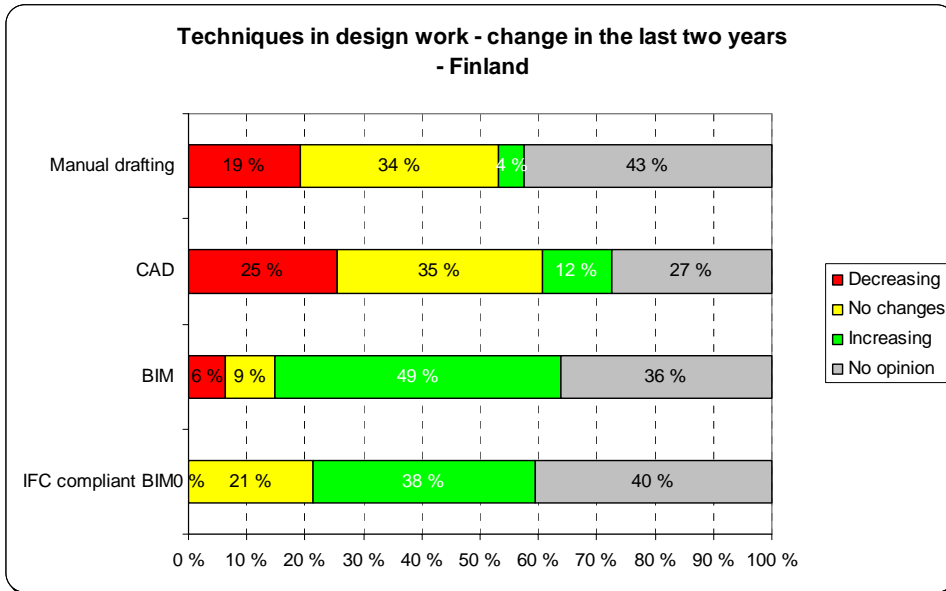


Figure 46: Changes in techniques used in design work - Finland.

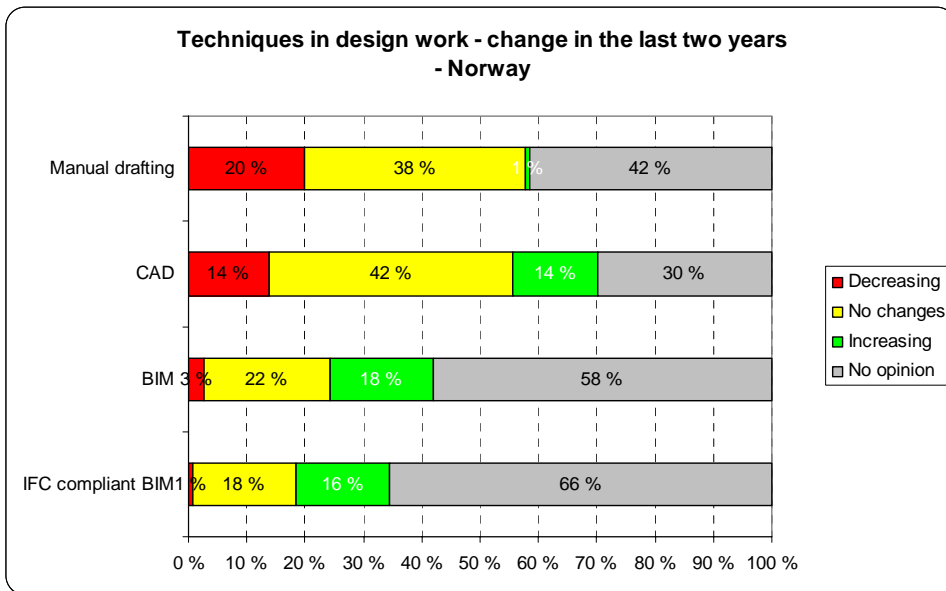


Figure 47: Changes in techniques used in design work - Norway.

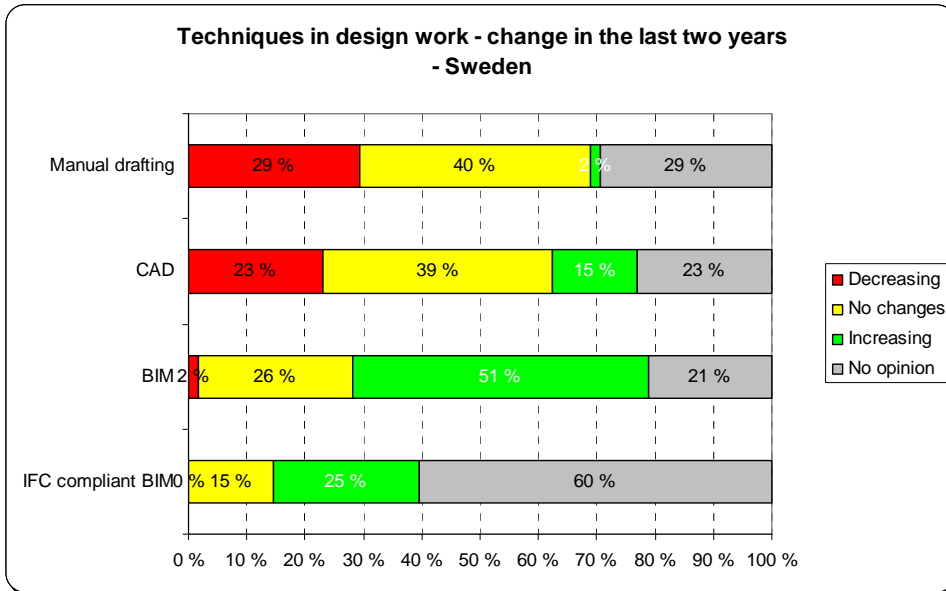


Figure 48: Changes in techniques used in design work - Sweden.

10.3 Level of computerization

The actors' level of computerizations is a kind of point of departure for using more advanced tools. Not surprisingly activities like "technical specifications" and "technical calculations" are most computerized, se Figure 49 to Figure 53. These activities are on the top for all the main domains.

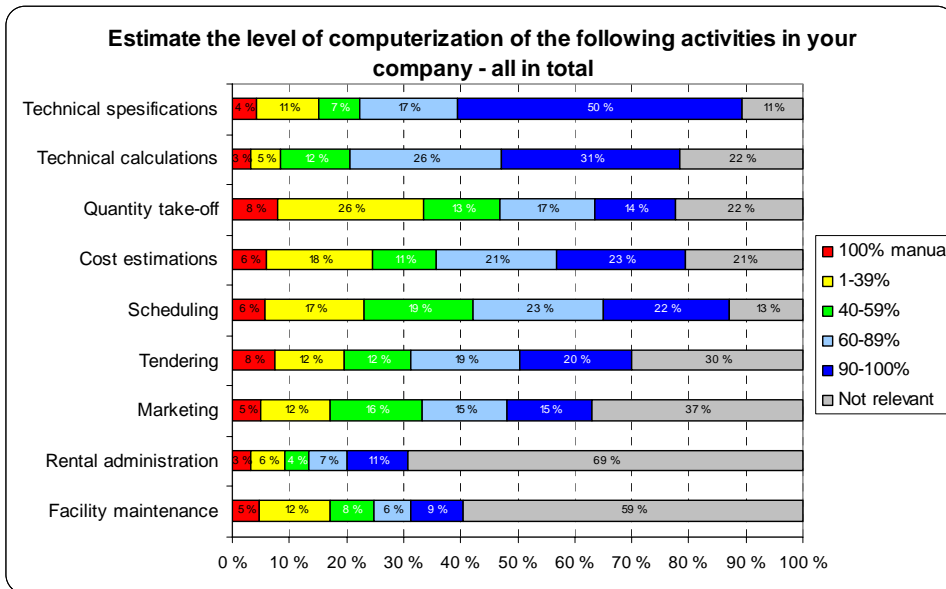


Figure 49: Level of computerization - all in total.

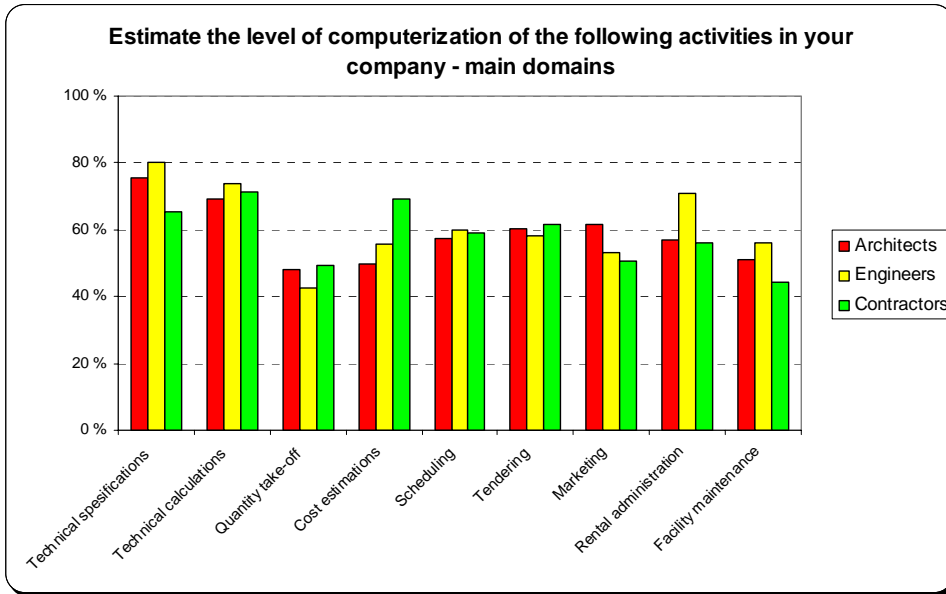


Figure 50: Level of computerization - main domains.

In Figure 50 to Figure 53 the answers “Not relevant” has been removed. Figure 51 gives an interesting comparison between architects in the Nordic countries. For almost every given activity in the survey the architects in Finland seems to be at a higher level of computerization compared to their Nordic neighbours.

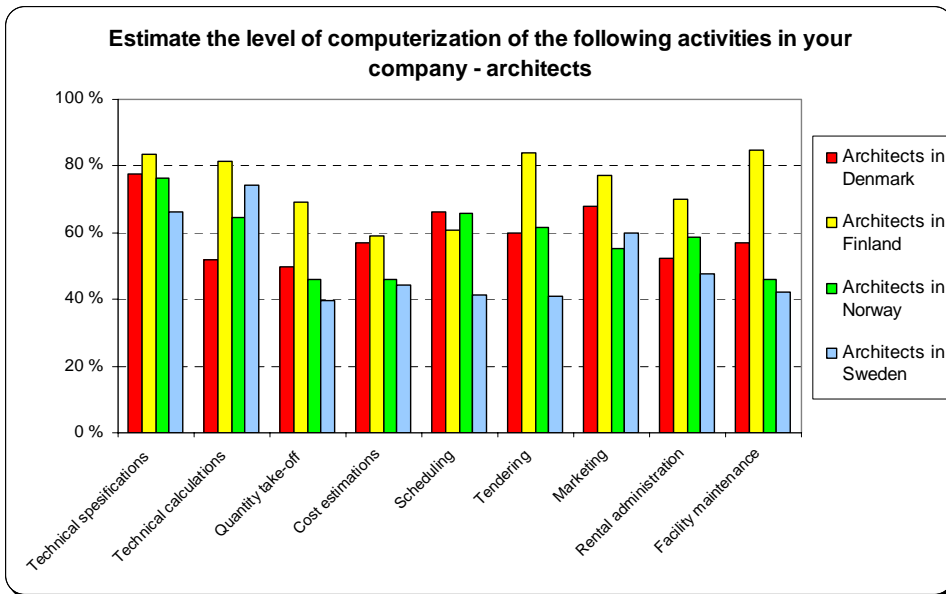


Figure 51: Level of computerization - architects / countries.

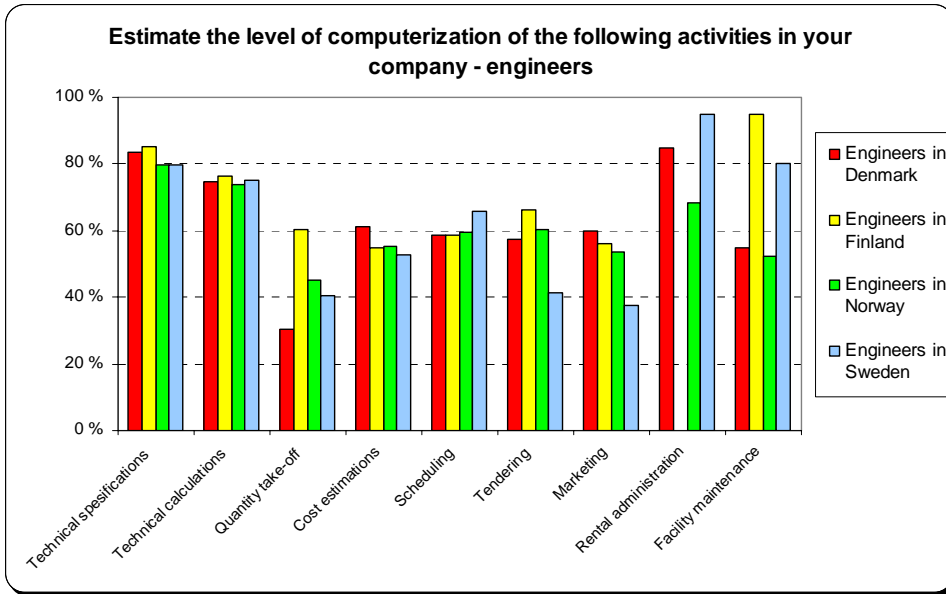


Figure 52: Level of computerization - engineers / countries.

