BIM Adoption in Iceland and Its Relation to Lean Construction

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Thesis submitted to the School of Science and Engineering
at Reykjavík University in partial fulfillment
of the requirements for the degree of
Master of Science in Construction Management

December 2011

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Abstract:

Firms and organisations within the Icelandic AEC sector have shown an interest in Building Information Modelling (BIM), even adopted it and applied it to several projects. The main purpose of this research is to explore where the Icelandic AEC sector stands in its implementation process of BIM.

The aim is pursued by reviewing implementation processes within public organisations in USA, UK, Norway, Denmark and Iceland. The results are compared against each other and gaps identified. The results indicate that there is a gap in the implementation process, where regulations on BIM use on public projects are lacking. Public organisations in Iceland are indeed adopting BIM but they cannot require it, only strive for it.

A survey will be executed within organisations and firms within the Icelandic AEC sector, to find out to what extent BIM is being applied in Iceland. Previous researches show synergies between lean construction and BIM. In relation to that it will also be explored if the Icelandic AEC sector is practicing lean construction principles and to what extent.

The survey results suggest that BIM is indeed being adopted in Iceland, 40% of respondents claim they are adopting BIM, mostly by architects and egnineers. The BIM maturity stage is somewhere inbetween maturity stage 1 and 2, due to the fact that no contractor reported on using BIM and only one firm reported of using lean construction.

The organisations driving the implementation process here in Iceland and public and private clients can possibly gain some advantages from this research, which maps down where the process is today, what is missing and what can be done to contribute to a better construction process.

Keywords: Building Information Modelling, lean construction, BIM adoption.

Úrdráttur

Fyrirtæki og stofnanir innan íslenska byggingariðnaðarins hafa sýnt upplýsingalíkönum mannvirkja áhuga á undanförnum árum, jafnvel innleitt það og beitt við nokkur verkefni. Tilgangur þessarar rannsóknar er að kanna hvar íslenski byggingariðnaðurinn stendur við innleiðingu upplýsingalíkana mannvirkja eða eins og það nefnist á ensku, Building Information Modelling, skammstafað BIM. Skammstöfunin BIM hefur fengið alþjóðlega útbreiðslu og verður því notuð í rannsókn þessari.

Innleiðingarferli opinberra stofnanna á Íslandi og í nágrannalöndum verða skoðuð sem og Bandaríkjanna og þau borin saman og bil tilgreind. Niðurstöðurnar gefa í skyn að bil sé í innleiðingarferlinu á Íslandi, þar sem engar reglugerðir um notkun BIM eru í gildi. Opinberar stofnanir geta því aðeins sóst eftir að BIM sé notað, en ekki krafist þess.

Framkvæmd var könnun innan fyrirtækja og stofnanna innan íslenska byggingariðnaðarins til að varpa ljósi á hverjir notast við BIM og að hvaða marki. Fyrri rannsóknir hafa sýnt fram á samvirkni milli lean construction og BIM. Í tengslum við það verður einnig kannað hvort íslenskur byggingariðnaður sé að tileinka sér aðferðir lean construction og þá að hvaða marki.

Af þátttakendum segjast 40% nota BIM, mest arkitektar og verkfræðingar. Niðurstöðurnar gefa í skyn að þroskastig BIM á Íslandi liggur á milli þroskastigs 1 og 2, þar sem enginn verktaki notast við BIM og aðeins eitt fyrirtæki segist notast lean construction.

Innleiðendur BIM á Íslandi sem og verkkaupar almennt, gætu hugsanlega nýtt sér niðurstöður rannsóknar þessarar við ákvörðun á innleiðingu BIM sem og næstu skrefum ferlisins. Niðurstöðurnar munu vonandi gefa skýrari mynd á stöðuna hérlendis og hvort eitthvað vantar uppá við innleiðingaferli BIM sem hefur það að leiðarljósi að stuðla að bættu ferli mannvirkjagerðar.

Lykilorð: Upplýsingalíkön Mannvirkja (BIM), lean construction, innleiðing BIM.

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"When we mean to build, we first survey the plot, then draw the model; and when we see the figure of the house, then must we rate the cost of the erection; which if we find outweighs quality, what do we then but draw a new model"

Shakespeare
King Henry IV
Ca. 1597

1 Introduction

In this chapter the reasons for choice of topic for this thesis are discussed and the background reviewed. Research questions/objectives are presented and how they are related to the research objectives. Research methodology will be reviewed and finally the structure of the research will be introduced.

1.1 Statement of the problem

It is a cliché within the construction industry that the quality is poor, budgets are unreliable and the price is too high. The industry has been accused of being stalled and there is a great need for improvement. Failures and errors are arising due to multifarious causes and occur in all steps of the construction process. There is a great need for enhancing the whole construction process, to obtain buildings of better quality, reduce cost, minimize project time and improve productivity.

Within the construction phase many problems and errors occur due to shortcomings in the design phase. Difficulties in communication, coordination and standardisation are amongst the problems facing the industry. Information is probably the most important construction “material”. That being said, the need for communicating design information effectively within the Architect, Engineer and Construction (AEC) sector, plays a big role in overcoming these interoperability issues. The sector needs to be able to insert information into a system, or different systems, that can be pulled out when needed, at different times in the lifecycle of a building or a facility.

According to McGraw-Hill Construction (2009) almost 50% of the AEC North American industry, is now using Building Information Modelling (BIM) and those using it are planning to increase their use significantly. The majority are also experiencing real business benefits, directly attributable to BIM.

It is stated that BIM facilitates to a better design, construction and operation process at all phases of the construction processes, when it is implemented appropriately. The gain is a more integrated design, better quality buildings at lower cost and reduced project duration (Eastman et al., 2008). That being said, the implementation process is very important for realizing the advantages BIM is said to give.

Lean methodology, based on the concepts and principles of the Toyota Production System, has been implemented within different industries, resulting in better customer value, more return on investment and better production flow. Lean construction is the term used when this methodology is applied to the construction industry (Howell, 1999). This methodology has been implemented around the world, within many different industries, but has not reached its full implementation within the construction industry.

The concept of Virtual Design and Construction and how they could be applied to lean construction have been explained (Khanzode et al., 2006). The synergies between BIM and lean construction have been evaluated (Sacks et al., 2010a) and the conclusion is that this combination can lead to an even better and more optimized construction process.

1.2 Aim and objectives

The purpose of this research was to explore which organisations, within the Icelandic AEC sector, are using BIM and to what extent. What the main drivers were for this implementation were reviewed and whether or not the users were experiencing good or poor results by using BIM. The reasons why organisations were not adopting BIM were also reviewed. Furthermore the investigation included whether these organisations were familiar with lean construction and if they were applying its principles within their organisations, and if so, to what extent.

In order to identify where the Icelandic AEC sector stands in implementing BIM, a road map showing what others have done was needed. Public organisations in four countries, the USA, the UK, Norway and Demark were reviewed, to map what had been done in order to support the implementation process of BIM in each country. Furthermore the public organisation in Iceland, GCCA, was reviewed.

1.2.1 Research questions

To measure these research objectives, the work is divided into two chapters. The first part was a comparison between public organisations in five different countries, including Iceland, where the following questions are were answered.

1.1. What has been done to support the adoption of BIM within the Icelandic AEC sector?
1.2. Is there a gap in the implementation process in Iceland?

The latter part of this research is to explore BIM adoption within the Icelandic AEC sector, in terms of the following questions:

2.1. To what extent is BIM being applied within the Icelandic AEC sector?
2.2. What is the driving force of the implementation process in Iceland?
2.3. To what extent is lean construction being practiced within the Icelandic AEC sector?

To be able to understand better how Icelandic industry is using BIM and how mature their use is, is crucial when deciding on what to do next. The results can hopefully give indications on where the AEC sector stands, find gaps, if any, within the implementation process, by plotting what other countries have been doing and compare that to what has been done in Iceland. This should give a better understanding of where bridges need to be built and facilitated to lead to a better implementation process, which is essential for obtaining a better construction process through BIM.

1.3 Research methodology

This chapter describes the methodology used in this research. First the field this research work falls under is identified. The chapter then proceeds to the research approach and methods used in this work, leading to a description of the process of the research.

1.3.1 Research classification

Research can be classified in a range from being pure research to applied research, with most research falling somewhere between these two extremes. (Robson, 2002) This research is classified as applied research, and is essentially positivist in nature.

1.3.2 Research approach:

Hypothesis testing has little use in this research, as the objective is not to prove or disapprove something. The purpose is to explore where in the implementation process of BIM the Icelandic sector is placed. In order to do that, other countries' implementation processes were reviewed, including Iceland's. All of these were then compared to one another. A questionnaire was then presented to the Icelandic AEC sector, designed to answer the objectives of this research. The results have hopefully given an indication of whether or not the implementation process in Iceland needs improvement and what steps should be considered next.

1.3.3 Research method, techniques and tools:

The research method is the framework of this thesis. The way data is gathered and analysed is decided in accordance with which research method is chosen. The choice of the method is therefore important. Research methods are divided into two main groups:

- Quantitative methods:
    - Facts and sets of facts are collected and the relationship between them is studied. Conclusions are conducted from scientific measuring techniques.
- Qualitative methods:
    - A subject is explored to gain insights from which theories might emerge. This method is preferred by most social scientist seeking insights into a particular situation or phenomenon, through close observation. Conclusions rely on the researchers' skills in recognising patterns.

In this study a quantitative research method was applied. The implementation process of BIM within public organisations responsible for implementing BIM was explored, and to what extent BIM was being used in the Icelandic AEC sector was ascertained. Furthermore, the relationship between BIM and lean construction was studied. Facts and sets of facts on the subject were gathered and studied, and conclusions were then drawn from scientific measuring techniques using SPSS software and Excel. There is much quantitative data available on BIM and lean construction; however, data on the best practices in implementing BIM are lacking.

The purpose of this research is descriptive, i.e. the research is concerned with portraying an accurate profile of the situation of BIM implementation in Iceland

To be able to put the Icelandic implementation process in a larger perspective a comparison between public organisations requiring BIM in other countries was reviewed and analysed, making it possible to identify that the implementation process in Iceland has a gap.

A survey is an appropriate tool when the purpose is descriptive. When a survey is conducted, information is collected in a standardised form from groups of people. A sample is carefully drawn up and the respondents presented with a questionnaire. Surveys have a few advantages: they are a relatively simple means of studying invisible characteristics such as values and attitudes; they can be adapted to collect generalizable information from almost any human population; and they permit high amounts of data standardisation. However, the data are affected by the respondents' characteristics, which are not always apparent to the researcher (Robson, 2002). Due to these advantages a questionnaire is considered an appropriate method for collecting the data, especially if the researcher is not able to see or observe the subject. The type of questionnaire used is self-completed by the respondent and is sent by email.

1.4 Structure of the thesis

This thesis has five main chapters. In the first chapter background, aims and objectives and research methods are described and the research objectives which this thesis is based upon.

The theoretical framework is presented in chapter two, which emphasises the theories of BIM, lean construction and the synergies between them. In the first chapter theories on what BIM consist of, the BIM process and model are reviewed, how it has and is affecting the AEC sector, its maturity scale, adoption process and planning, and at the end a conclusion drawn. Furthermore, a literature review on lean construction and the synergies between them are put forward.

The third chapter describes the methodology and methods used in this study. The methodology lists how the comparison part of this thesis was conducted. Furthermore it describes how the survey was carried out.

The results from the research work are presented in chapter four. The results from the comparison part are first presented. Each organisation, including one in Iceland, is compared against each other. The results map what these organisations have done to support the implementation of BIM in the AEC sector in their country. Next the results from the survey are presented and listed. Significant results are analysed in subchapters. When significant gaps were found, the need for improvement was identified. Finally a conclusion is presented based upon the results.

In the fifth chapter, a discussion of the results, the research work and its findings are presented. A general discussion and final conclusion is provided and the chapter ends with recommendations for further research.

2 Theoretical framework

In this chapter, theories on BIM and lean construction are reviewed, which will guide the reader on to the main topic of this research, BIM and lean construction, and the relationship between them. First, the theories on BIM are reviewed, how it works and how it is adopted. Second, lean construction is reviewed, its principles and practices, to illustrate how the philosophy is adjusted to construction processes. Finally, theories on the connection between BIM and lean construction are discussed, as presented in published works.

2.1 Building Information Modelling

The construction industry and researchers have a number of views as to what BIM is.

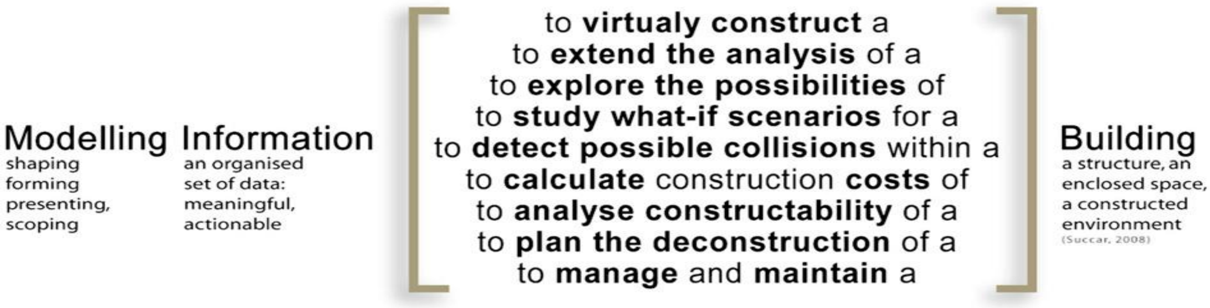

Figure 1 Succar, 2009

"A modelling technology and associated set of processes to produce, communicate and analyse building models." (Eastman et al., 2008, p. 13)

"The process of creating and using digital models for design, construction and/or operations of projects. " *(McGraw-Hill Construction, 2009, p. 4)*

BuildingSMART International, a not for profit organisation supporting open BIM through the lifecycle, defines BIM as:

"A new approach to being able to describe and display the information required for the design, construction and operation of constructed facilities."[1]

The NBIM Standard (NBIMS) is the published body of works designated and managed by the NBIMS Project Committee. They are responsible for designating and managing BIM-related standards for the United States building industry. Their definition of BIM is:

[1] http://buildingsmart.org/

"A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM can represent viewports – graphically and in text and table form, of a building from any practitioner perspective – Architect, Specifier, Engineers, Fabricators, Leasing Agents, General Contractors and so on. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during it life cycle from inception onward." (Charter for the National Building Information Model (BIM) Standard Project of the buildingSMART alliance, 2008, p. 1)

As pointed out by McGraw-Hill Construction (2007), BIM can mean different things to different professionals. The term is not only defined in various ways according to particular professions, but also there is confusion on three different levels. Some might say BIM is a software application, others, a process for designing and documenting building information, and still others could say it is a whole new approach to practice and advancing the professions which requires the implementation of new policies, contracts and relationships amongst project stakeholders.

Here the definitions of BIM have been reviewed and BIM is regarded as the process of creating and managing information on a construction project by creating a virtual reality, and being able to share that data and information in digital format.

2.1.1 The BIM process

The BIM process gives project teams opportunity to virtually plan and build construction projects before any bigger commitments to money and time are made, i.e. enhanced constructability analysis. By virtually building the project, a common understanding and knowledge is enhanced in the project team. (Pikas et al., 2011)

Major process changes have been documented (Eastman et al., 2008; Khemlani, 2009) and are listed below:

- Increased engagement of construction knowledge and enhancement of team skill in the design process.
- Development of detailed design earlier than has been common with traditional systems.
- Co-located teams.
- Contractual arrangements to share pain and gain.
- Introduction of new roles, such as BIM managers or consultants.

BuildingSMART claim that BIM combines different threads of information used in construction into a single operating environment, reducing the need for different types of paper documents. They also state that the quality of communication between different participants is crucial to enable effective use of BIM.

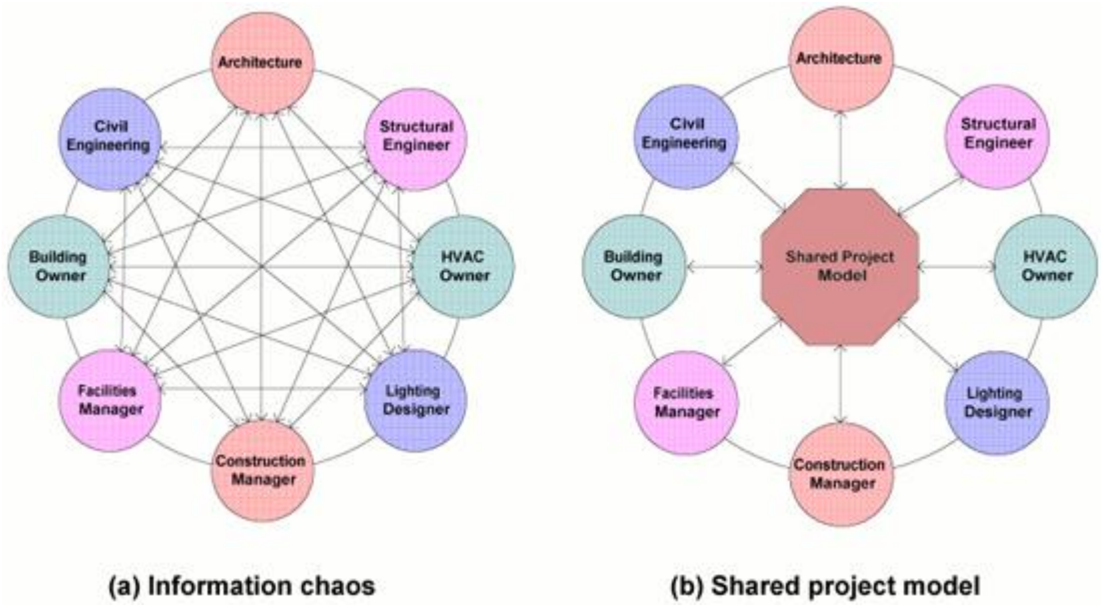

Figure 2: Traditional process vs. BIM process[2]

In order to adopt BIM, there are three main elements that must be present, often referred to as the BIM triangle. These elements can be built-in on open, international standards.

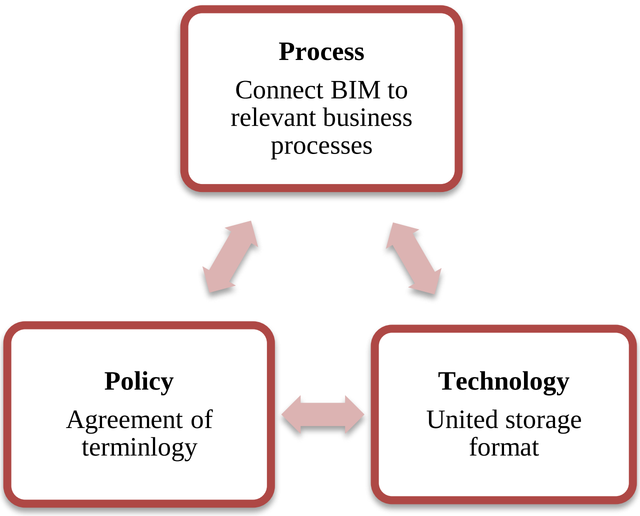

Figure 3: BIM triangle

BuildingSMART Alliance has developed standards for each main element to support open BIM through the life cycle of a building.

International Framework for Dictionaries (IFD) is a data dictionary which brings together disparate sets of data into common view of the construction project, independent of whether that information comes from a product manufacturer or the designer. It can cope with different languages. This product serves as an agreement on terminology.

[2] http://www.aecbytes.com/viewpoint/2007/issue31-images/fig1.png

Industry Foundation Classes (IFC) is a data model, developed by buildingSMART, serving as the united storage format. It is able to hold and exchange data between different proprietary software applications. The data schema comprises information covering the many disciplines that contribute to a building throughout its lifecycle. The real value lies in the openness of this schema. IFC can be used to exchange and share BIM data between applications developed by different software vendors, and by that it becomes a platform to solve interoperability issues.

Information Delivery Manual (IDM) is the buildingSMART standard for processes connecting BIM to relevant business processes by offering a understanding for all project stakeholders of what is needed when exchanging information. It provides detailed specification of the information that a particular user (architect and building owner) needs to provide at a point in time and groups together information that is needed in associated activities, i.e. cost estimating. [3]

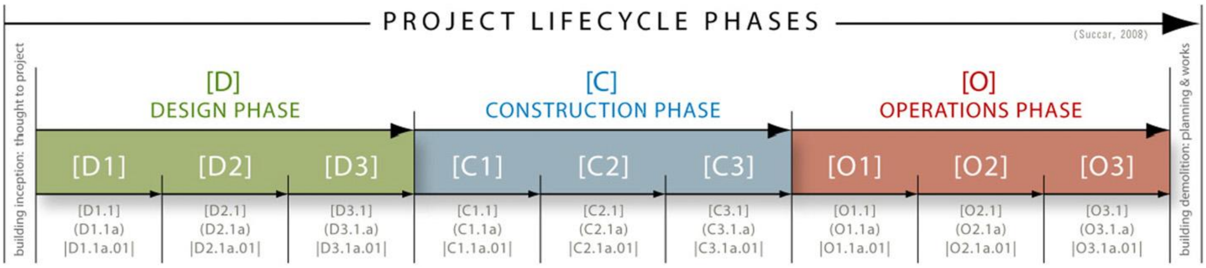

Figure 4: Project lifecycle phases identified by Succar (2009)

In a BIM process data sharing happens throughout the entire lifecycle of the building. These data can include the initial design data, geospatial information, financial and legal data, MEP, layout, building product specifications, environmental and energy simulations and other data that architects, engineers, contractors, owners and facility managers use throughout the project's lifecycle (McGraw-Hill Construction, 2007). The data are created and managed with suitable products, which usually use 3D dynamic software to bind information shapes, spatial relationships, quantities and properties of the building. The model produced serves as a database providing accurate digital information on the design, fabrication, construction, project management, logistics, materials and energy simulation. The 3D models are effectively produced and tested across different parameters. All this helps to identify potential construction conflicts at the design stage and when quantifying the materials, resulting in a better construction process. The AEC industry's stakeholders are experiencing a shift, technological and procedural (Succar, 2009).