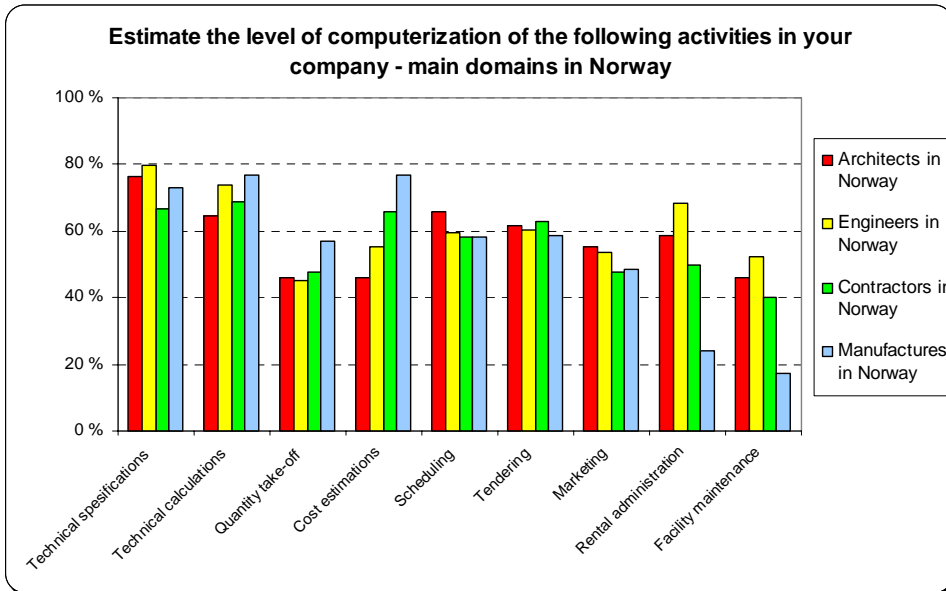


Figure 53: Level of computerization - main domains in Norway.

10.4 Utilization of information and communication technology in collaboration

Today use of Internet and Extranet-based services are prerequisite for participating in increasing numbers of projects. Figure 54 to Figure 56 show to what extent the respondents use Internet and Extranet when exchanging, distributing and storing project information between companies. Surprisingly only approximately 30% of the engineering companies says Internet / Extranet is used more often than 50% of the projects. Finland and Sweden seem to have the lead, compared to Denmark and Norway, see Figure 55.

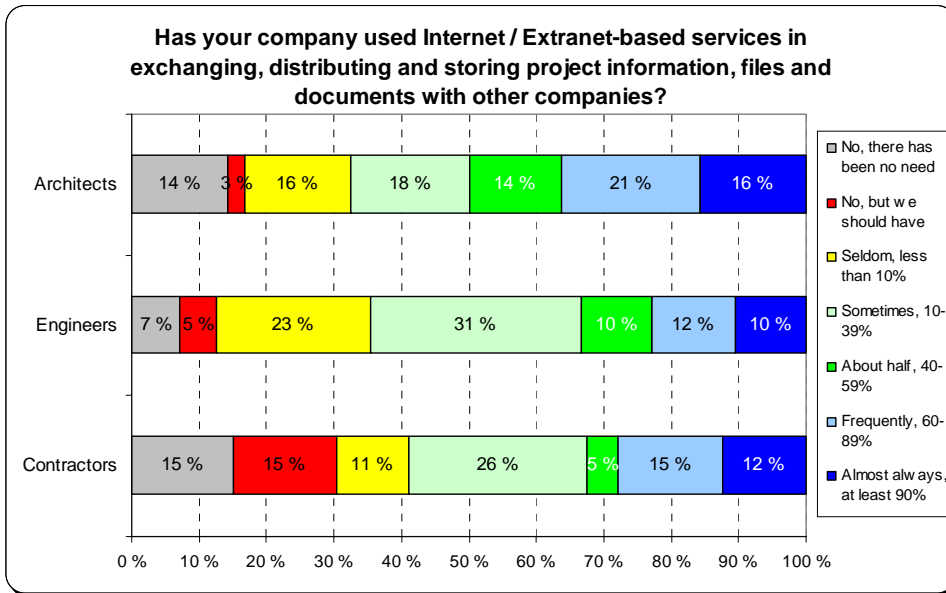


Figure 54: Utilization of Internet / Extranet-based services - main domains.

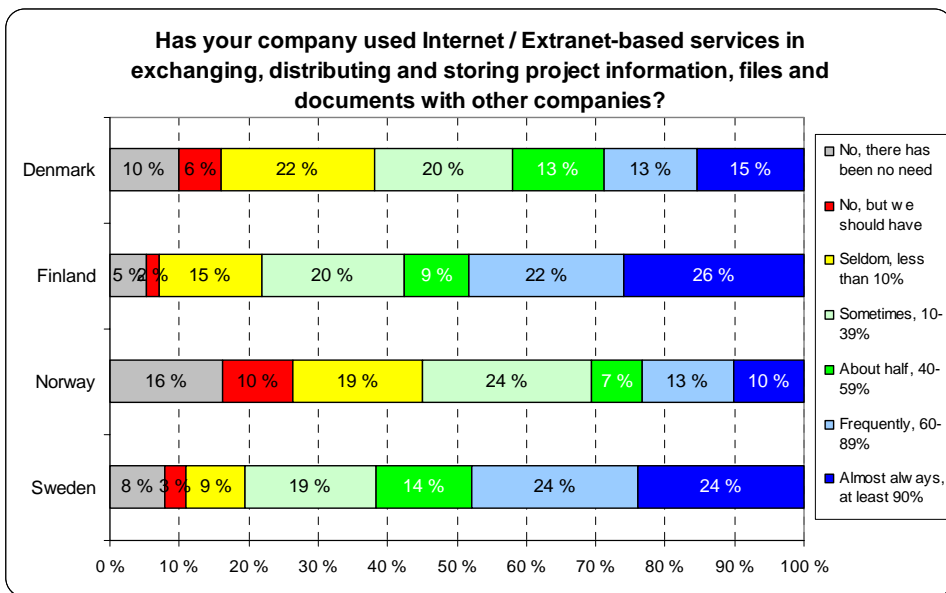


Figure 55: Utilization of Internet / Extranet-based services - countries.

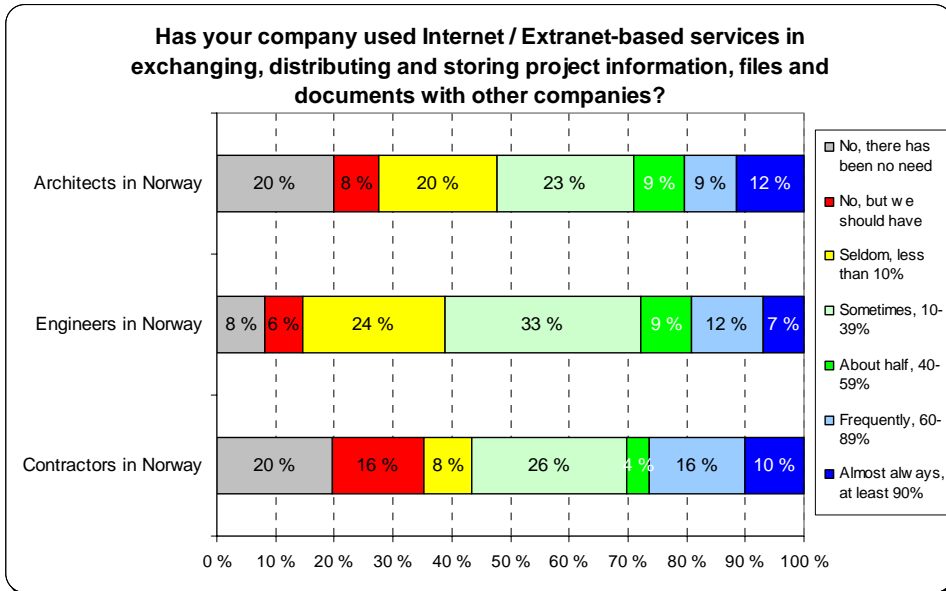


Figure 56: Utilization of Internet / Extranet-based services - main domains in Norway.

What about exchange information when utilizing BIM? Figure 57 to Figure 59 illustrate that there is still a way to go. Nevertheless there are many actors who has tried BIM or “should have” tried it.

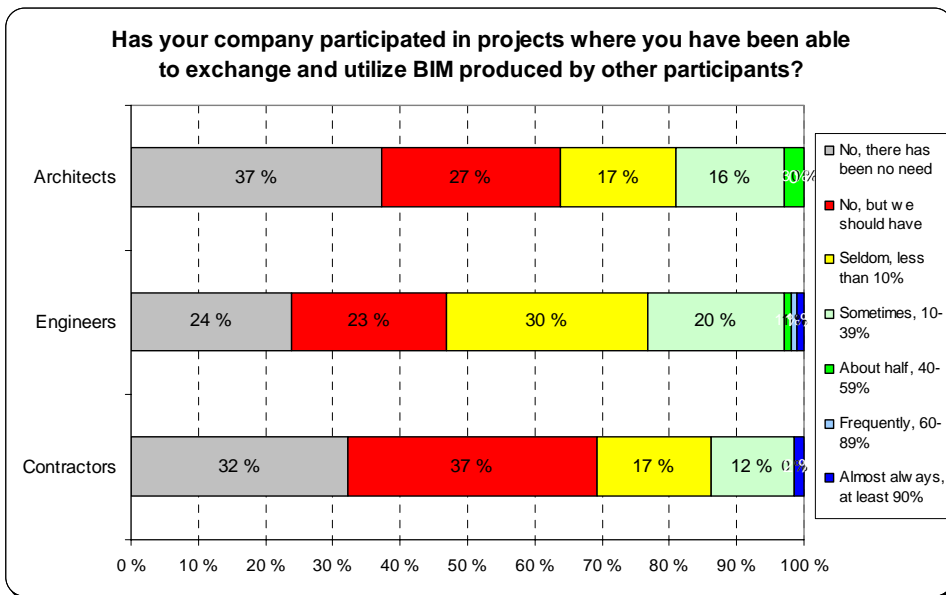


Figure 57: Utilization of BIM produced by other participants - main domains

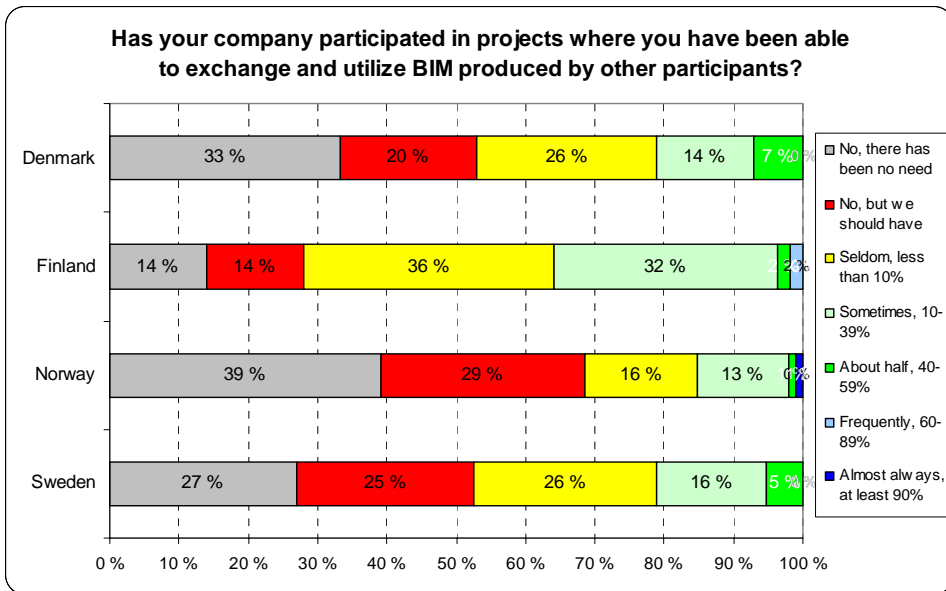


Figure 58: Utilization of BIM produced by other participants - countries.