2.1.2 A BIM Model

The BIM model contains the physical and functional characteristics of a structure composed of intelligent objects rather than lines, arcs, and text, as when producing drawings in conventional CAD. BIM is able to render multiple views of data, including

[3] http://buildingsmart.org/

2D drawings, lists, text, 3D images, animation and time/scheduling (4D) and cost (5D). A model containing more than three dimensions is called n-Dimensional (nD) modelling technique. An nD model is an extension of the BIM that incorporates multi-aspects of design information required at each stage of the lifecycle of the building facility. This tool will enable construction stakeholders to cohesively and comprehensively work within their own specialised discipline on one model. Furthermore, it is capable of negotiating and collaborating to bring about new designs by enabling true what-if analyses of design decisions. (Aouad et al., 2005)

The combination of time and 3D is called 4D model. The 3D model is linked to scheduling software and thereby given a start and finish date to each element or group of elements in a 4D model, enabling the model to be played as a simulation.

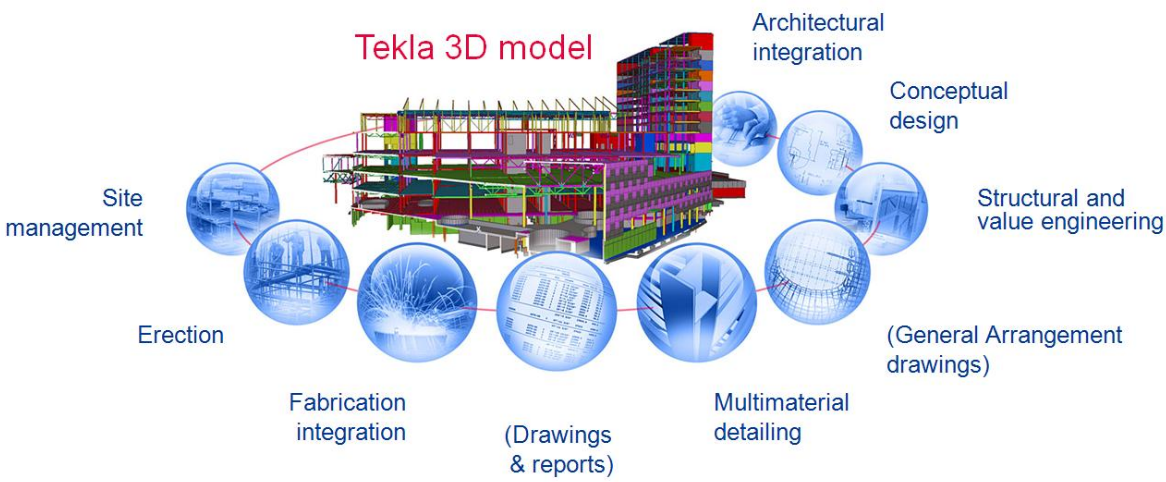

Figure 5: BIM workflow from Tekla Structures [4]

A 5D model is when a 3D constructability analysis, quantity take-off and estimating and schedule are combined into one system. If there is a design change, quantities are updated, resulting in an automated cost and time effect.

2.1.3 BIM and the AEC sector

By implementing BIM risk is reduced, design intent is maintained, quality control is streamlined, communication is clearer, and higher analytic tools are more accessible (CRC for Construction Innovation, 2007a, p. 9)

BIM has become a proven technology, and is no longer in its infancy. There are still a number of inefficiencies that need to be overcome, but BIM systems are achieving efficiencies by introducing an order of precision. Other affects include: reduced risk of information loss between design, project management and construction team because all members have access to the same model at the same time (Hardin, 2009).

[4] http://www.ecobuild.co.uk/exhibitor-list/profile/2658/tekla-uk-ltd.html

Sacks et al. (2010b) point out potentials BIM has not yet introduced, such as greater efficiencies, as software systems improve and computer processing power increases. Streamlined processes throughout a building's lifecycle through the integration of design, engineering, construction, maintenance and decommissioning information about a built asset project into a single rich model.

BIM-based applications provide for the extraction of accurate and consistent drawings of any set of objects or specified view of the project (Eastman et al. 2008) resulting in reduced time needed and errors associated with generating construction drawings (Pikas et al. 2011).

Table 1 Impact of BIM in different disciplines

Architects and BIM	Engineers and BIM	Contractors and BIM	Owners and BIM
Are using BIM the most and have adopted the technology over a few years.	Are moving more and more towards the adoption of BIM	Few contractors have adopted BIM. Half of them have never used it partly due to its cost and partly due to limited use by others.	Few owners use BIM, but it is of increasing interest to them.
When producing drawings with a BIM-based application, less drawing time is needed and the drawings produced are more accurate and consistent, because the application is able to take a view from any point in the model.	They are more likely to be the only team members on a project using BIM on a typical project. Data translation across software applications is not interoperable on a particular project.	Contractors utilize BIM for quantity take-offs, scheduling and administration more often than 3D visualisations and interference detection purposes.	BIM provides a critical database of facility information that can be used for operators and maintenance.
They are frustrated by the lack of adoption of BIM elsewhere in the industry.		Information on actual start and completion of work on site is easily gathered and fed back to the BIM application, which produces an animated model (4D) showing actual activity on site over time. Actual schedule is compared to planned schedule allowing better communication between contractors and subcontractors.	The BIM database contains closeout documentation and maintenance of information, easily accessed in the field and easily maintained and linked to the 3D model for better visualization. Making maintenance and management of facilities more efficient.
		Monitoring can also be used to track material delivery, handovers from design to construction and from construction to client resource flow etc.	

When not applying BIM, information exchange between different project participants is not as concise, as when conventional CAD systems are used. Project participants exchange information between each other, and use all kinds of software. A lot of repeated work is done, e.g. drawings to be drawn again, resulting in an insufficient process. The risk of information loss is higher and design intent often gets lost. This makes the construction process insufficient. Also when exchanging data, between CAD systems, it is done in 2D. The risk of design failure increases, such as having air conditioning systems pass through beams, resulting in insufficient design documents.

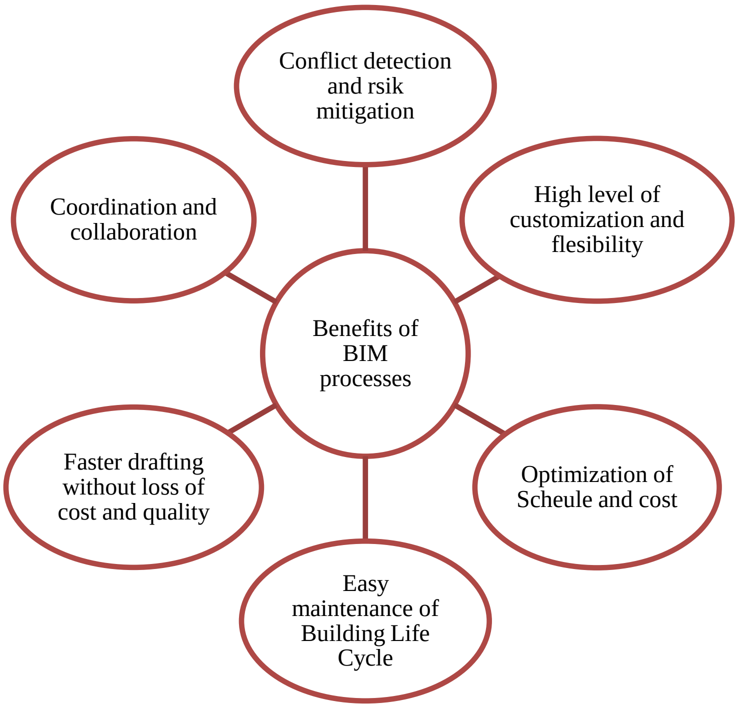

Figure 6: Benefits of BIM processes

Stanford University Center for Integrated Facilities Engineering (CIFE) figures based on 32 BIM projects indicates benefits such as (Kunz and Gilligan, 2007) the following.

- Up to 40% elimination of unbudgeted change.
- Cost estimation accuracy within 3%.
- Up to 80% reduction in time taken to generate a cost estimate
- A savings of up to 10% of the contract value through clash detections.
- Up to 7% reduction in project time.

When using BIM instead of conventional CAD, the drawing process is different. Instead of drawing each floor with lines and arcs, you draw the whole building at one time. It is critical to prepare yourself well, and to divide the whole building into modules. The building being drawn relies on this module net. Furthermore, before the drawing process begins, construction parts need to be defined, though they can easily be changed later on in the process. At first it seems like it takes more time to model the building due to the results (i.e. the drawings themselves). But when the model is ready, the drawings are easily produced. In a BIM application it is possible to extract any view, 3D or 2D, and apply on previously defined paper (layout). Most companies using BIM have prepared their own standard of sheets, resulting in effortless paper setup when the model is ready.

Kahnzode (2007) identifies benefits of 4D modelling in a case study. By applying a 4D modelling co-ordination within subcontractors schedules are assisted. The model allows visualization of tasks and the relationships between work of different sub-trades and equipment placement. Communication of schedule intent was clearer between different stakeholders. The project team had better understanding of the interdependencies between activities, which are more difficult to visualize on a critical path method schedule. Furthermore, the 4D model communicated work flow over time, compared to conventional bar-chart schedules. Constructability issues and sequencing problems prior to construction were identified. Optimal sequence of work was clearer, resulting in more efficient construction process. Lastly, the 4D model showed the status of construction at any time in the project, which was useful to enhance co-ordination on equipment and material deliveries.

Hardin (2009) states that information produced in a BIM project is intended to be routinely shared. When two or more people from the same discipline are to work on a single model, it is important to define who is responsible for what and how to manage and develop the model. Each person can be assigned different responsibilities, one person able to edit walls, floors and roofs and another person is assigned furnishings. It is also possible to check out the object to edit, enabling others to edit it, then check it back in to the model.

When drawing in 3D CAD application, the model is made of multiple files, storing each floor. With this system, when change is made in one file, it does not show in another file immediately. When two or more people are working on a project, they cannot rely on the fact that what they see has not been changed. Also, only one person can work in one file. In a BIM application the model is stored in one file. When one or more people are working on one model, there is a need to define who has access to what in the model. Version control and updates need to be maintained on the model. It is also possible to check out one object, e.g. wall, edit the object and check it back into the model. Meanwhile others cannot edit that particular object.

BIM is very different from CAD, and without proper training, users will try to force BIM to work as their CAD system did. It is important to set time aside to produce templates for the firm or for the project. It is also important to determine the purpose of the model, as it dictates the level of detail required.

Other BIM-related disadvantages include the manpower cost and time involved to build the 3D model, especially when there are constant changes. Also when BIM software is used in detailed modelling, it creates large file sizes, making it difficult to use it in project sequencing (Ford, 2009).

2.1.4 BIM adoption

The BIM adoption rate is slower within the AEC industry than anticipated (Arayici et al., 2011; Eastman et al, 2008) identify challenges in implementing BIM, as listed below.

- Overcoming the resistance to change, and getting people to understand the potential and the value of BIM over 2D drafting.
- Adapting existing workflows to lean oriented processes.
- Training people in BIM, or finding employees who understand BIM.
- Understanding of the required high-end hardware resources and networking facilities to run BIM applications and tools efficiently.
- Required collaboration, integration and interoperability between the structural and the MEP designers/engineers.
- Clear understanding of the responsibilities of different stakeholders in the new process by construction lawyers and insurers.

Adapting to the BIM process requires significant changes in the way construction businesses work, and at almost every level within the building process. New workflow has to be established, training of staff on new processes and software is needed, and responsibilities must be reassigned to show how construction is modelled.