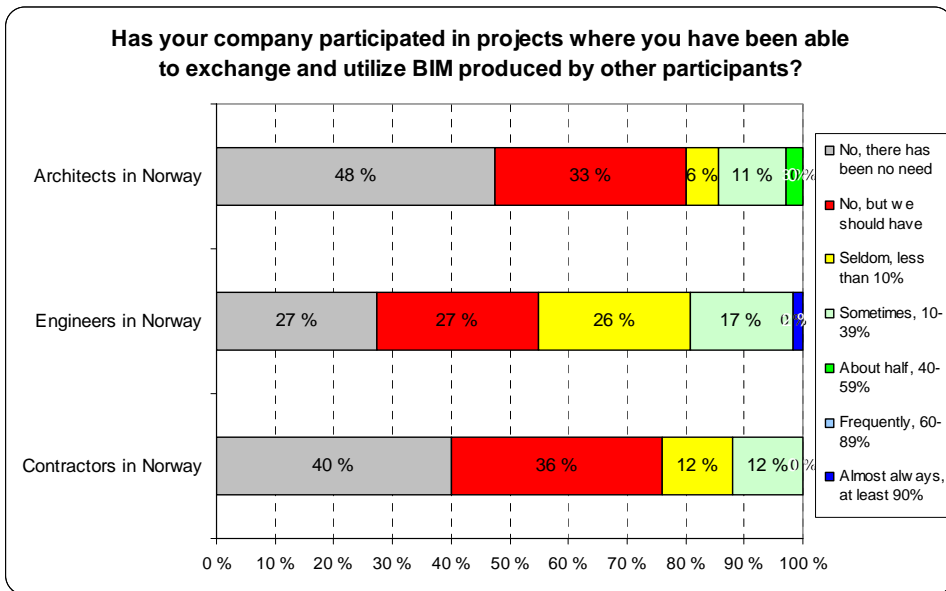


Figure 59: Utilization of BIM produced by other participants - main domains in Norway.

If using BIM, how large part of the exchange has been based on IFC? This question gave few answers, so the result should be analysed with reservations. The numbers of respondents on this part are given in Figure 60 and Figure 61.

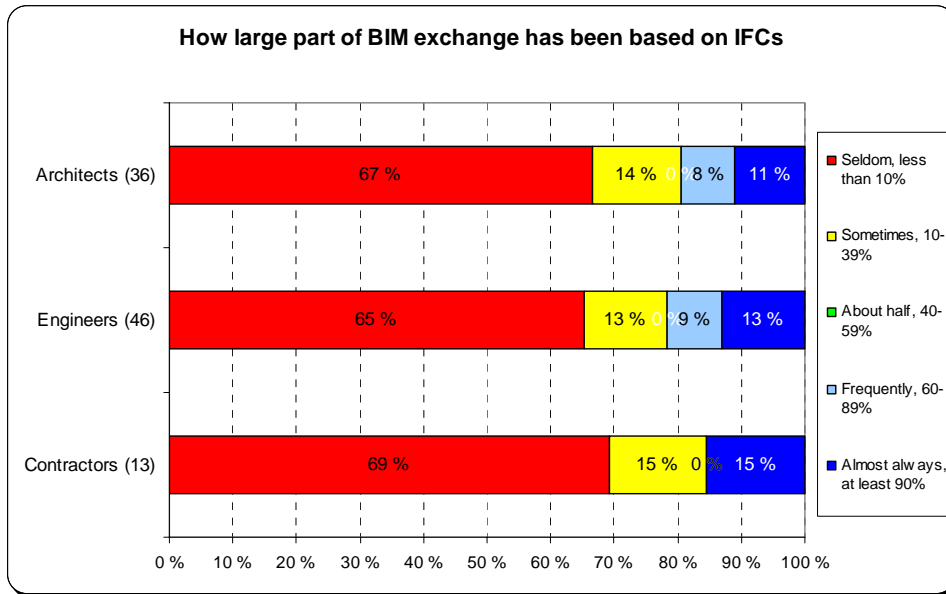


Figure 60: If BIM exchange, how much based on IFCs - main domains.

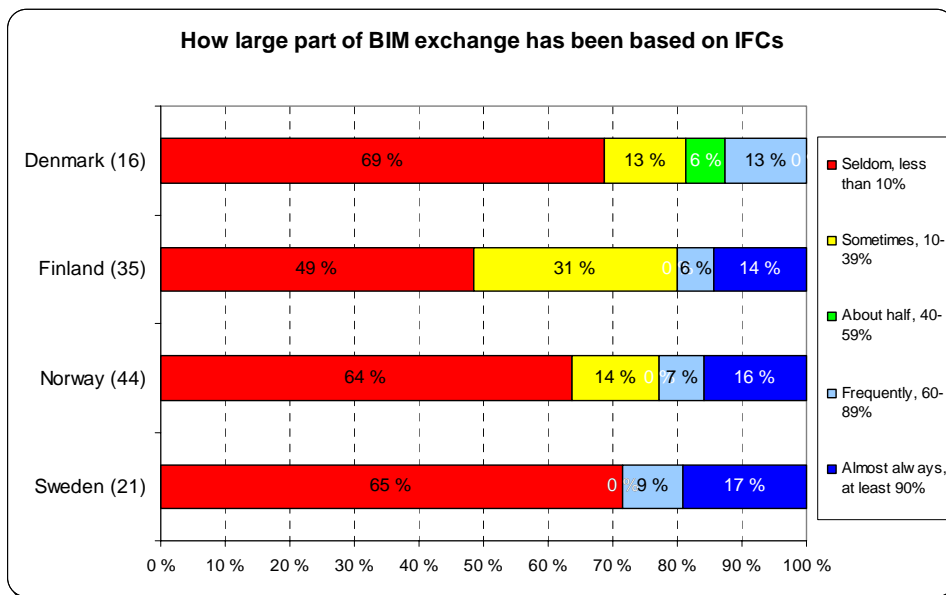


Figure 61: If BIM exchange, how much based on IFCs - countries.

10.5 Utilization of BIM and IFC format

When do the actors use BIM? This part had some predefined tasks. Figure 62 illustrates that a major part of actors generally answer “less than 10%” or “not relevant”. Among other results, this presentation would be of great interest to repeat later in order to measure the areas of use.

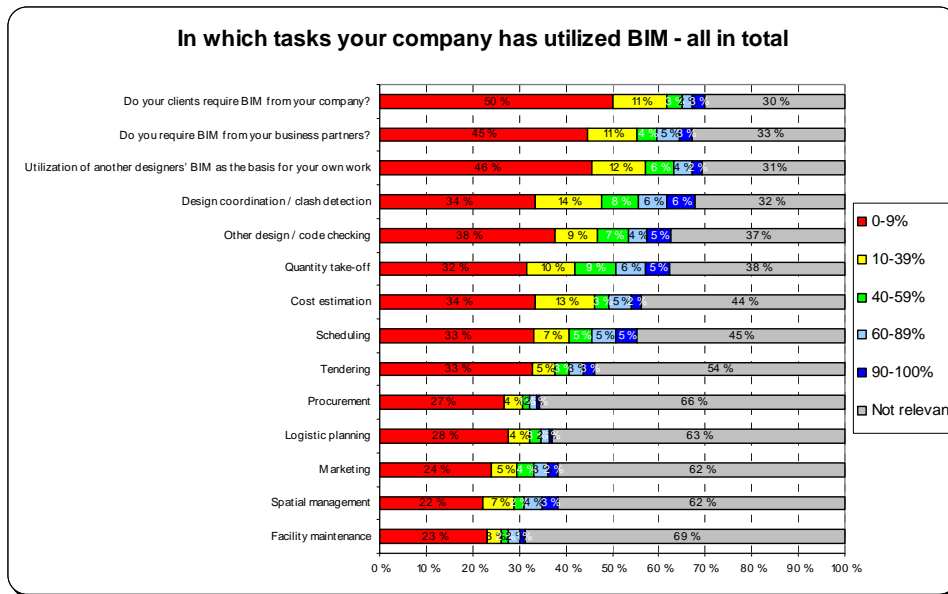


Figure 62: When utilize BIM - all in total.

The same issue is also presented in Figure 63 to Figure 66. In these figures the category “not relevant” is included and represented by 0%.

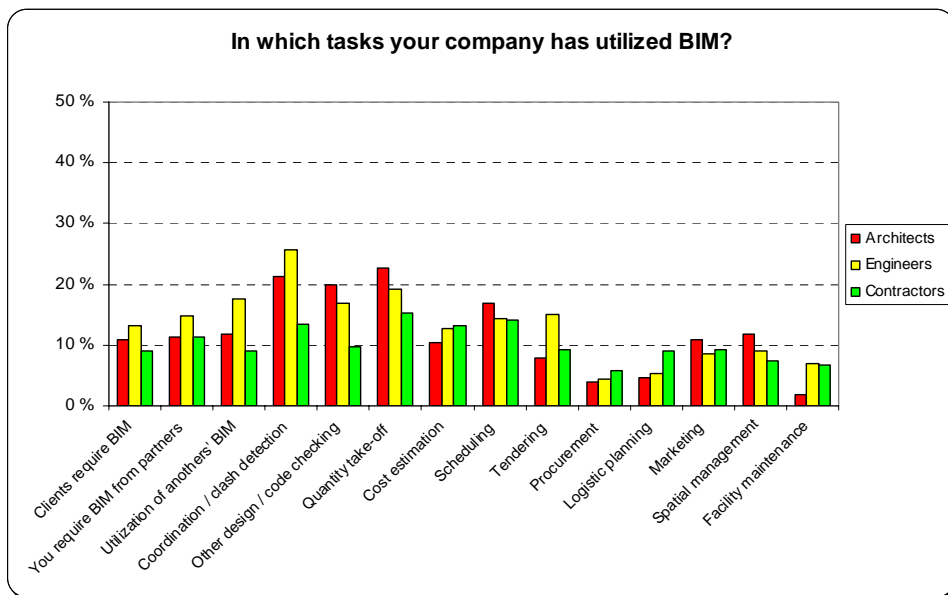


Figure 63: When utilize BIM - main domains.

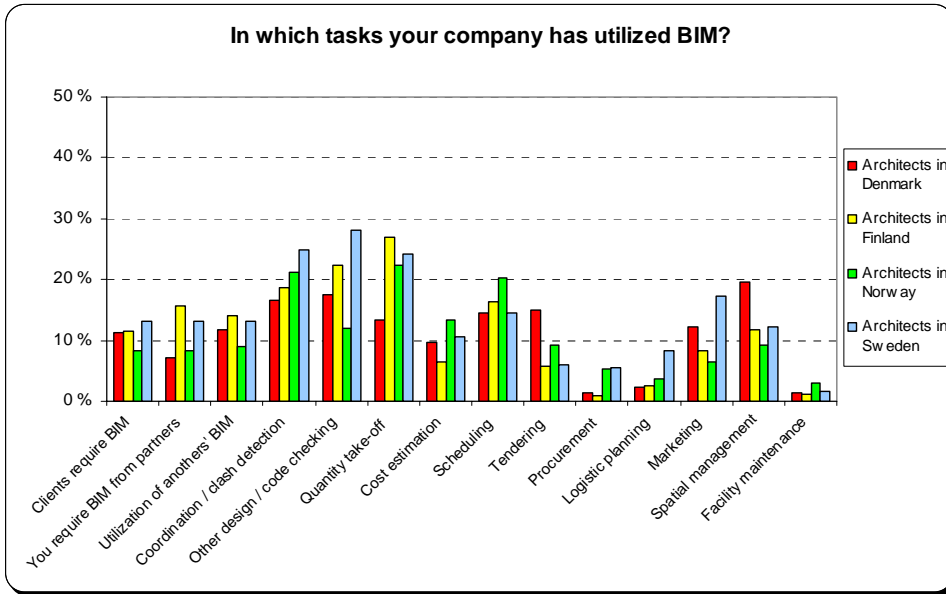


Figure 64: When utilize BIM - architects / countries.

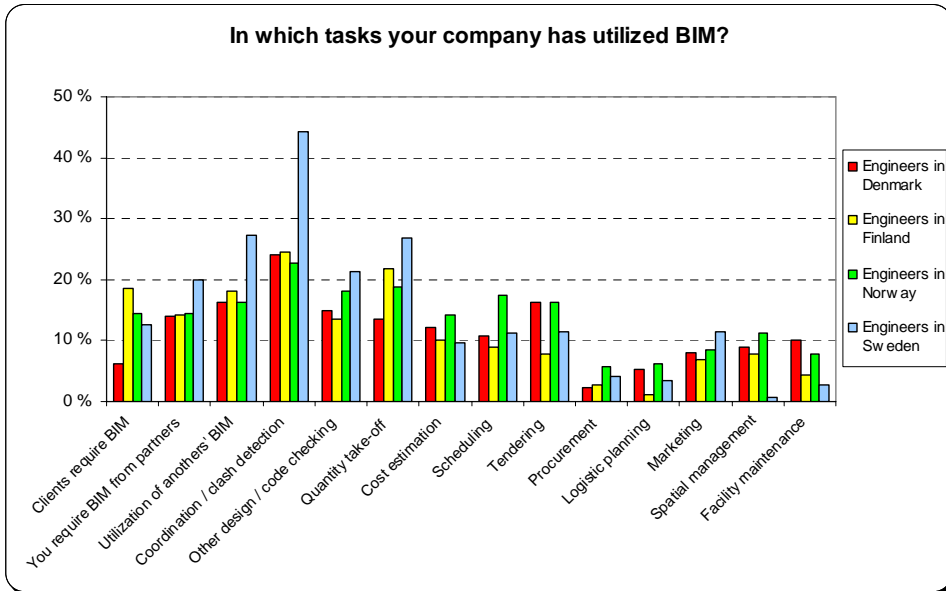


Figure 65: When utilize BIM - engineers / countries.