The technical reasons can be broadly classified into three categories (Bernstein and Pittman, 2005).

1. The need for well-defined transactional construction process models to eliminate data interoperability issues.
2. The requirements that digital design data be computable.
3. The need for well-developed practical strategies for the purposeful exchange and integration of meaningful information among the BIM model components.

The management issues cluster around the implementation and use of BIM. A clear consensus on how to implement and use BIM is lacking. No single document or treatise on BIM that covers its application or usage exists (Azhar et al., 2008). The BIM process needs to be standardised and guidelines for its implementation need to be defined. Defining how to develop and operate the building information model is necessary as well as how developmental and operational cost is distributed. With more use of BIM, collaboration within project teams should increase.

It is important to keep in mind that by adopting BIM, it changes the way work is done, for example, changes in staffing, project organisation, and on how a firm uses the information contained within the building model. These changes need to be addressed prior to implementation.

BIM Maturity Stages

Succar (2009) explores some of the publicly available international guidelines and introduces a BIM Framework, where conceptual parts are identified and examples of their application are provided. The framework deliverables are listed and presented. BIM implementation is divided into three maturity stages.

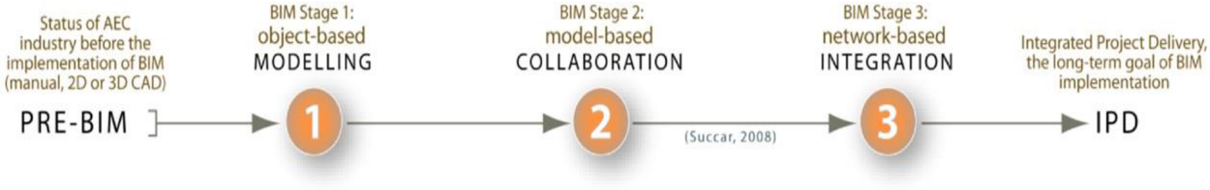

Figure 7: BIM maturity stages, Succar (2009)

First a fixed starting point is identified, Pre-BIM, the status before implemenation. Next three BIM maturity stages are identified and implementation maturity levels are delineated. Then a variable ending point is identified, which allows for unforseen future advancements in technology. Integrated Project Delivery (IPD) is noted as the long-term goal of implementing BIM and is chosen as an attempt to include all pertinent BIM visions.

Construction projects pass through three major lifecycle phases: Design (D), Construction (C) and Operations (O). These phases are then subdivided into sub-phases which are in turn further subdivided into multiple activities, sub-activities and tasks.

The volume and complexity of changes identified in BIM stages are transformational and cannot be implemented without traversing incremental evolutionary steps. Each step can either be a prerequisite for reaching a stage or a maturity level within each stage.

Pre-BIM Status:

Dependence is placed on 2D documentation to describe 3D reality. Though 3D visualisations are used, these are often disjointed and reliant on 2D documentation and detailing. Quantities, cost estimates and specifications are generally not linked to the visualisations model or documentation.

Stage 1:

An object-based 3D parametric software tool, similar to Revit, ArchiCAD and Tekla, is used. Users produce models within the design, construction or operation phases. This model is the basis for the 2D documentation and 3D visualisation.

Stage 1 is similar to Pre-BIM Status, with no significant model-based interchanges between different disciplines. Data exchanges and communication continues to be asynchronous and disjointed. The process changes are minor, so contractual relations, risk allocations and organisational behaviour are the same as in Pre-BIM Status.

- 3D, parametric design elements
- Design information
- Documentation for outputs
- Conceptual design and analysis

Table 2: Impact on each discipline in stage 1

Architecture	MEP Engineering	Structural Engineering	Civil Engineering	Construction
Design accuracy and quality	Leverage arch. Data to improve design accuracy and quality	Assessment of design performance	Design accuracy and quality	Design accuracy and quality
Estimating opportunities	Improve systems coordination	Performance optimization	Calculate material quantities	Estimating opportunities
Productivity increases	Achieve productivity increases		Improve document coordination	Productivity increases
Accurate, efficient documentation	Facilitate preliminary analysis		Accurate, efficient documentation	
Early evaluation of complex constructability	Accurate, efficient documentation			

Stage 2:

Players within stage 2 are actively collaborating with other disciplinary players. This may occur in many technological ways using non-proprietary format, such as IFC file format, or through proprietary formats (i.e. between Revit Architecture and Revit Structure through the .RVT file format).

The communication continues to be asynchronous, but the separating lines between disciplines and lifecycle phases start to fade. Contractual amendments become necessary and modelling performed at each lifecycle phase (design, construction and operation) start to fade, while higher-detailed construction models move forward and replace lower-detail design models.

- Link models to analysis tools
- Visualize real-world appearance
- Model-based assessment processes

Table 3: Impact from stage 2

Architecture	MEP Engineering	Structural Engineering	Civil Engineering	Construction
Assessments of design performance for LEED and other sustainable rating criteria	Assessments of design performance for LEED and other sustainable rating criteria	Assessment of design performance	Assessments of design performance for LEED and other sustainable performance criteria, structural performance	Assessments of design performance for LEED and other sustainable rating criteria
Performance optimization	Performance optimization	Performance optimization	Performance optimization	Increase schedule predictability
Design visualization quality			Collaborate with internal teams	Performance optimization
			Design visualization quality	Clash detection

Stage 3:

In this stage, semantically-rich integrated models are created, shared and maintained collaboratively through the project life-cycle phases. Models in this stage become interdisciplinary nD models, where complex analyses at early stages of design and construction are allowed. Model deliverables include business intelligence, lean construction principles, green policies and whole lifecycle costing. The Project Lifecycle is now phase-less. In this stage, major changes are necessary on contractual relationships, risk-allocation models and procedural flows. A shared interdisciplinary model is necessary to provide two-way access to project stakeholders, which will eventually facilitate into Integrated Project Delivery.

- Convergence of models
- Model-based communication between disciplines
- Lifecycle model utilization
- Model-based fabrication

Table 4: Impact from stage 3

Architecture	MEP Engineering	Structural Engineering	Civil Engineering	Construction
Coordination and clash detection	Coordination and clash detection	Coordination and clash detection	Coordination and clash detection	Coordination and clash detection
Reduced RFIs and change orders	Reduced RFIs and change orders	Reduced RFIs and change orders	Reduced RFIs and change orders	Reduced RFIs and change orders
IPD opportunities	IPD opportunities	IPD opportunities	IPD opportunities	IPD opportunities
More accurate building components			Collaborate with external companies on building team	Collaborate with external companies on building team
			Reduce risk and liability concerns	Integration of fabricated components

Integrated Project Delivery:

Integrated Project Delivery (IPD) is defined by the AIA California Council as:

"A project delivery approach that integrates people, systems business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction."[5]

IPD principles are applied to contractual arrangements and IPD teams will usually include members well beyond the basic triad of owner, designer and contractor. Tight collaboration between key participants is required from early design through project handover. IPD can be delivered without BIM, but to efficiently achieve the collaboration required, BIM is an effective tool. The collaboration IPD is built on, is best suited to business models that promote early involvement of key participants, equitably balance risk and reward, have compensation structures that reward "best for project" behaviour, clearly define responsibilities without chilling open communication and risk taking, and implement management and control structures built around team decision making with facilitation, as appropriate.

Integrated Project Delivery (IPD) is defined as the long-term vision of BIM as an amalgamation of domain technologies, processes and policies. This term is used as an attempt to include all pertinent BIM visions irrespective of their originating sources.

BIM Adoption Planning

The technology, process and organisational investments required to implement BIM are considerable and costly. To adopt BIM substantial changes in how the industry has been designing and building projects are required. One of the primary motivations for professionals in the AEC sector to adopt new technologies is the opportunity for direct

[5] A Working Definition Version 2, 2007, AIA California council.

gains and benefits in their own operations. Another motivation is clients' requirements. The stakeholder benefitting the most from BIM being adopted is the client or the owner.

A change must be desireable before implementation. Either external pressure or perceived rewards needs to exist and the change must be technically and organisationally possible. Furthermore, it must respond to the conditions that made it desireable in the first place. Owners pay for the product and it is therefore in their interest to demand more value, increase productivity and elminate waste.

BIM can be of great value for both public and private owners. Public owners are often also managers of their buildings, and it is here the BIM adds major value. Owners experience infomation loss between the end of construction and beginning of the management phase, resulting in an insufficient facility management. BIM can help the owner, by being a pool information on the facility

BIM adoption is planned through four stages, identified by Coates et al. (2010). They discuss the preliminary findings of an on-going research project funded by the Cooperative Research Centre of Construction Innovation which aims to identify these gaps and come up with specifications and guidelines to enable greater adoption of the BIM approach in practice.

Stage 1: detail review and analysis of current practice

- Process mapping of current practices.
- Conducting soft system analysis.
- Stakeholder review and analysis.
- Identification of competitive advantages from BIM implementation.

Stage 2: identification of efficiency gains from BIM implementation

- The main characteristics of BIM implementation strategy and the subsequent efficiency gains are clarified after stage 1.

Stage 3: Designing of new business processes and technology adoption path.

- Production of detailed strategies, documentation of lean process and procedures, identification of key performance indicators.
- Documentation of BIM implementation plan.

Stage 4: Implementation and roll-out of BIM

- Piloting BIM on three different projects (past, current and future), training the staff and stakeholders, devising and improving companywide capabilities and documentation.

Stage 5: Project review, dissemination and integration into strategy plan.

- Sustaining new products and processing offerings, evaluation and dissemination of the project.

Hardin (2009) identifies ten steps for implementing BIM. First it is advised to develop a simple statement about how BIM aligns with the goals of the organisation and how to use it in the future, as well as the organisation's stance on technology. The owner needs also to be involved in this initial discussion of strategy, due to decisions on investments in software, hardware and staff. The steps are as follows:

1. Identify a BIM manager.
2. Develop an estimate of cost and time to implement and use BIM software.
3. Develop an integration plan.
4. Start small.
5. Keep the manager trained.
6. Support the manager by starting a department.
7. Stick to the plan but remain flexible.
8. Create resources.
9. Analyse implementation.
10. Monitor new software proposals and industry trends.

2.1.5 Conclusion on BIM

In this chapter the term BIM has been reviewed, what it is and what it consists of. Furthermore, the difference between traditional construction processes and BIM process has been reviewed. A framework for BIM and the implementation process was discussed, although there is a lack of literature on the best practice for implementing BIM, due to its newness and how it changes the whole construction process.

BIM is a methodology on how to manage and access data on buildings and facilities. It is applied throughout the facilities lifecycle. It provides owners and operators with the best information available, enabling them to make the best value decisions and reducing total ownership cost. BIM is not a software solution; it concentrates on the processes of organizing, managing, accessing and sharing building and facilities information, making this information accessible throughout the lifecycle of the building. The "I" is the real value of BIM, were information is integrated, and shared transparently. The model then becomes an integral part of the decision-making process throughout the design, construction and management of the building. To deliver this information and data a clear strategy is applied, a BIM process, where the goal is to maximise the return on investment by defining a fluid flow of data use throughout the whole project life-cycle. The client gets more complete information, resulting in improved quality, efficiency and sustainable buildings.