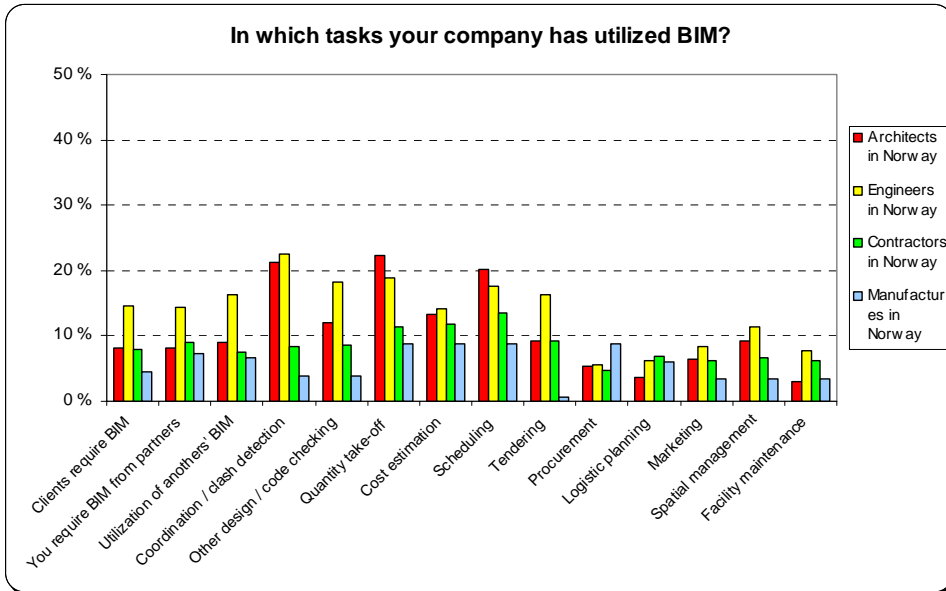


Figure 66: When utilize BIM - main domains in Norway.

The former question about tasks where BIM has been utilized was followed by a question about utilizing IFC. Not surprisingly the use of IFC is even lower than the use of BIM, see Figure 67 to Figure 71.

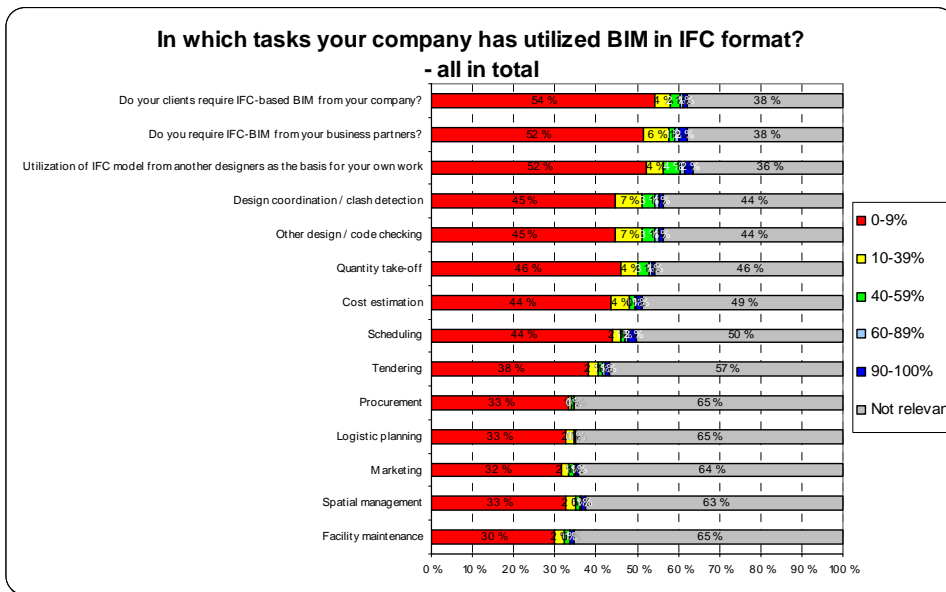


Figure 67: When utilize BIM in IFC format - all in total.

As for previous figures in this part, the category “not relevant” is represented by 0% in the figures below.

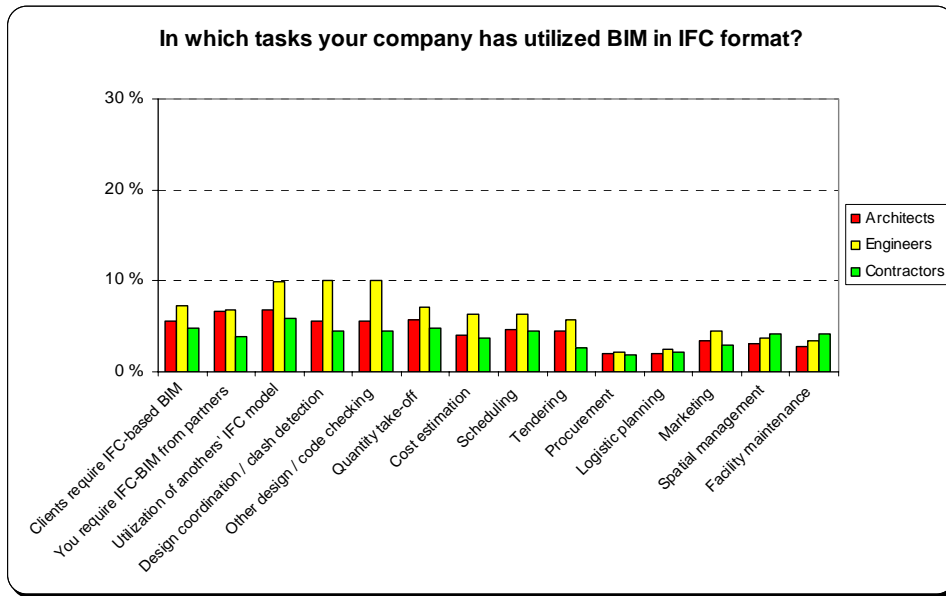


Figure 68: When utilize BIM in IFC format - main domains.

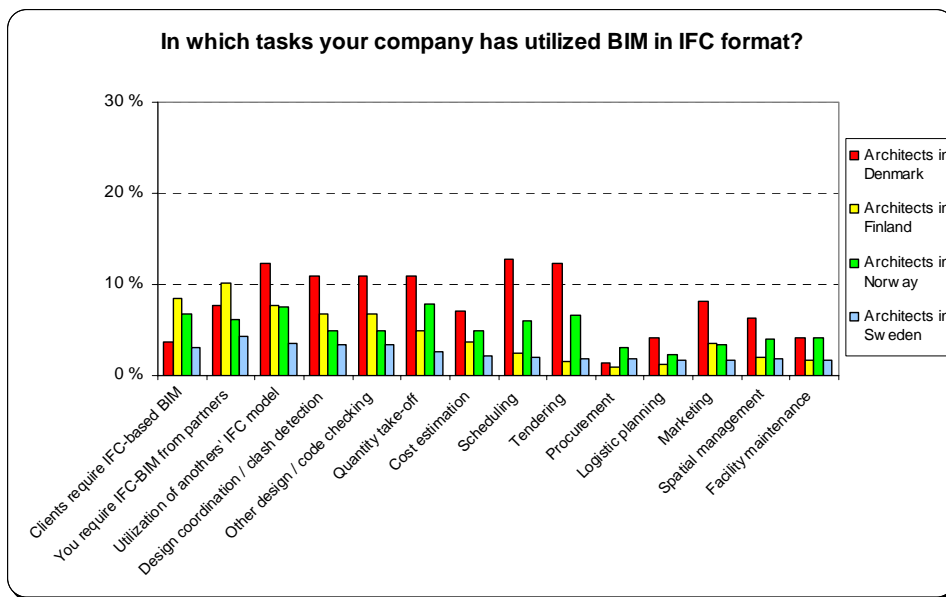


Figure 69: When utilize BIM in IFC format - architects / countries.

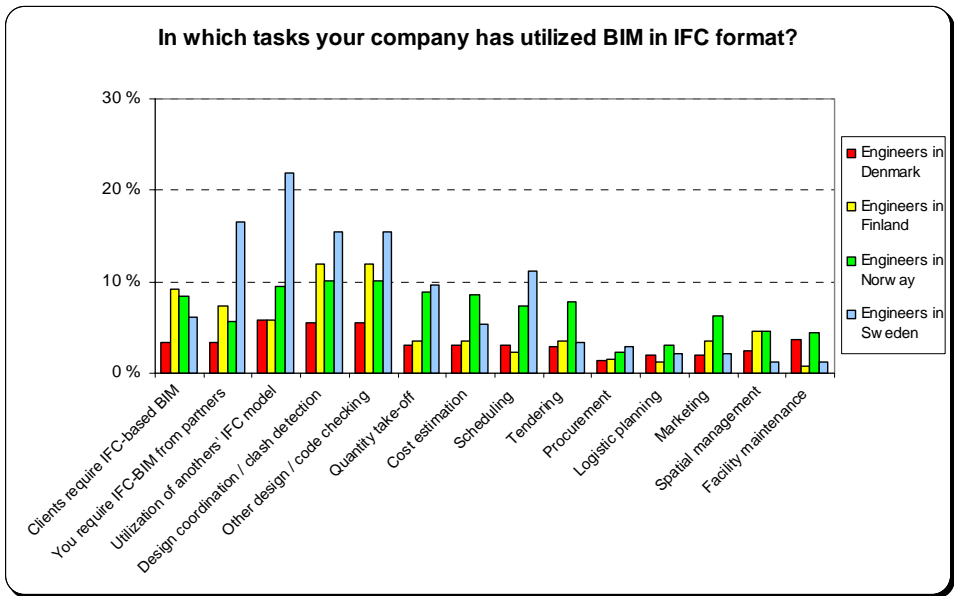


Figure 70: When utilize BIM in IFC format - engineers / countries.

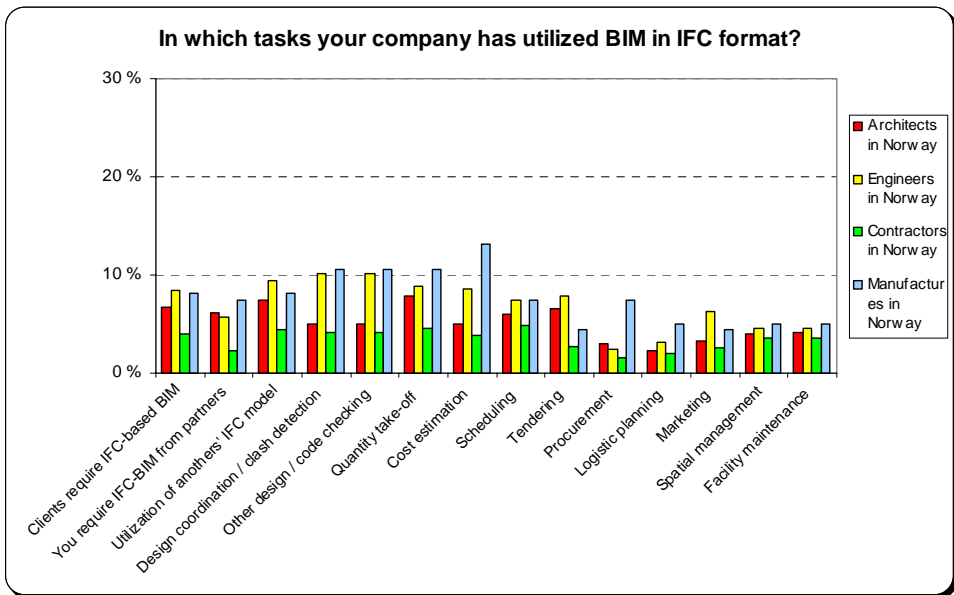


Figure 71: When utilize BIM in IFC format - main domains in Norway.

10.6 Role of ICT: Motives for decisions, problems and obstacles, advantages and benefits, plans for next years

The last part of the survey deals with the role of information technology in the companies. These questions are independent of utilization of BIM and IFC. Nevertheless these results give an interesting background and will to some extent describe the environmental in which BIM and IFC are introduced.

Figure 72 to Figure 75 show the percentages in each category of answers for all respondents and for the main domains.

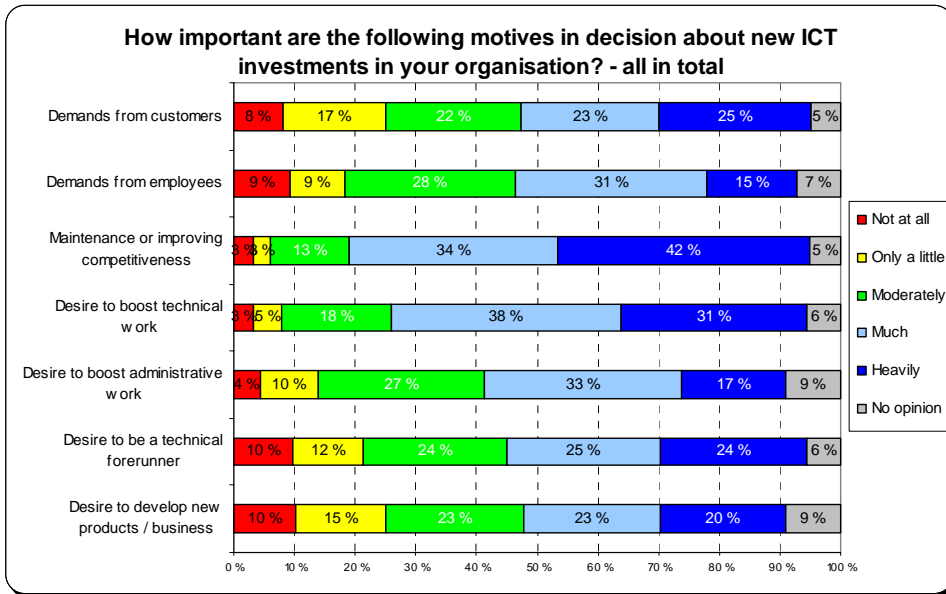


Figure 72: Motives for decision about ICT investments - all in total.

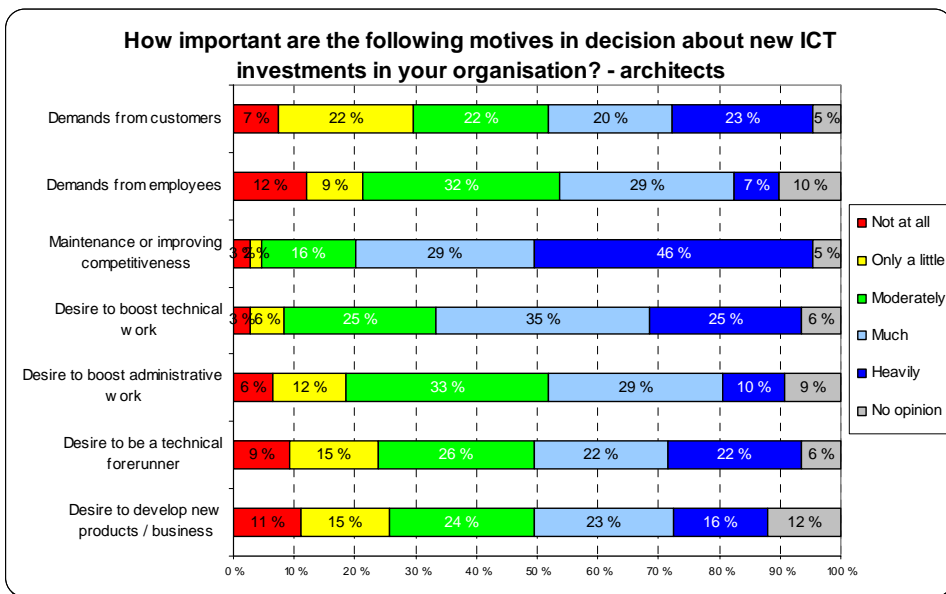


Figure 73: Motives for decision about ICT investments - architects.

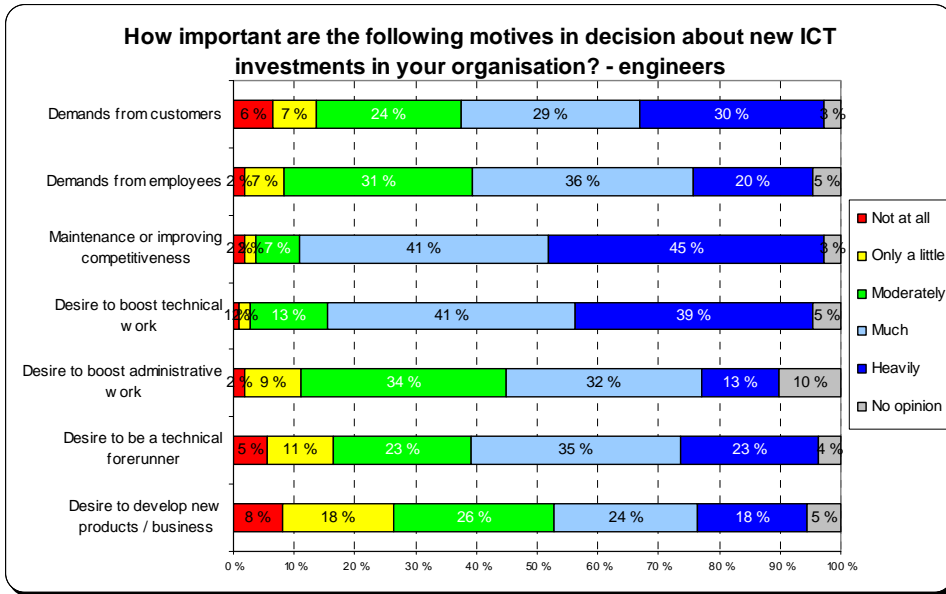


Figure 74: Motives for decision about ICT investments - engineers.

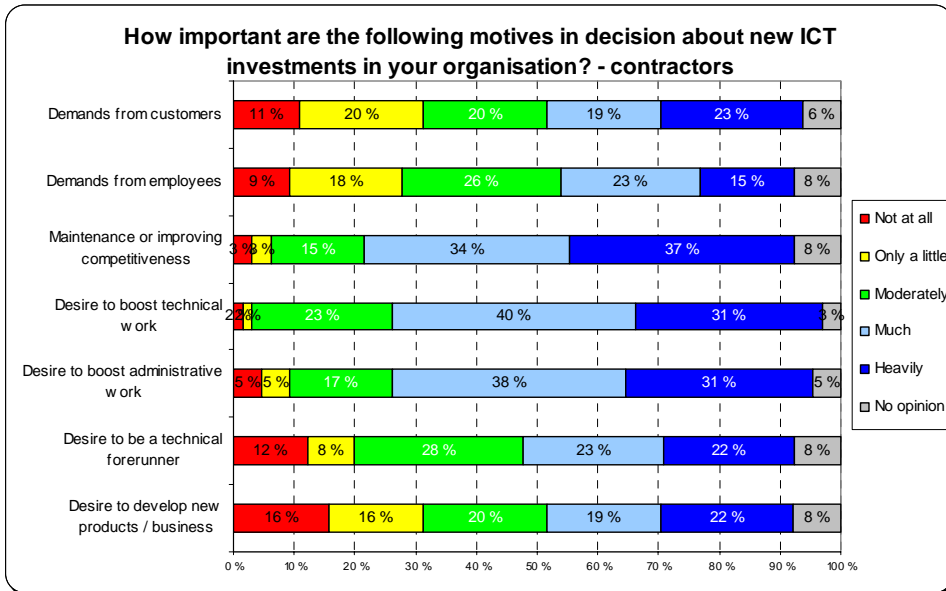


Figure 75: Motives for decision about ICT investments - contractors.

The next three figures, Figure 76 to Figure 78, illustrate the same results, by means of a calculated value for each parameter.

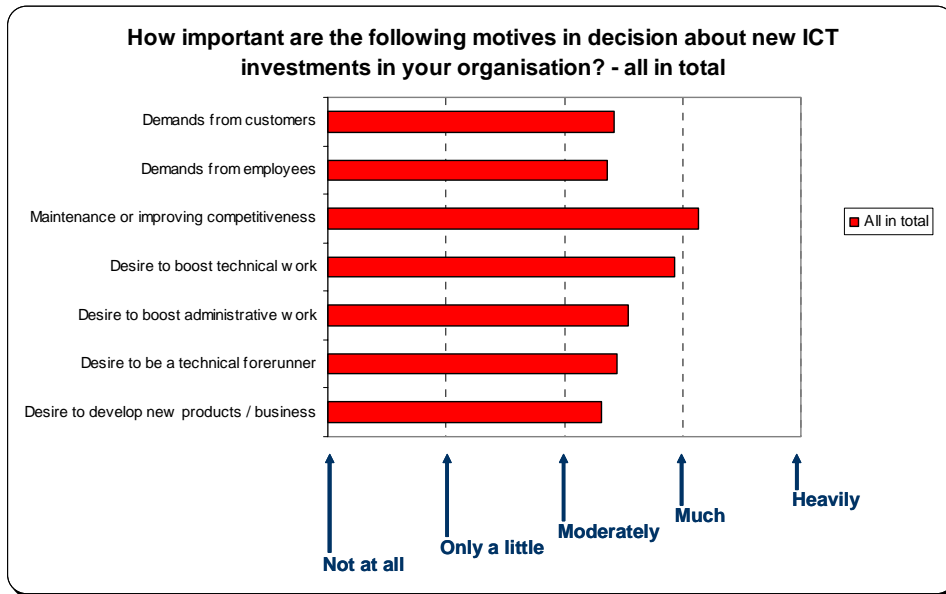


Figure 76 Motives for decision about ICT investments - all in total.

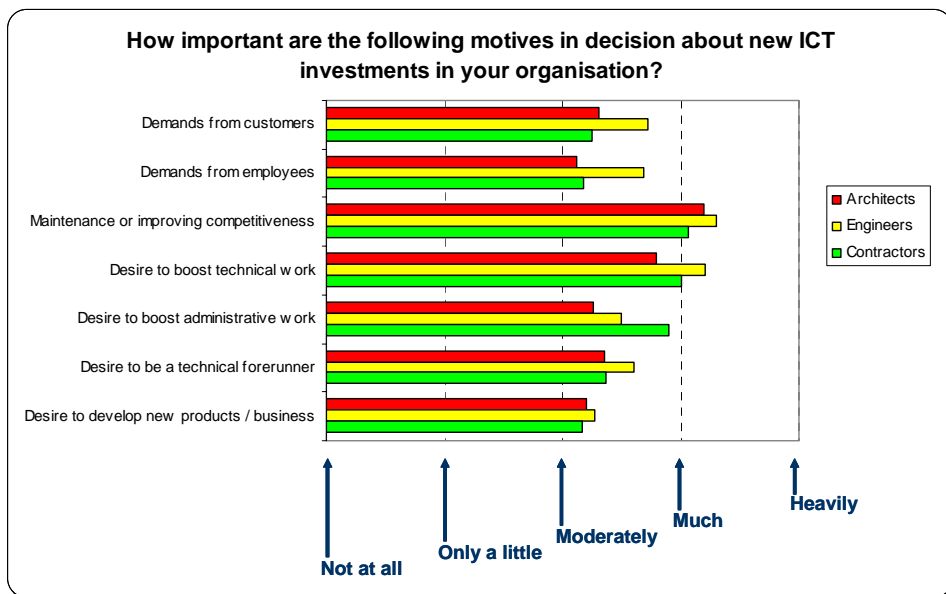


Figure 77: Motives for decision about ICT investments - main domains.

Note that the two motives below are the number 1 and 2 motives for all main domains, architects, engineers and contractors;

1. Maintenance or improving competitiveness
2. Desire to boost technical work

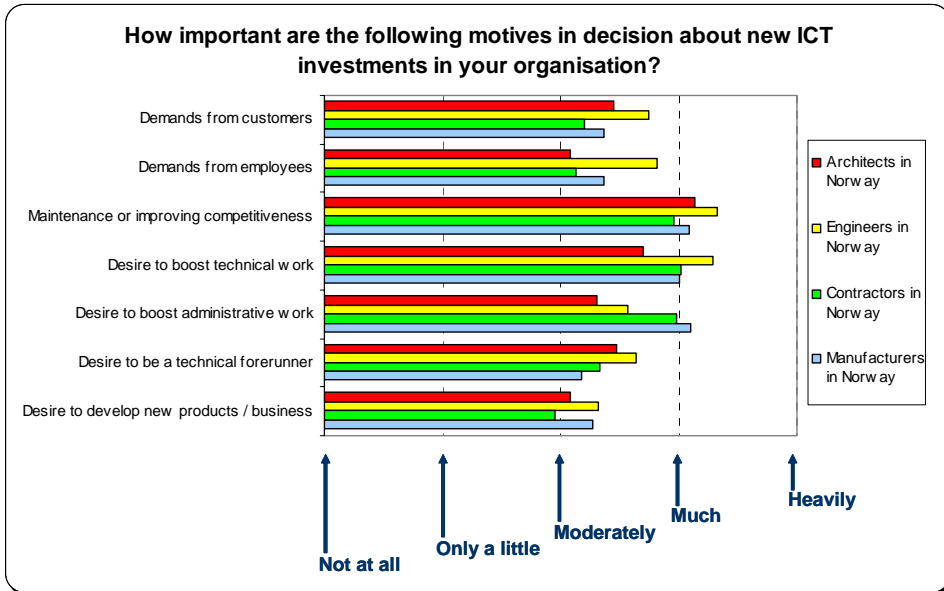


Figure 78: Motives for decision about ICT investments - main domains in Norway.