Within the BIM process, a building model is produced, using supporting software. This model can be viewed and manipulated in 3D. Added to that is clash software, which achieves reduction in total operation cost, through designs and constructed facilities, making them more reliable, maintainable and accessible. Furthermore, the BIM model can be linked to schedule software enabling better communication between contractors and other project participants. The schedule becomes more reliable. Delivery of material is also managed, making the flow more visual.

BIM offers many realizable advantages over CAD, but the ability to share the intelligent building information produced between projects stakeholders is critically important to gain BIM's full potential. Information sharing is essential to achieve the urgent need for better interoperability between disciplines and software applications across the industry. That said, it is extremely important that BIM applications are able to communicate irrespective of vendor.

2.2 Lean construction

2.2.1 Lean philosophy

Lean construction is a philosophy from lean manufacturing, originally developed within Toyota. It is a different way of thinking, planning and executing a project. This is accomplished by changing the focus of management from optimizing separate technologies, assets and vertical departments to optimizing the flow of products and services through the entire value stream that flow horizontally across technologies, assets and departments to the customer.

Continuous improvement is used to prevent the same mistake repeating. Waste is eliminated by designing processes so they need less human effort, less space, capital and time, for less cost and with fewer defects. This new way of production, Lean production, has been implemented within various manufacturing industries around the world, including construction.

Lean consists of five main principles:

1. Specify value: Value is defined by the ultimate customer. Often value is distorted by pre-existing organizations, adding complexity of no interest to the customer.
2. Identify the value stream: ALL actions needed to bring a product to the customer.
3. Flow: Create flow in the value chain.
4. Pull: Create pull effect in the value chain. Sell one. Make one.
5. Pursue Perfection: Create a culture of continuous improvement within the organization. Reducing time, space, cost and mistakes does not stop. [6]

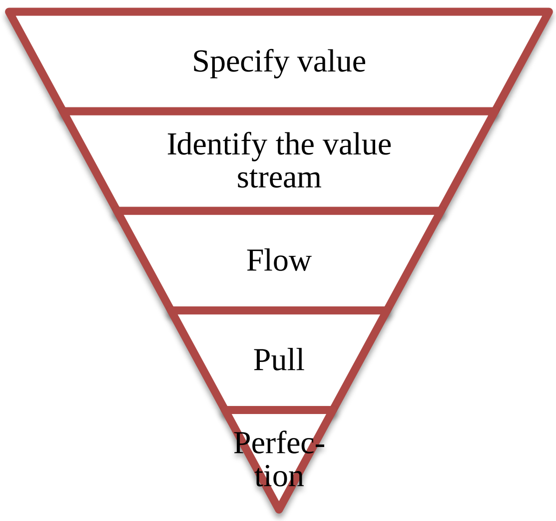

Figure 8: Lean principles

[6] http://leanforum.wordpress.com/2007/01/13/de-5-principper-bag-lean-thinking/

By implementing lean practices, the whole production process is turned around and a cultural change within the organization is needed. Critical success factors are the in-depth understanding of production processes and resources involved in them, responsibility and authority placed with the workforce, real time feedback on performance and training and multi-skilling.

2.2.2 Lean construction

Lean construction is commonly thought of being the continuous process of eliminating waste, meeting all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of a constructed project (NASFA et al., 2010).

Lean production is the inspiration for lean construction. The difference between construction and manufacturing is significant. Finished goods in manufacturing are transportable to retailers or end customers and often the same parts are produced in mass volume. Construction deals with larger units; additionally, the construction industry has three other features, on-site production, one-of-a-kind projects and complexity. Many of the principles and tools from the Toyota Production System are applicable in the construction sector; there are also ones that are different and inapplicable. The focus is still the same: reducing waste, increasing value and continuous improvement (Ballard, 2001). This approach changes the way work is done throughout the construction delivery process because the process is seen as a chain with materials that increase in value until the building is ready for use. The building and its delivery process are designed together, revealing and supporting the customers' needs. Work is structured throughout the process to maximize value and eliminate waste. Efforts to manage and improve performance are aimed at improving the whole project performance, not just performance at each stage. Planning and control systems performance are also measured and improved (Howard, 1999).

The combined effect of these three features is to reduce uncertainty by increasing control over the process itself. Within the construction process, significant uncertainty exists throughout the project, such as weather conditions, soil conditions, owner changes and the interaction between multiple operations, can produce unique circumstances that could be as critical as the planned activities and which have a significant impact on the project cost (Salem et al. 2006).

Benefits from implementing lean construction are identified by Salem et al. (2006). A project was under budget and three weeks ahead of schedule; furthermore, subcontractors were more satisfied with their relationships with the general contractor. The average percentage plan completion was 76%, 20 points above the initial performance. No major injuries occurred during the project, and the incident rate was below that for similar projects in the same company. Most of the planners associated the performance of the project with the implementation of lean construction techniques, and they would like to continue with most of the tools. In particular, they enjoyed the learning process involved in the new approach of lean construction.

To fully and effectively apply lean principles in construction, the focus must be on the whole construction process. All stakeholders must be committed, involved and work together to overcome obstacles.

Lean construction principles are as follows:

- Eliminate waste
- Specification of value from the perspective of end user or customer
- Identification of the process delivering what the customer values (the value stream) and eliminating all non-value adding steps.
- Make the remaining value adding steps flow without interruption by managing the interfaces between different steps.
- Let the customer pull – do not make anything until it is needed, then make it quickly
- Pursue perfection by continuous improvement.

The transfers of lean manufacturing techniques to construction are reviewed and discussed by Salem et al. (2006) as follows:

Flow variability:

- Technique
    - Last Planner
        - Reverse phase scheduling
        - Six week look-ahead plan
        - Weekly work plans
        - PPC charts

Lean manufacturing production levelling addresses the impact of flow variability. Production levelling techniques control the impact of fluctuating demand levels controlled by optimizing the sequence of products with minimum batch sizes. The techniques used are product sequence scheduling, flexible standard operations, multi-functional layout design and total preventive maintenance. When practicing lean construction, flow variability has a great influence due to the late completion of one trade, which can affect the overall completion time of a project. Last Planner (LPS) is a technique that supports the realization of plans in a timely manner (Ballard, 2000). This technique makes the people accountable for the completion of individual assignments at the operational level. The LPS process starts with the reverse phase schedule. A detailed work plan is produced between trades, for each phase. Based on this, a look-ahead schedule is produced. This schedule only contains tasks to be completed during the coming weeks and the backlog of ready work. Each planner prepares weekly work plans to control the workflow. Those tasks that are not completed on time are analysed, the root cause is determined, and an action plan is produced to prevent future recurrences of the problem.

Process Variability:

- Technique:
  - Fail-safe for quality
    - Check for quality
    - Check for safety

Autonomation is the concept that immediate action should be taken to prevent defects at the source so that they do not flow through the process. Within lean manufacturing, visual inspection allows the workers the autonomy to control their own machines so that when they identify defective parts, they can stop the process to identify the root cause. The technique used is fail-safe. Due to the difficulty in finding defects before installation, quality in construction has focused on conformance. Lean construction focuses efforts on defect prevention. Fail-safe actions can be implemented on a job site to ensure first-time quality compliance on all assignments.

Transparency:

- Technique:
  - Five S's
    - Sort
    - Straigthen
    - Standardise
    - Shine
    - Sustain
  - Increased visualisation
    - Commitment charts
    - Safety signs
    - Mobile signs
    - Project milestones
    - PPC charts

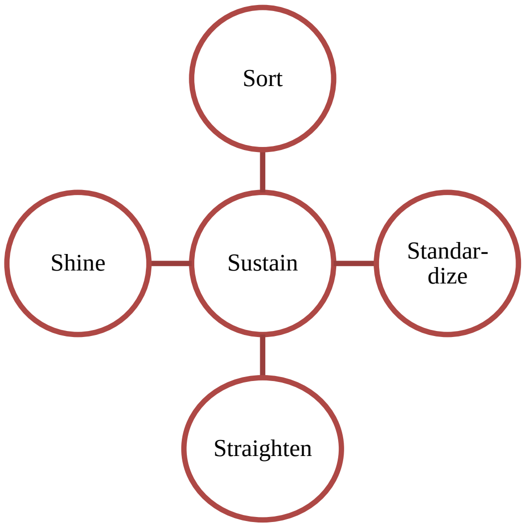

Figure 9: 5 S's in lean construction

In lean manufacturing, any resource that does not add value is regarded as a waste that should be eliminated from the system. To identify this, the five S's can be used: sort, straighten, standardize, shine and sustain. In lean construction the five S's make the job site more transparent, so the materials flow effectively between warehouses and specific jobs in the field. Due to the mobility of workstations in construction, increased visualization may help the identification of the work flow and create awareness of action plans on site.

Continuous Improvement:

- Technique:
  - Huddle meetings
    - All foremen meeting
    - Start of the day meeting

- First-run studies
    - Plan
    - Do
    - Check
    - Act

Continuous improvement is not directly linked to any specific technique. All lean techniques are set to drive continuous improvement through problem solving and creative thinking. In lean manufacturing, quality circles provide for an opportunity for workers to participate in the improvement of the process. Quality, maintenance, cost reduction and safety issues are worked out by a team that provides potential solutions for future activities. This is used to implement new ideas and is also a learning process of that workers experience. The Plan, Do, Check and Act (PDCA) cycle (Ballard and Howell, 1997) is used to develop this operation. A work process is planned. Process steps are analysed and unneeded steps are eliminated. New ideas are tested, the “do”. Then what actually happens is described and measured, or “checked”. The acting phase is when the team is reconvened, and teammates communicate the improved method as the standard to meet. To ensure continuous improvement, the team’s capabilities must be best used to develop both individual and joint contributions.

2.2.3 Conclusion

Lean construction is a production management-based approach to project delivery. It refers to the application and adoption of the underlying concepts and principles of the Toyota Production System to construction. This approach changes the whole construction process. The design and delivery process are designed together, and the line between them fades. At the project delivery phase, work is structured throughout the process aiming at maximizing value and reducing waste. Total project performance is improved and managed, because it is more important than reducing cost and increasing the speed of any activity. The performance is what is emphasised, measured and improved. By making specialists in design, supply and assembly work closely together, value is delivered to the customer and waste is reduced.

2.3 BIM and lean construction

Toyota selected carefully the information and communication technology (ICT) opportunities that were needed. Only those that could reinforce the business processes directly were selected, after being tested to see whether they actually “fit” appropriately into the organisational infrastructure. Within the lean construction community, BIM is seen as a tool to leverage a project data, because it provides a platform for visualizing workflow in control systems that also enable pull flow, process transparency and deeper collaboration between project stakeholders (Sacks et al. 2010).

BIM reinforces the core construction processes. Rischmoller et al. (2006) used a set of lean principles as a theoretical framework, to evaluate the impact of what they termed

Computer Advanced Visualization Tools (CAVTs). Value generation during the design stage of the construction project was their focus. They concluded, after a case-study over a four-year period, that applying CAVT resulted in waste reduction and improved flow and better customer value, indicating a strong synergy between lean construction principles and CAVT.

Khanzode et al. (2006) conducted a case study of the effort to integrate lean construction processes with BIM. They focused on linking Virtual Design and Construction (VDC) with lean project delivery process. The VDC concepts represent BIM or aspects of BIM due to the similarities in underlying principles and technologies. The results confirmed that VDC enhances the lean project delivery process when applied at the correct stages. The authors reported that literature on linking BIM to lean construction process was lacking and provided an initial set of guidelines.