The next four figures focus on the problems and obstacles the increased use of ICT has caused in the organization; see Figure 79 to Figure 82. Note that the respondents had to mark maximum the three most important areas. This restriction gives a good comparison between the predefined problem areas, but will not form a true picture of the “total problem level”.

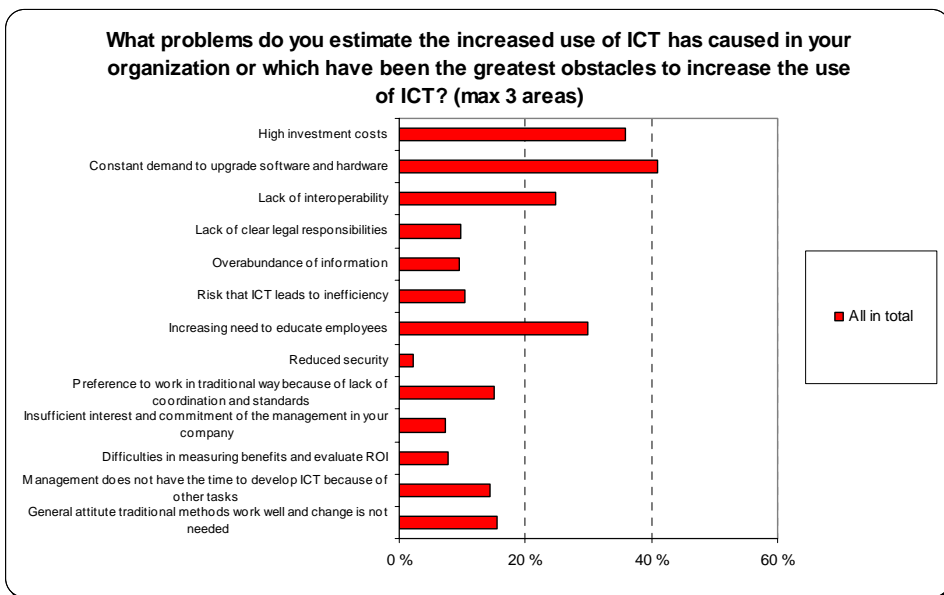


Figure 79: Problems and obstacles when increased use of ICT - all in total.

We observe that architects, engineers and contractors agree on the category number 1, 2 and 3, see Figure 80. When it comes to problems and obstacles, the three most important areas are;

1. Constant demand to upgrade software and hardware
2. High investment costs
3. Increasing need to educate employees

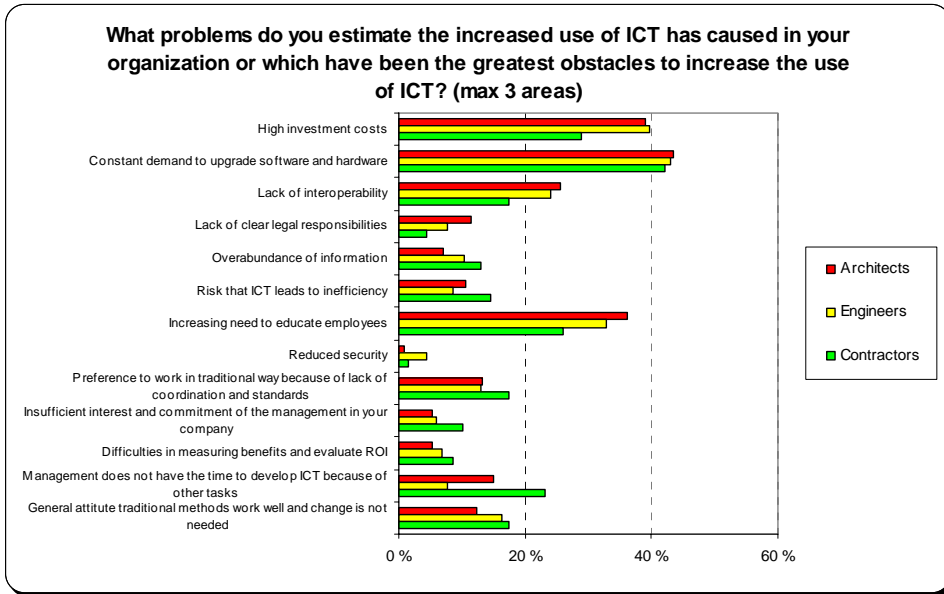


Figure 80: Problems and obstacles when increased use of ICT - man domains.

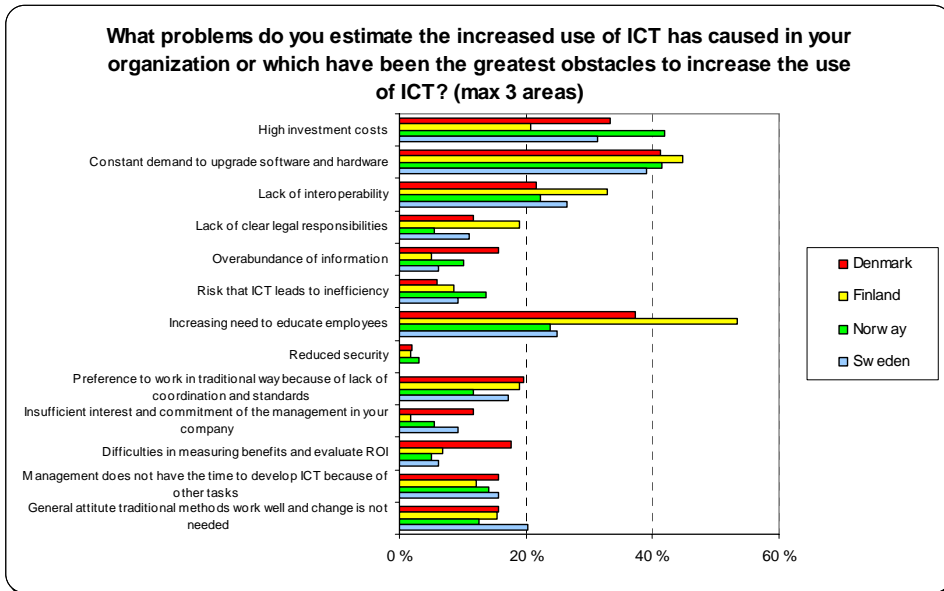


Figure 81: Problems and obstacles when increased use of ICT - countries.

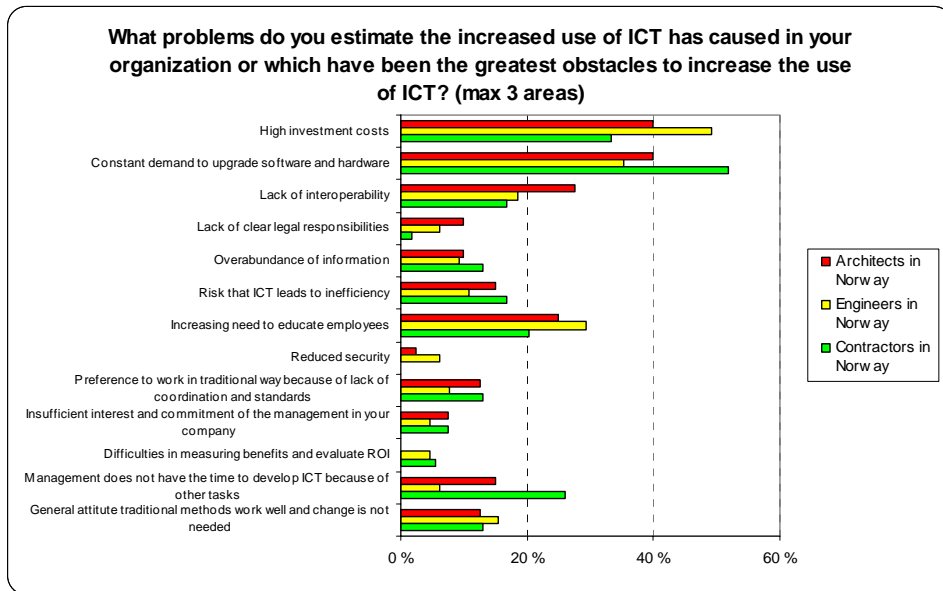


Figure 82: Problems and obstacles when increased use of ICT - main domains in Norway.

The questionnaire also dealt with advantages and benefits using ICT, see Figure 83 to Figure 86. As for the former figures, the respondents had to mark maximum the three most important areas.

Again, the respondents (all main domains: architects - engineers - contractors and all countries; Denmark - Finland - Norway - Sweden) agreed on the most important area for advantages and benefits;

1. Improved quality of the work.

50% of the respondents had this area on top three! They also seemed to agree on the next three most important areas;

2. Work can be done faster.
3. Improved information management and communication.
4. Improved possibilities to share information.

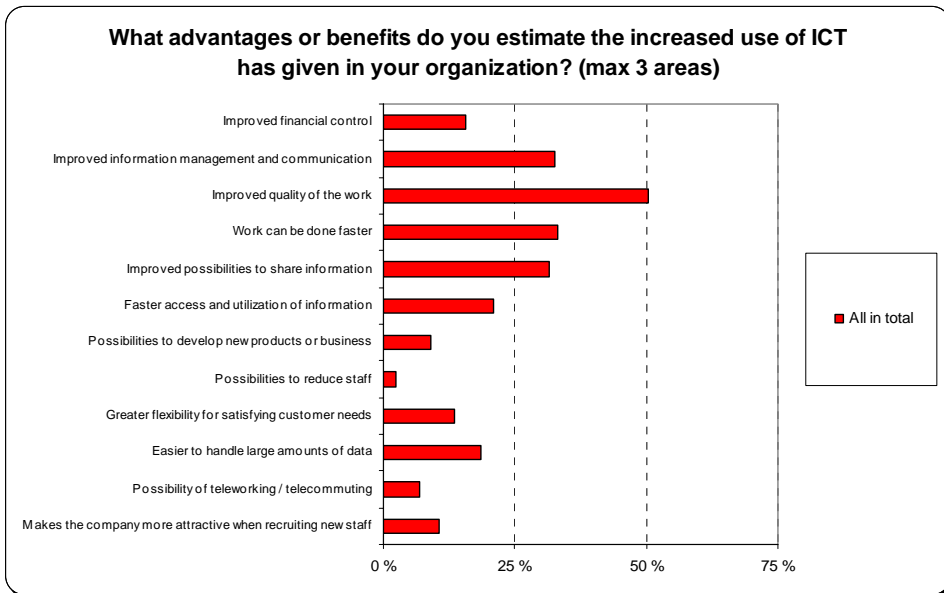


Figure 83: Advantages and benefits when increased use of ICT - all in total.

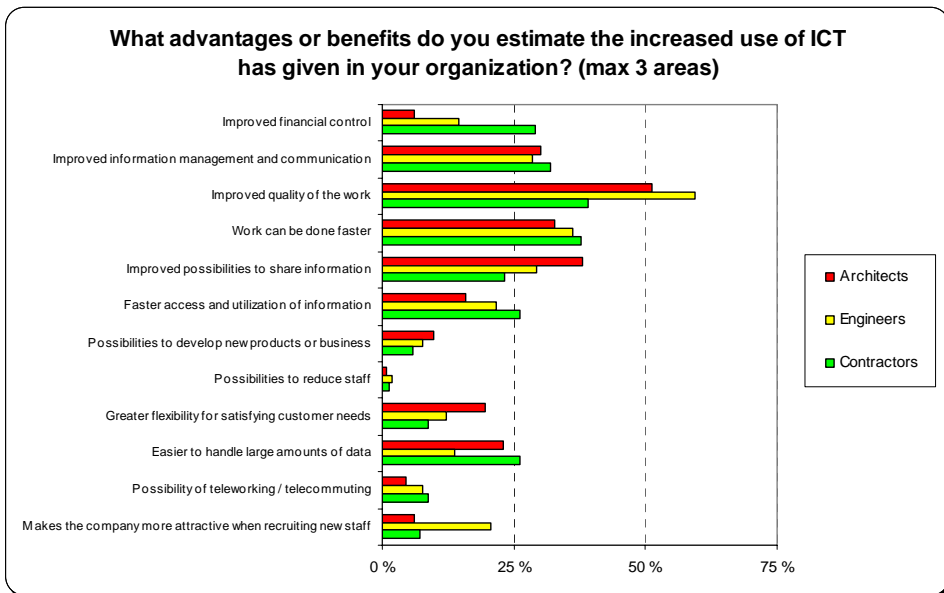


Figure 84: Advantages and benefits when increased use of ICT - main domains.