Khanzode (2010) concluded that by using VDC and lean methods results in better co-ordination and better construction process. It also brings together the product, the organisation and the process factors that are important for co-ordination. Lean methods and BIM can reduce rework, though the none-use of VDC is more significant. Furthermore, it presents performance and outcome metrics that the project team can use to manage the co-ordination process.

Sacks et al. (2010a) produced a matrix (table 5) of how lean principles and BIM functionalities work together (x) and when they do not (o). This matrix can be used as a basis for understanding how BIM and lean construction are optimizing the construction process together. The interconnections between them imply that a project on a lean journey should consider using BIM for enhancing lean outcomes. Conversely, those using BIM should ensure that their adoption process is contributing to the fullest extent to making their processes leaner. On this matrix, they conclude that there is a strong synergy between lean construction principles and BIM functionality and the high interaction between lean and BIM suggest that perhaps the parallel adoption should be in small steps.

Lastly, they contend that for comprehensive realization of benefits, changes in information and material processes, BIM tools, and lean construction principles should be rooted in conceptual understanding of the theory of production in construction. This issue does not come out of any specific cell or group of cells in the matrix but derives from a holistic view of the situation. As such, this implies that in construction management a closer interaction between theory and practice, between academia and industry, is needed than has hitherto been the case.

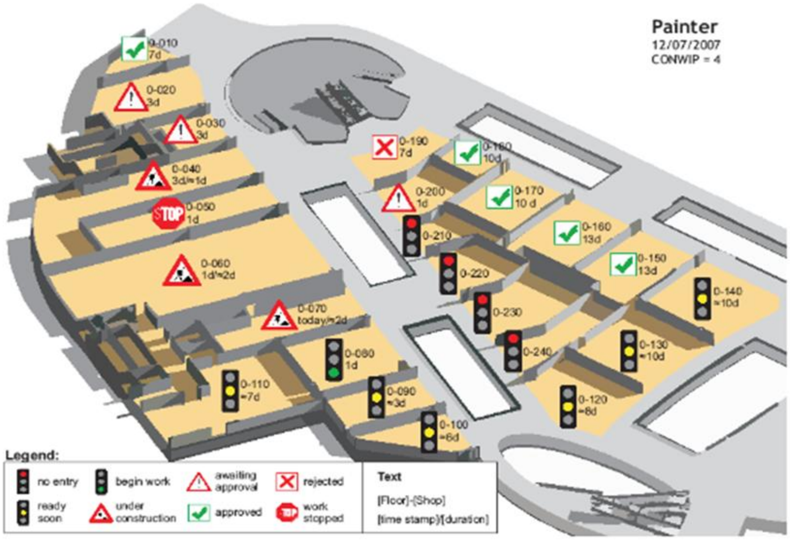

Figure 10: 3D model and kanban used together (Sacks et al, 2010b)

Figure 10 is an example of how a 3D model can be useful to show work status for a trade. The people performing the work provide a status report, without additional tasks. Field software is required to be linked to BIM system, and is used to track and report data from site personnel.

Sacks et al. (2009) illustrated that the use of BIM and related technologies enables a pull flow mechanism that reduces variability within the construction process.

IPD and VDC are emerging techniques that leverage BIM to provide an integrated project management and collaboration platform. IPD places emphasis on engendering collaboration through a central common contract, while the latter focuses primarily on skilled use of information technology (Kunz and Gilligan, 2007).

The 3D modelling process was implemented in parallel with a traditional project delivery method. Constructability reviews, through modelling the design documents, found more than 200 issues at each stage that were not found by the parallel traditional constructability process (Kala et al. 2010). This resulted in reduction of errors occurring in the execution stage.

2.4 Conclusion on the relation between BIM and lean

BIM is no longer a new trend and there are stakeholders who have understood the benefits BIM promises. Those benefits, value maximization and waste reduction, are in line with the benefits lean construction promises. Whether or not lean construction practices are desired, the outcome is the same. BIM applications enable the full effect of lean principles. By using BIM, the processes become leaner, waste has been reduced and value increased. When BIM and lean construction principles are used together the construction process becomes even more enhanced. The project team becomes more able to tackle complex dynamic and challenging target goals to deliver a project.

Table 5: Synergies between BIM and lean construction procuced by Sacks et al. (2010)

		BIM Functionality																	
		Visualization of form	Rapid generation of design alternatives	Reuse of model data for predictive analysis			Maintenance of information and design model integrity		Automated generation of drawings and documents	Collaboration in design and construction		Rapid generation and evaluation of multiple construction plan alternatives			Online /electronic object-based communication				
Lean Principles		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Reduce variability																			
Get quality right the first time	**A**	x	x	x		x	x	x	x		x	x		x		x	x		
Focus on improving upstream flow variability	**B**			x	x	x	x	x					x	x	x			x	x
Reduce cycle time																			
Reduce production cycle durations	**C**		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	
Reduce inventory	**D**								o			o	o	o	x	x			x
Reduce batch sizes (strive for single piece flow)	**E**														x	x			x
Increase flexibility																			
Reduce changeover times	**F**			x								x					x		
Use multi skilled teams	**G**										x								
Select an appropriate production control approach																			
Use pull systems	**H**														x	x		x	x
Level the production	**I**									x			x						
Standardize	**J**													x		x			
Institute continuous improvement	**K**																		x
Use visual management																			
Visualize production methods	**L**		x											x		x			
Visualize production process	**M**		x										o	x	x	x			
Design the production system for flow and value																			
Simplify	**N**	x										o							
Use parallel processing	**O**		x		x					x				x					
Use only reliable technology	**P**								x						o	o		o	o
Ensure the capability of the production system	**Q**								x										
Ensure comprehensive requirement capture	**R**	x		x		x					x								
Focus on concept selection	**S**			x	x	x							x						
Ensure requirement flow down	**T**	x				x	x				x					x			
Verify and validate	**U**	x		x	x	x		x			x		x	x	x				x
Go and see for yourself	**V**	x													x				x
Decide by consensus, consider all options	**W**	x									x			x		x			
Cultivate an extended network of partners	**X**																	x	

Eliminate waste:

By integrating information, using BIM, rework of drawings and documentation is reduced, resulting in improved communication between stakeholders and better quality of drawings and documentation. Waste is reduced in the design process and on site. By tying design information to cost estimate, budget and schedule, manual work is avoided and the information of the management system is synchronized at all times.

Specification of value from the perspective of end-user or customer

Virtual reality is used to describe the facility to be built. The client sees what he is about to buy, and is able to criticise if he is not satisfied. Furthermore, it is easier to explain the reasons for why the design is the way it is.

Identification of the process delivering what the customer values (the value stream) and eliminating all non-value adding steps

The high level of visualizations in BIM enables project team to simultaneously explore both product and process design. Virtual reality describes the construction process, aiding the value stream to be identified, stimulating waste reduction and reducing non-value adding steps.

Make the remaining value adding steps flow without interruptions by managing the interfaces between different steps

To have the ability to proactively change daily tasks assignments in close co-ordination with all parties makes it easier to manage the flow. By visualizing workflow in control systems enables deeper collaboration between teams on and off site. 4D scheduling helps identify bottlenecks and improve flow.

Let the customer pull - do not make anything until it is needed, then make it quickly

Because of the integration of the model, information can easily be pulled from the model at any time, with updates on design changes, cost, and time. The better integration of information should reduce errors. Pull effect is achieved and reduced variability within the construction process.

Continuous improvements

A work schedule, linked to BIM, plans the process. Then they are procured, and what actually happens is described and measured, i.e. with constructability reports given to architects and engineers. In future projects, mistakes identified are most likely not repeated.

Transparency

BIM-based visualization interfaces are important tools for providing process transparency. Virtual construction and high level of project visualisation held develop a common understanding among project partners. Lean construction stresses the need for a better co-operation between stakeholders at the early stages of a project. By facilitating a cross functional team, maximum value can be generated for the project stakeholders. For a transparent process, communication and data sharing is important. A BIM process pulls the project team together and enables them to communicate and share data effectively. Transparent process is also established when field system is linked to BIM software, resulting in continuous information flow between project stakeholders.

Although lean principles and BIM do not rely on each other, there is a strong synergy between them. BIM applications enable the full effect of lean principles. Effective BIM is about the process, and lean is an operating system for implementing new processes and tools. When BIM is fully integrated within organisations, IPD is reached, the processes become leaner, waste has been reduced and value has been increased. The value of BIM can be enhanced even more if used with lean principles. These two approaches aim at the same objectives, reduce waste and increase value.

3 Empirical study

An applied research study with quantitative methods was executed. In this chapter this method is discussed. The research is divided into two parts, and therefore this chapter is divided into two subsections.

1. Comparison between public organisations implementing BIM
2. Survey establishing where the Icelandic AEC sector stands

In each subchapter, respondents, measurement equipment, execution and measurement/results are discussed, which then proceeds to a conclusion where the process is described.

3.1 A comparison

The aim with this comparison work was to map what other public organisations have done to drive the implementation of BIM. The purpose was to gain knowledge on the implementation of BIM and to give an understanding of what problems these organisations are facing and also to understand if or how they are measuring their status on the implementation within organisations.

In order to measure and compare the implementation process driven by BIM in Iceland, it is important to know where other countries stand. Facts and sets of facts were gathered, based on previous published studies made on the subject, and a comparison framework was produced. Literature on the best practice framework for implementing BIM is lacking, and therefore the author found no real comparison. Instead public organisations were reviewed with the aim of ascertaining what they have done to implement BIM within their own country. The questions were designed after reviewing the literature on BIM adoption processes (see chapter 2). The results are to be taken as a road map on what has been done in each country. Hopefully the results have identified any gaps in the implementation initiative in Iceland.

3.1.1 Participants (BIM initiatives)

Public organisations that are globally leading BIM adoption and are leaders in research on BIM were chosen for comparison. These countries being reviewed were the United States (USA), the United Kingdom (UK), Norway, Denmark and Iceland. They were picked because of how often these countries were mentioned in literature on BIM and lean construction, and because it is interesting to look at what neighbouring countries are doing.

In each country there are numerous organisations that are implementing BIM. Those organisations that were reviewed are those that are serving public facilities, and therefore represent the client or owner, working on spreading the news, and offering guidance to other organisations.

3.1.2 Execution

A framework was produced addressing issues on what needs to be done when driving a process change. From that framework, information and facts on each organisation was gathered through the organisations' websites and reviewed. Each organisation was rated based on the information found. The results are presented in chapter 4 and discussed in chapter 5.

3.2 Survey

A survey was carried out in the Icelandic AEC sector. Respondents were asked to give their answers on a 5 point Likert scale. This survey was conducted to give deeper understanding about where the Icelandic AEC sector stands in adopting the BIM process and if there is a connection between BIM and lean construction. Because of the high level of synergy between the two approaches it is important to establish the degree of adoption of the two in Iceland.

3.2.1 Respondents

Respondents from all disciplines within the AEC sector, including owners and organisations involved in educating key stakeholders, were asked to fill in and return they survey. The survey was sent to 103 organisations within the sector, whose valid email addresses were available from trade unions in each field. The sample size was small. The aim was not to try to apply the results to the whole population of the AEC sector but to demonstrate whether there is something happening within the sector.

3.2.2 Measurement

A questionnaire was presented to respondents, based on the literature review presented in chapter two, with questions on factors connected to BIM adoption and lean construction. The questionnaire is divided into 5 parts plus questions about the respondent's background, and is presented in full in Appendix B.

Respondents were asked to give their answers on a 5 point Likert scale where they specify their level of agreement or disagreement with a statement, the highest level being "strongly agree" and the lowest level being "strongly disagree".

To analyse the findings the statistical program SPSS was used. Excel was used to produce tables and figures. The example size was small but useful in demonstrating what is happening within the sector. The aim was not to apply the results to the AEC sector as a whole, but to demonstrate whether or not BIM is being adopted. The results are presented in chapter 4 and discussion of results in chapter 5.

3.2.3 Execution

The questionnaire was created and conducted through a web survey program, www.createsurvey.com. Three individuals read and answered the pilot version to check if instructions were understandable, to check the timing and to check if the answers were received into the database of createsurvey.com. The timing was between 10-15 minutes which was mentioned in the e-mail to respondents, as shown in appendix A.

The survey was begun on October 10, 2011 and closed on October 26, 2011. During this period iterations were sent out twice, through www.createsurvey.com, where it was possible to track who had not responded, so that the repeats were only sent to those that had not responded.

4 Results

In this chapter the results from the research, implementation of BIM in Iceland and its relation to lean construction, are introduced. The research was divided into two parts, a comparison of public organisations supporting BIM implementation and a survey. First the results from the comparison are introduced, then the results from the survey.

4.1 Comparison

For the cross-country comparison a set of questions was designed and a matrix produced. The purpose of this matrix is to show what has been done in each country to support BIM adoption. The questions were designed based on the literature on BIM adoption and implementation and the minimum requirements needed to be able to implement BIM. A short review on organisations supporting BIM adoption in each country follows.

4.1.1 Comparison matrix

Table 6: Comparison between countries

	USA	UK	Norway	Denmark	Iceland
Signed public statement	Yes Know for certain	No Working group recommends to form a strategic level alliance	Yes Know for certain	Yes Know for certain	Yes Know for certain
BIM required in public projects	Yes From 2007	No Fully collaborative 3D BIM as a minimum by 2016	Yes From 2007	Yes From 2007	No Strived for after tender
Courses on BIM available	Yes	Yes	Yes	Yes	No
Universities offering BIM training	Yes	Yes	No	No	No
Downloadable guides on BIM and BIM adoption	Yes	Unsure	Unsure	Yes	Yes
Research programme	Yes	Yes	Unsure	Unsure	No
BIM-Manual	Yes	Yes	Yes In native language	Yes In native language	Yes
Team work with buildingSMART	Yes	Yes	Yes	Yes But not directly	Yes But not directly

Each country was given points; when the answer was "yes", four points were given. Two points were given if the answer was "unsure". Zero points were given if the answer was "no".

Table 7: Results on ratings on each country

	USA	UK	Norway	Denmark	Iceland
Points	32	22	26	28	16

4.1.2 Review of organisations

National BIM Standards (NBIMS)

The Facility Information Council (FIC) of the National Institute of Building Sciences (NIBS) has formed a committee to create a National Building Information Model Standard (NBIMS). It seeks to facilitate life-cycle building process integration by providing a common model for describing facility information, common views of information based on the needs of businesses engaged in all aspects of facility commerce, and common standards for sharing data between businesses and their data processing applications. By doing that, they are knitting together the broadest and deepest constituency assembled for the purpose of addressing the losses and limitations associated with errors and inefficiencies in the building supply chain. A common information model is expected to reduce building costs, ensure liability, construction schedules and operating costs, and increase building performance, safety and efficiency.

BuildingSMART Alliance

The BuildingSMART Alliance, formerly known as the International Alliance for Interoperability is a public/private initiative operating within the National Institute of Building Sciences. It was first set up in North America in June 1995. It was created to spearhead technical, political and financial support for the use of advanced digital technology in the real property industry. This cross-industry alliance aims at improving efficiency and the cost effectiveness of the design, construction and facilities management sectors, emphasising information sharing and BIM. It promotes the use of Building Information Models (BIMs) and is leading the development and promotion of open data standards. They developed the open IFC standard (Industry Foundation Classes), also known as the buildingSMART Data Model, which was accepted by ISO (ISO/PAS 16739: 2005). A full ISO accreditation is in progress. Their goal is to eliminate 31% of current waste by the year 2020, by supporting the building sector in managing and sharing information and data throughout the lifecycle of a building or a facility.

USA

GSA is committed to a strategic and incremental adoption of 3D-4D-BIM technologies and recognizes that BIM is not only a 3D-geometric representation but a process. In 2003 a National 3D-4D-BIM Program was established. In order to successfully integrate computer models into project co-ordination, simulation and optimisation, information needs to generate feedback.

In 2007 GSA required all submissions for final concept approvals to the Office of Chief Architect to be spatial program BIMs and all projects are encouraged to deploy mature 3D-4D and BIM technologies at strategic project phases in support of specific project challenges. Their website provides an easily accessible guide series on BIM and how to adopt it.

Wisconsin followed in GSA footsteps and was the first state to institute a systematic adoption of BIM practices for state-funded construction projects.

The Texas Facilities Commission followed Wisconsin and now requires BIM modelling for all state design and construction projects.

UK

The Construction Project Information Committee (CPIC) is the UK government's initiative providing best practice guidance on BIM adoption from the preparation of construction production information and making sure this best practice is disseminated throughout the industry.

BuildingSMART in the UK and Ireland is an alliance of organisations within the construction and facilities management industries, dedicated to improving processes within the industry through defining the use and sharing of information.

The Collaborative Electronic Information Exchange (CITE) is an initiative within the UK construction industry where data exchange specifications are developed by the industry for the industry, enabling the industry to move forward together. CITE has teamed up with the BuildingSMART division in the UK and Ireland.

In March 2011 a Strategy Paper for the Government Construction Client Group was published by the BIM Industry Working Group.

It recognized that at this early stage in the international maturity of BIM there is an opportunity for significant synergies in a combined international effort in developing BIM policy, implementation and mobilisation strategies. There is a real opportunity for the UK Government Construction Client Board to take a leading role in shaping the future international development of BIM by adopting strategic level collaboration approaches with their peers from other national governments.

They recommend that the Government Construction Client Board forms a strategic level alliance with the US Federal Facilities Council, the US National Institute of Building Sciences (including GSA) and their equivalent in Scandinavia and Europe.

On their website, it is stated that they will engage with other institutes, industry groupings and standard setting organisations developing knowledge on the implementation of BIM practices and seek comment on its BIM implementation strategy as it progresses.[7]

[7] http://www.bis.gov.uk/policies/business-sectors/construction/research-and-innovation/working-group-on-bimm

Norway

Statsbygg (Norwegian GSA) lays the foundation for a better and more efficient building process and the management of buildings by using BIM technology for the building industry. In October 2011 their BIM Manual was updated in Norwegian and English. In May 2007, they declared that BIM would be used of all their projects and building processes during 2010, and in 2007 at least five projects adopted BIM. In November 2011 they stated, on their website, that an open-BIM will be required in all public construction projects, thereby enhancing quality of the construction project and reducing costs.

Denmark

Digital Construction is the Danish government's initiative to ensure increased efficiency in the Danish construction sector through public claims. Their goal is to influence the use of the same data and plans in all phases of the building process. Since January 2007 the construction industry has been required to use Information and Communication Technology (ICT) to communicate electronic tendering, projects web, BIM and electronic hand-overs. Through BIPS, Denmark participates in the Scandinavian buildingSMART.

In 2010 a Danish and English version of digital construction was published, explaining what Digital Construction is and how to abide by the Danish regulations.

Since 2007 construction companies and consultants have had to comply with ten specific requirements concerning the use of IT, if they wish to provide consultancy services or execute public construction projects. These requirements apply to all construction projects exceeding DKK 3 million. Electronic hand-over applies to construction projects exceeding DKK 15 million. The use of 3D models is mandatory and required for construction projects exceeding DKK 20 million.

Iceland

The Icelandic Construction Technology Platform, which is a part of the European Construction Technology Platform, established the project BIM-Iceland. The goal was to strengthen consensus between public buyers and enhance quality in design and construction in public building projects and reduce lifecycle cost. In 2008, four people from the Government Construction Contracting Agency (Framkvæmdasýsla ríkisins), Reykjavik Energy (Orkuveita Reykjavíkur), the Innovation Centre of Iceland (Nýsköpunarmiðstöð Íslands) and The Division of Planning and Construction of Reykjavik City (Framkvæmda- og eignasvið Reykjavíkurborgar) initiated the project BIM-Iceland. Their goal was to implement the use of compatible information models within the field of designing public buildings and to increase the quality of design and accuracy of building information in order to reduce building and operation costs. BIM-Iceland has published a project report on what their work, which is reviewed here.

- Three stages of BIM implementation requirements were established:
  - Stage 1: Designers hand in a model to buyer/client on IFC, but contractors get traditional 2D drawings, produced from the model. A spatial program from the models is also to be handed in
  - Stage 2: The same as stage 1, but with complementary like quantity take-offs, cost estimates and even energy simulation all that information is produced from the model. Contractors get the model to use during construction and hand in as-built information in a model for the buyer/client.
  - Stage 3: Same as stage 2, but with complementary on simulations and a life cycle model.
- The BIM-lab was set up to enable users of information models to have ready access to try out information exchange between different software, and to provide education about BIM.
- The BIM-Manual was published in Icelandic in co-operation with foreign specialists.
- A website was set up, to provide information on BIM. Articles on BIM in Icelandic and other languages were made accessible, and a booklet for beginners was published.
- Numerous meetings, lectures and presentations were held across the country where pilot projects were presented, the benefits of BIM introduced and information on how it has evolved, thus addressing most construction stakeholders.
- BIM-Iceland is a project that has come to an end but the organisations behind the project are still implementing BIM with pilot projects. BIM requirements are being striven for when possible. Due to the recession (beginning in 2008) not as many public projects have been executed as before.

GCCA is not requiring BIM yet, but after tendering they strive for BIM by asking all participants if they would like to adopt BIM in the project. Most of the companies are using this opportunity to experience BIM.

4.1.3 Conclusion on comparison

Governments are participating in implementing BIM in all countries that were reviewed. They are recognising the benefits BIM is said to achieve, and by that trying to get the sector to adopt the use of BIM. Government organisations have set requirements that projects are to be produced using BIM. Meanwhile they are also offering guidance and education on the matter. Pilot projects and research programmes are being held.

All but one organisation have signed a public statement of intention to support BIM with open standards. By that they are agreeing to share AEC/FM-related information throughout the lifecycle of capital facilities globally and across all disciplines and technical applications, which is the key to achieving the goal of a better built environment for end-users, clients and stakeholders. IFC from the International Alliance for Interoperability is recognized as a leading example of an open, freely-available, BIM standard specification for sharing data throughout the lifecycle across multiple professional disciplines and technical applications in the AEC/FM sector.

Two of the organisations, UK and Iceland, have not set requirements for BIM use but have stated that they will in the future. Iceland is striving for BIM, after tendering, and the UK has stated it will before 2016. The rest of them have been doing so for several years.

The public organisations are all linked to buildingSMART, indicating that they recognize the need to solve interoperability issues.

The public organisations are performing as clients and through their initiatives are producing a client driven implementation process.

BIM is being implemented after the National Building Information Model standards (NBIMS) and various governments follow their lead, indicating a global teamwork towards this innovation.