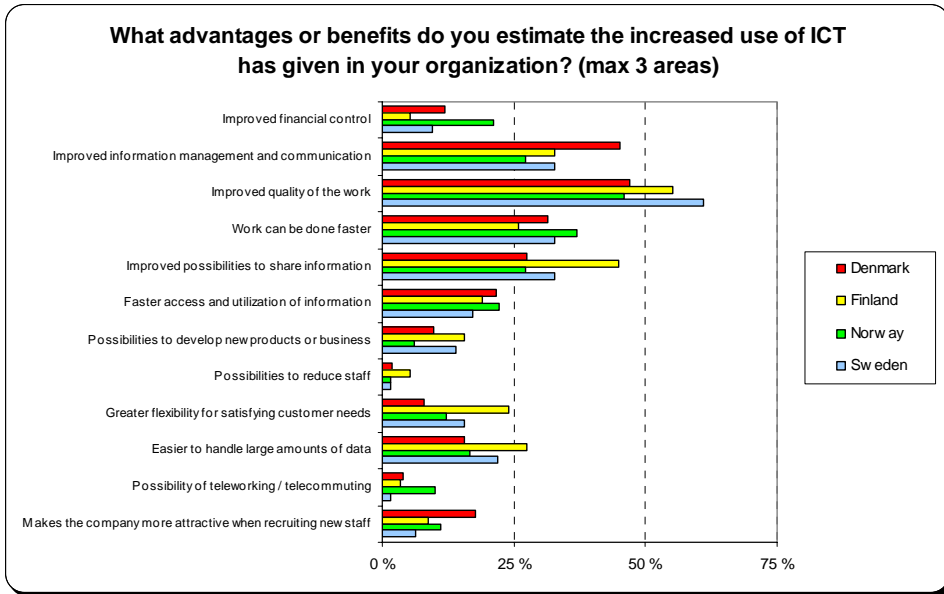


Figure 85: Advantages and benefits when increased use of ICT - countries.

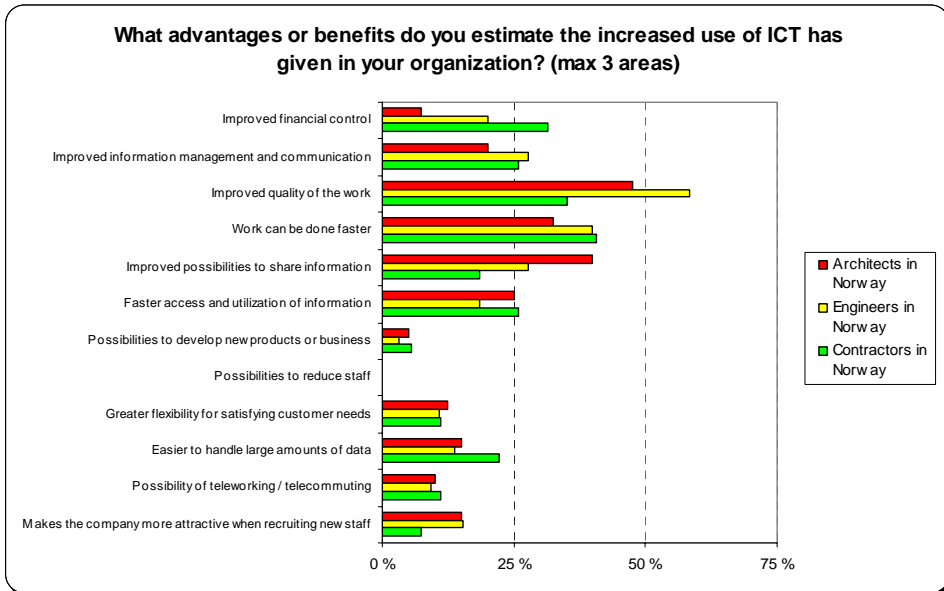


Figure 86: Advantages and benefits when increased use of ICT - main domains in Norway.

The last section looks ahead and into which areas the actors plan to increase the use of ICT the next two years. As for the former figures, the respondents had to mark maximum the three most important areas. We find both agreement and disagreement among these answers; see Figure 87 to Figure 90.

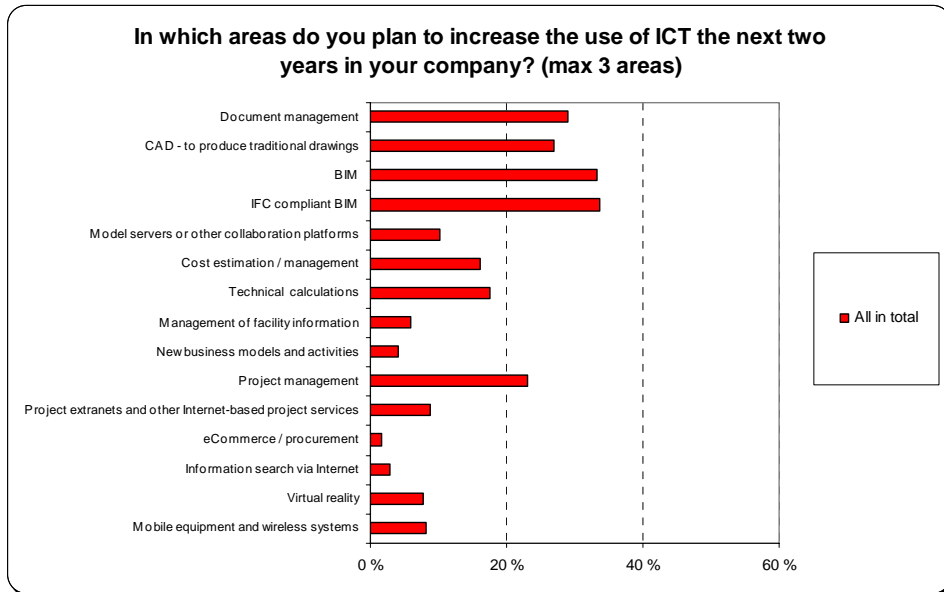


Figure 87: Plan areas for increasing the use of ICT - all in total.

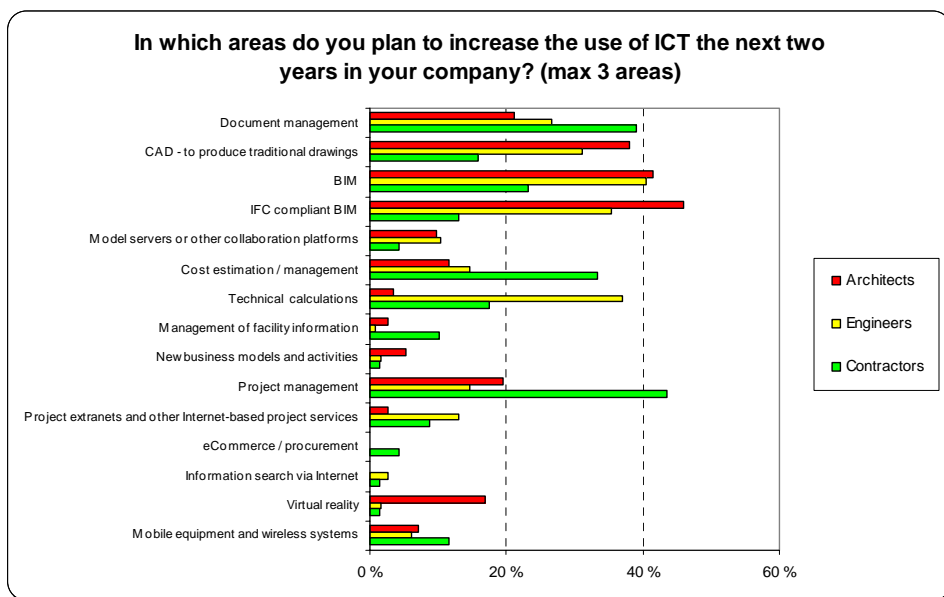


Figure 88: Plan areas for increasing the use of ICT - main domains.

Architects and engineers gave top score to these three categories

1. IFC compliant BIM
2. BIM
3. CAD - to produce traditional drawings

Contractors, on the other hand, gave highest preferences to:

1. Project management
2. Document management
3. Cost estimation / management

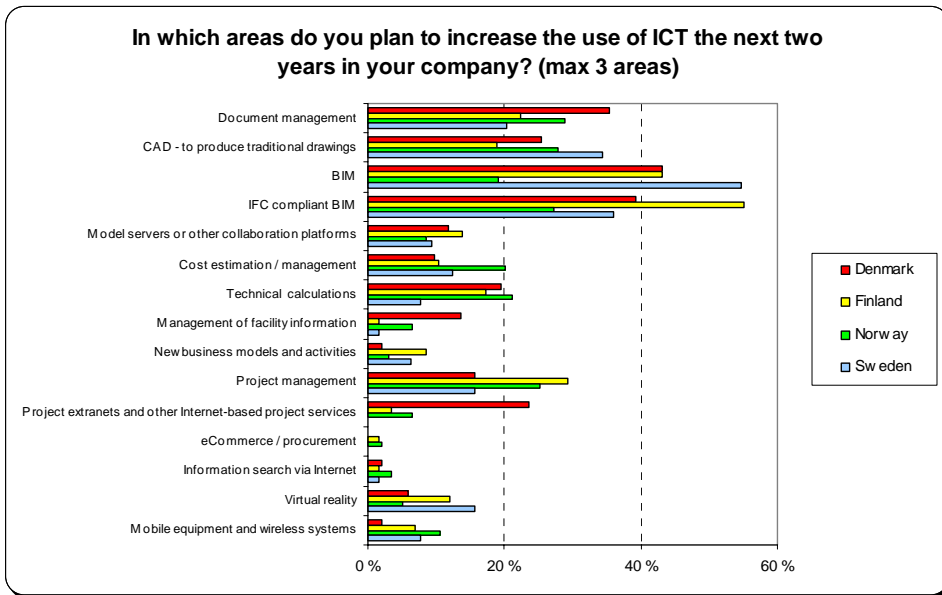


Figure 89: Plan areas for increasing the use of ICT - countries.

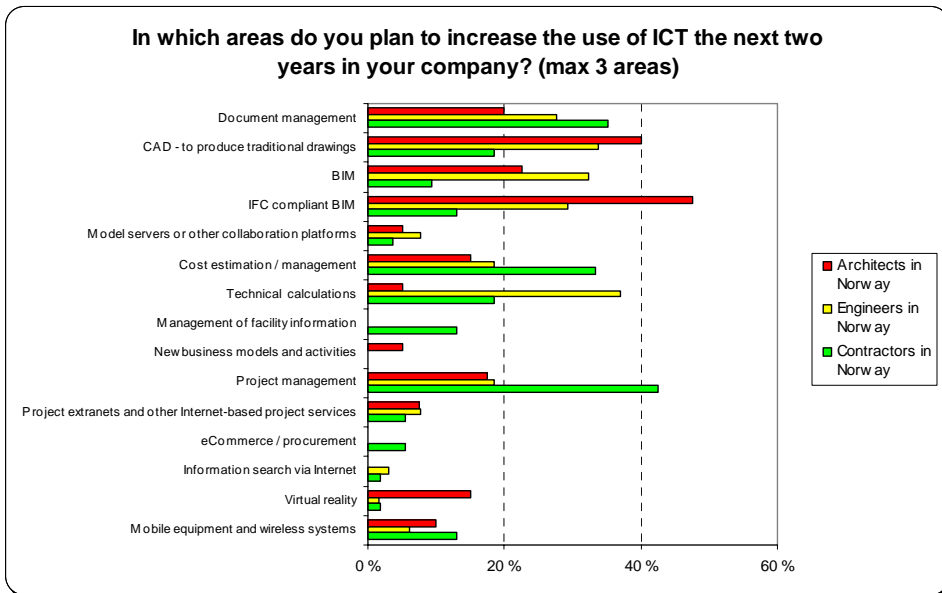


Figure 90: Plan areas for increasing the use of ICT - main domains in Norway.

10.7 BIM Barometer Questionnaire

BIM Barometer 2007**Questionnaire of the use of Building Information Models (BIM) and Industry Foundation Classes (IFC) in building construction sector**

This questionnaire includes 10 questions related to the use of BIM and IFC in the building construction sector.

The questionnaire is a part of ERAbuild program's study "Review of the Development and Implementation of IFC compatible BIM" funded by Danish Authority for Enterprise and construction (Denmark), Formas (Sweden), Forskningsrådet (Norway), PSIBouw (Netherlands) and Tekes (Finland). The study is performed by SINTEF (Norway), VTT (Finland), Eurostep (Sweden) and Ramboll (Denmark).

Answers will be handled as confidential information and all identifying information will be separated from the data in the analysis process. Individual answers or information of the respondents will not be given to any outsiders under any conditions. If you have any inquires about the questionnaire, please contact Arto.Kiviniemi@vtt.fi

The information in this section will be used only for 1) identifying answers coming from the same company, 2) making sure that there are not several answers from the same respondent, and 3) emailing the results back to the respondents. This information will be separated from other material in the analysis process.

Company:	<input type="text"/>
Department:	<input type="text"/>
Country:	<input type="text"/>
Postal code:	<input type="text"/>
Respondent's name:	<input type="text"/>
Respondent's email:	<input type="text"/>

Do you want the report of the results? Would you allow us to contact you by email if we have further questions?

- | | |
|---------------------------|---------------------------|
| <input type="radio"/> Yes | <input type="radio"/> Yes |
| <input type="radio"/> No | <input type="radio"/> No |

Information of your domain and company

Which of the following domains describes your company branch best? *(You can select only one)*

- Architect
- Multidisciplinary Engineering
- Structural Engineer
- Building Services Engineer (both HVAC and Electrical)
- HVAC Engineer
- Electrical Engineer
- Facility Management
- Owner
- Main Contractor
- Building Services Contractor (both HVAC and Electrical)
- HVAC Contractor
- Electrical Contractor
- Building material or component manufacturer
- Other, please describe:

How many employees do you have in your company working in the building construction sector in your country?

Office (white collar)	<input type="text" value="0"/>	Site (skilled labor)	<input type="text" value="0"/>	in total	<input type="text" value="0"/>
-----------------------	--------------------------------	----------------------	--------------------------------	----------	--------------------------------

Has your company participated in the work or is it a member of IAI (International Alliance for Interoperability) and/or buildingSMART?

- Yes
- No

The following questions may include parts which are not relevant for your company. In that case, please select the "Not relevant" option. In any case, please, fill all rows.

Definition: BIM (Building Information Model) is an object-oriented, AEC-specific 3D-model – a digital representation of a building to facilitate exchange and interoperability of information in digital format.

Computers and software

1. Which of the following techniques you use in your design work?

Estimate the proportional volume of each technique in your design work and mark also the change in the last two years.

Technique	% of design	Change in the last two years			Not relevant
		-<	No changes	+>	
Manual drafting	0 %	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
CAD (Computer Aided Drafting)	0 %	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
BIM (Building Information Model)	0 %	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
IFC compliant BIM	0 %	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In total	%	<i>The total value should be 100% if design is relevant for your company.</i>			

2. Estimate the level of the computerization of the following activities in your company?

	100% manual	Computerized				Not relevant
		1-39%	40-59%	60-89%	90-100%	
Technical specifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technical calculations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quantity take-off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost estimations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tendering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marketing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rental administration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Facility maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Utilization of information and communication technology in collaboration

3. Has your company used Internet/Extranet-based services in exchanging, distributing and storing project information, files and documents with other companies?

- Yes
- No, but we should have
- No, there has been no need

--> If yes, how much this has been used?

.....

Seldom, less than 10% of our projects

Sometimes, 10-39% of our projects

About half, 40-59% of our projects

Frequently, 60-89% of our projects

Almost always, at least 90% of our projects

4. Has your company participated in projects where you have been able to exchange and utilize Building Information Models (BIM) produced by other participants?

- Yes
- No, but we should have
- No, there has been no need

--> If yes, how much this has been used?

 Seldom, less than 10% of our projects
 Sometimes, 10-39% of our projects
 About half, 40-59% of our projects
 Frequently, 60-89% of our projects
 Almost always, at least 90% of our projects

How large part of the above BIM exchange has been based on IFCs?

 Seldom, less than 10% of BIM exchange
 Sometimes, 10-39% of BIM exchange
 About half, 40-59% of BIM exchange
 Frequently, 60-89% of BIM exchange
 Almost always, at least 90% of BIM exchange

5a. In which tasks your company has utilized BIM?

	Use of BIM					Not relevant
	0-9%	10-39%	40-59%	60-89%	90-100%	
Do your clients require BIM from your company?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you require BIM from your business partners?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Utilization of another designers' BIM as the basis of your own work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design coordination/clash detection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other design/code checking	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quantity take-off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost estimation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tendering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Procurement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Logistics planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marketing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Spatial management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Facility maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

5b. In which tasks your company has utilized BIM in IFC format?

	Use of IFC exchange					Not relevant
	0-9%	10-39%	40-59%	60-89%	90-100%	
Do your clients require IFC-based BIM from your company?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you require IFC-based BIM from your business partners?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Utilization of IFC model from another designer as the basis of your own work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design coordination/clash detection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other design/code checking	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Quantity take-off	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost estimation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Tendering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Procurement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Logistics planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marketing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Spatial management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Facility maintenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

The role of information technology in your company

6. How important are the following motives in decision about new ICT investments in your organization?

	Not at all	Only a little	Moderately	Much	Heavily	No opinion
Demands from customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Demands from employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Maintaining or improving competitiveness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Desire to boost technical work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Desire to boost administrative work	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Desire to be a technical forerunner	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Desire to develop new products/business	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other <input type="text"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. What problems do you estimate the increased use of ICT has caused in your organization or which have been the greatest obstacles to increase the use of ICT?

Mark in maximum three most important areas. Leave empty if you have not identified any problems or obstacles.

- High investment costs
- Constant demand to upgrade software and hardware
- Lack of interoperability
- Lack of clear legal responsibilities
- Overabundance of information
- Risk that ICT leads to inefficiency
- Increasing need to educate employees
- Reduced security
- Preference to work in the traditional way because of lack of coordination and standards
- Insufficient interest and commitment of the management in your company
- Difficulties in measuring benefits and evaluate ROI
- Management does not have the time to develop ICT because of other tasks
- General attitude that traditional methods work well and change is not needed
- Other obstacles/problems:
- Other obstacles/problems:

8. What advantages or benefits do you estimate the increased use of ICT has given in your organization?

Mark in maximum three most important areas. Leave empty if you have not identified any advantages or benefits.

- Improved financial control
- Improved information management and communication
- Improved quality of the work
- Work can be done faster
- Improved possibilities to share information
- Faster access and utilization of information
- Possibility to develop new products or business
- Possibility to reduce the staff
- Greater flexibility for satisfying customer needs
- Easier to handle large amounts of data
- Possibility of teleworking/telecommuting
- Makes the company more attractive when recruiting new staff
- Other benefits:
- Other benefits:

9. In which areas do you plan to increase the use of ICT the next two years in your company?

Mark in maximum three most important areas. Leave empty if you are not planning to increase the use of ICT.

- Document management
- CAD (Computer Aided Drafting to produce traditional drawings)
- BIM
- IFC compliant BIM
- Model servers or other collaboration platforms
- Cost estimation/management
- Technical calculations
- Management of facility information
- New business models and activities
- Project management
- Project extranets and other Internet-based project services
- eCommerce/procurement
- Information search via Internet
- Virtual reality
- Mobile equipment and wireless systems
- Other growth area:
- Other growth area:

10. Any comments or feedback about the questionnaire?

11 Appendix 2 - Software Used

BIM and IFC based BIM Software used in the Nordic countries

Extra question sent out to 300 organizations in November 2008

In total 71 organizations out of the 300 answered. These 300 were the ones that answered the questionnaire and answered yes to get additional questions.

Country	Architects	Engineers	Contractors	All others	Total
Denmark	1	2	1	2	6
Finland	9	4	0	3	16
Norway	11	6	4	4	25
Sweden	14	1	2	3	20
The Netherlands	0	1	1	2	4
Total number	(35)	(14)	(8)	(14)	[71]

Table 12: Number of answers per country and discipline

In this summary, only the most used software are listed. The tables present the number of organizations using the specific software. One organization can be using multiple softwares.

The material is not so rich in some areas. The most reliable material is for the architects in Sweden, Norway and Finland.

Some of the software are more viewers oriented, but are still included in the tables.

11.1 BIM software used (the most used ones)

In the list a tool, Navisworks, not primarily aimed for design is included as it was listed by a significant number of organizations. It is supporting model comparison, and therefore it will not be listed among the design tools in the main part of the report.

Software	Architects	Engineers	Contractors	All others	Total
ADT	8	4	6	3	21
Revit	8	1	1		10
Revit Struct		3	1		4
Tekla Struct		5	1	1	7
Bentley	4	2			6
AD MEP		1			1
Archicad	18	1	2	5	26
MagiCAD		5	4		9
Navisworks	5	1	5		11
Allplan		1			1
Total number	(43)	(24)	(20)	(9)	[96]

Table 13: Total number of answers per BIM Software and discipline

Software	Architects	Engineers	Contractors	All others	Total
ADT		1	1	1	3
Revit	1				1
Revit Struct		1			1
Tekla Struct		2			2
Bentley					
AD MEP		1			1
Archicad				1	1
MagiCAD		2	1		3
Navisworks					
Allplan					
Total number	(1)	(7)	(2)	(2)	[12]

Table 14: BIM Software per discipline in Denmark

Software	Architects	Engineers	Contractors	All others	Total
ADT	3				3
Revit	2				2
Revit Struct					
Tekla Struct					
Bentley	1				1
AD MEP					
Archicad	3	1		2	6
MagiCAD		1			1
Navisworks	2				2
Allplan		1			1
Total number	(11)	(3)	(0)	(2)	[16]

Table 15: Software per discipline in Finland

Software	Architects	Engineers	Contractors	All others	Total
ADT	4	2	2	1	9
Revit	3		1		4
Revit Struct		1			1
Tekla Struct		3			3
Bentley	1	2			3
AD MEP					
Archicad	4			1	5
MagiCAD		2	1		3
Navisworks	2		3		5
Allplan					
Total number	(14)	(10)	(7)	(2)	[33]

Table 16: Software per discipline in Norway

Software	Architects	Engineers	Contractors	All others	Total
ADT	1	1	2	1	5
Revit	2				2
Revit Struct					
Tekla Struct			1	1	2
Bentley	2				2
AD MEP					
Archicad	11		2	1	14
MagiCAD			2		2
Navisworks	1		2		3
Allplan					
Total number	(17)	(1)	(9)	(3)	[30]

Table 17: Software per discipline in Sweden

Software	Architects	Engineers	Contractors	All others	Total
ADT			1		1
Revit		1			1
Revit Struct		1	1		2
Tekla Struct					
Bentley					
AD MEP					
Archicad					
MagiCAD					
Navisworks		1			1
Allplan					
Total number	(0)	(3)	(2)	(0)	[5]

Table 18: Software per discipline in the Netherlands

11.2 IFC based BIM software used (the most used ones)

The list is in addition to the ordinary CAD applications showing DDS viewer, Navisworks, and Solibri model checker, which are no authoring tools. They are used for analysis of the IFC models by geometry and/or properties.

Software	Architects	Engineers	Contractors	All others	Total
ADT	5	3	3	1	12
Revit	6		1		7
Revit Struct		2			2
Tekla Struct		4	1		5
Bentley	2	2	1	1	6
DDS viewer	1	1		1	3
Archicad	13	1	1	5	20
Solibri	4	2		1	7
Navisworks	1	1	3		5
MagiCAD		4	2		6
Allplan		2			2
Total number	(32)	(22)	(12)	(9)	[75]

Table 19: Total number of answers per IFC based BIM Software and discipline

Software	Architects	Engineers	Contractors	All others	Total
ADT		1	1		2
Revit	1				1
Revit Struct					
Tekla Struct		1			1
Bentley				1	1
DDS viewer				1	1
Archicad				1	1
Solibri		1		1	2
Navisworks					
MagiCAD		1	1		2
Allplan					
Total number	(1)	(4)	(2)	(4)	[11]

Table 20: IFC based BIM Software per discipline in Denmark

Software	Architects	Engineers	Contractors	All others	Total
ADT	1				1
Revit	1				1
Revit Struct					
Tekla Struct					
Bentley	1				1
DDS viewer	1	1			2
Archicad	3	1		2	6
Solibri	4	1			5
Navisworks	1				1
MagiCAD		1			1
Allplan		1			1
Total number	(12)	(5)	(0)	(2)	[19]

Table 21: IFC based Software per discipline in Finland

Software	Architects	Engineers	Contractors	All others	Total
ADT	3	2	2		7
Revit	2		1		3
Revit Struct		1			1
Tekla Struct		3			3
Bentley		2			2
DDS viewer					
Archicad	3			1	4
Solibri					
Navisworks			2		2
MagiCAD		2			2
Allplan		1			1
Total number	(8)	(11)	(5)	(1)	[25]

Table 22: IFC based Software per discipline in Norway

Software	Architects	Engineers	Contractors	All others	Total
ADT	1			1	2
Revit	2				2
Revit Struct					
Tekla Struct			1		1
Bentley	1		1		2
DDS viewer					
Archicad	7		1	1	9
Solibri					
Navisworks			1		1
MagiCAD			1		1
Allplan					
Total number	(11)	(0)	(5)	(2)	[18]

Table 23: IFC based Software per discipline in Sweden

Software	Architects	Engineers	Contractors	All others	Total
ADT					
Revit					
Revit Struct		1			1
Tekla Struct					
Bentley					
DDS viewer		1			1
Archicad					
Solibri					
Navisworks		1			1
MagiCAD					
Allplan					
Total number	(0)	(3)	(0)	(0)	[3]

Table 24: IFC based Software per discipline in the Netherlands