4.2 Survey results

This chapter presents the results of the survey. First the respondents who participated in the research will be described, and then the descriptive statistics are introduced, where average, standard deviation and number of answers are put forward. Respondents were asked to report their level of agreement on a 5 point Likert scale. Where the mean was above 3, it was interpreted as respondents a positive towards that statement. When the mean was between 2.5 and 3 it is interpreted as a neutral response. When below 2.5 respondents were negative to that statement. Lastly, limitations of the research are presented. The survey was presented to respondents in Icelandic, but has been translated here. The questionnaire is presented in full in appendix B.

4.2.1 Respondents' background

The survey was sent to 103 firms and organisations within the Icelandic AEC sector. A total number of 47 submitted the survey, representing a response rate of nearly 46%. Firms and organisation that participated, were small organisations (less than 10 employees), with a total number of 23 or 49 %, medium size organisations, with a total number of 13, or 28% and large organisations, with a total number of 11, or 23% (figure 11).

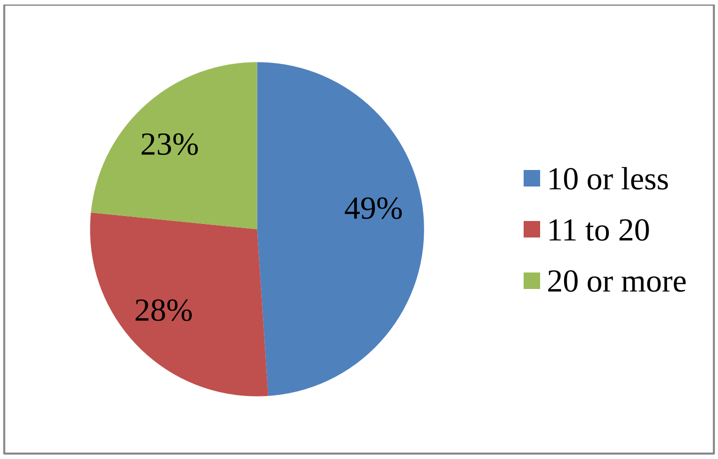

Figure 11: Distribution of responses

Respondents were asked what field their organisation operated in (figure 12), where it was possible to mark with more than one option. Architects were those who mainly submitted the survey at 48.9% with those associated with planning followed at 40.4%.

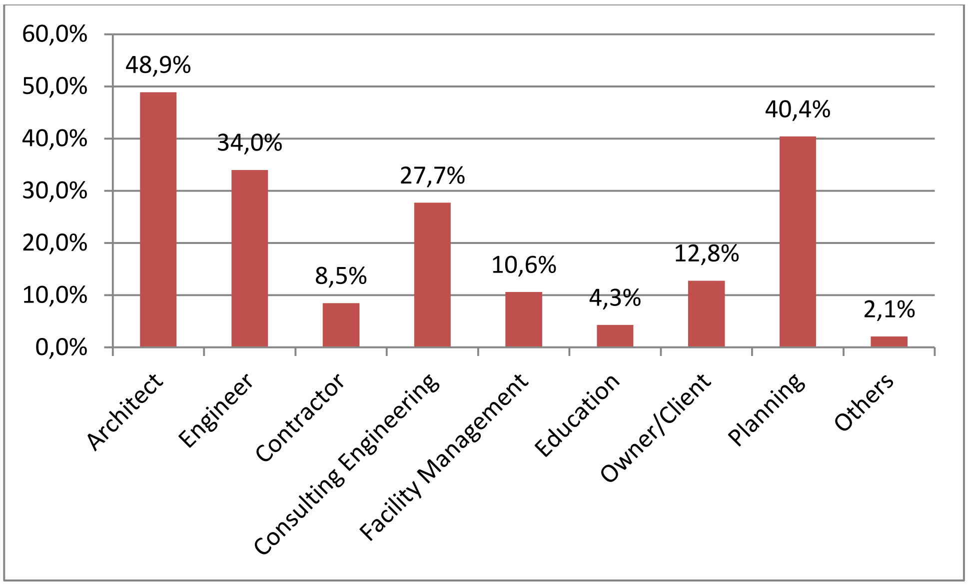

Figure 12: Respondents' field of work

4.2.2 Part 1: Knowledge on BIM and lean construction

The first part aimed to identify the respondent's knowledge of BIM and lean construction. Respondents were asked if they have heard of BIM and lean construction. Furthermore they are asked to identify the definition of BIM and lean construction. Then those respondents who actually knew what BIM and lean construction are were asked to what degree they thought these two worked well together. A total number of 41 claimed they had heard of BIM, or 87%. Of these 41, 83% actually knew the definition of BIM. A total number of 12 claimed they had heard of lean construction, or 26%. When asked about the definition of lean construction, a total of 11 answered correctly, or 92%. A total of 8 or 73% of the respondents who actually know what BIM and lean construction are, thought these two worked well together.

Respondents were asked how likely they thought that new projects within their organisation would be drawn by them: 17% of respondents thought it likely but 40% were neutral.

When asked if respondents had heard of BIM-Iceland, 81% report they had. The majority were neutral when asked if satisfied with the work BIM-Iceland has done, 18% were unsatisfied and 16% were satisfied. This could be an indication that the work BIM-Iceland has done has not been introduced or promoted well enough.

4.2.3 Part 2: BIM adoption

This chapter's aim is to identify whether organisations are using BIM and to explore their skill with BIM software. BIM software is the tool to adapt to BIM processes. To measure if organisations are adapting to BIM, respondents were asked on their usage of BIM software. A total of 19 reported that they do, or 40% (figure 13).Those reporting not to be using BIM software were asked to go directly to question 18 on CAD software.

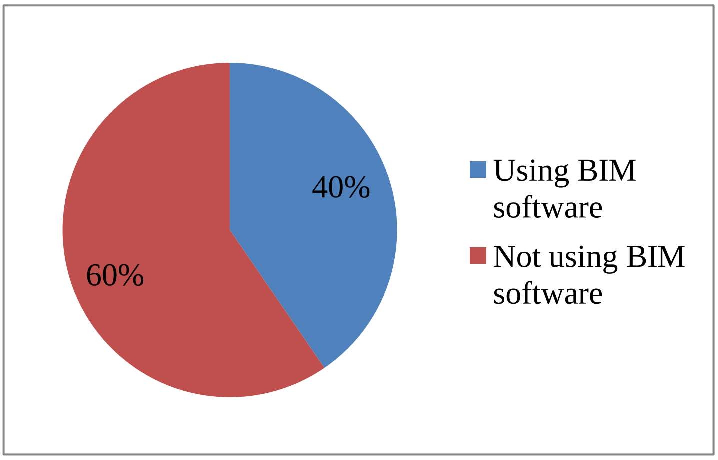

Figure 13: Frequency of use of BIM software

Respondents were asked to state their discipline. Architects were primary adopters of BIM, where 53% claimed they used BIM software, followed by engineers with 50% (figure 14). These results are similar to McGraw-Hill Construction (2009), where 58% of architects were using BIM; 42% of engineers in the US were using BIM and 37% of owners. Of those contractors that submitted the survey, none of them were using BIM software, against 49% of contractors in the US. This could be an indication that the introduction and promotion of BIM to contractors is lacking. This low number can also be the result of the financial crisis here in Iceland.

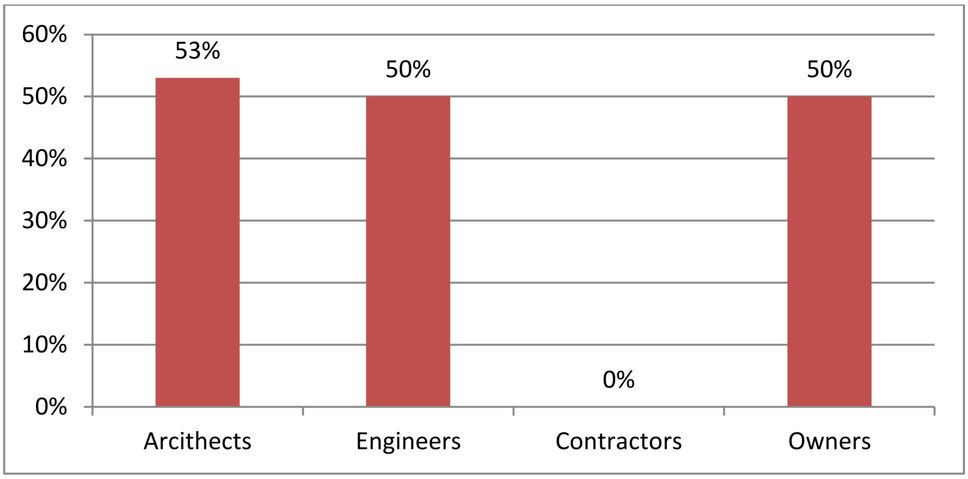

Figure 14: Frequency of BIM software use between architects, engineers, contractors and owners

Respondents using BIM were asked to state which BIM software they were using and to rate themselves on their skills with the software they were using. The aim was to identify if the respondents lacked training in BIM software.

Autodesk Revit seems to be the software mostly used by the respondents (figure 15). A total of 12 were using Revit, or 63.2% of those who used BIM. Autodesk Architecture Desktop was next, with 36.8% and 31.6% are using Tekla. No one claimed to be using Nemetschek AllPlan. It should be noted, that respondents were able to report usage of more than one type of software.

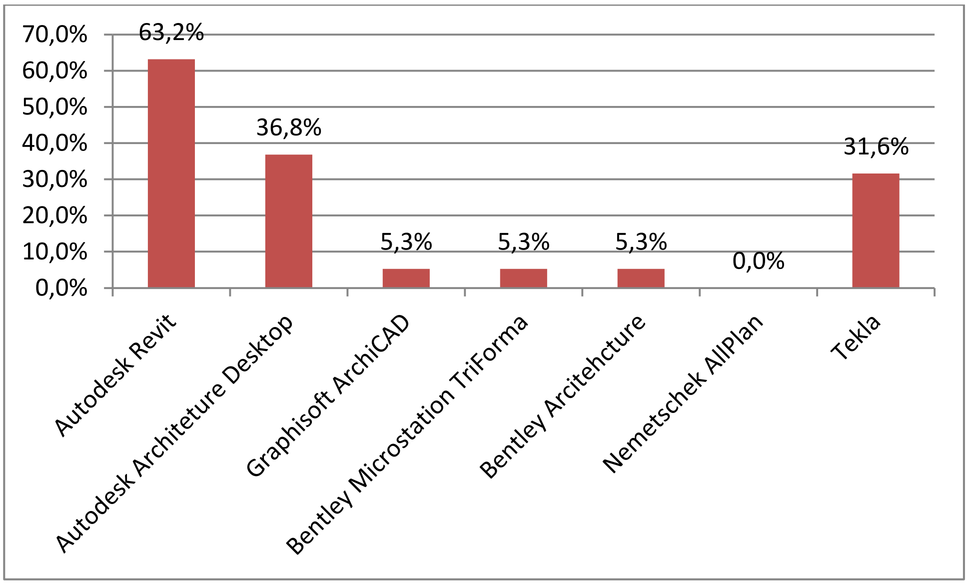

Figure 15: Frequency of use of specified software

Respondents using BIM were asked to rate their skill with BIM software used within their organisation: 48% of respondents, or almost half, consider themselves above average (figure 16).

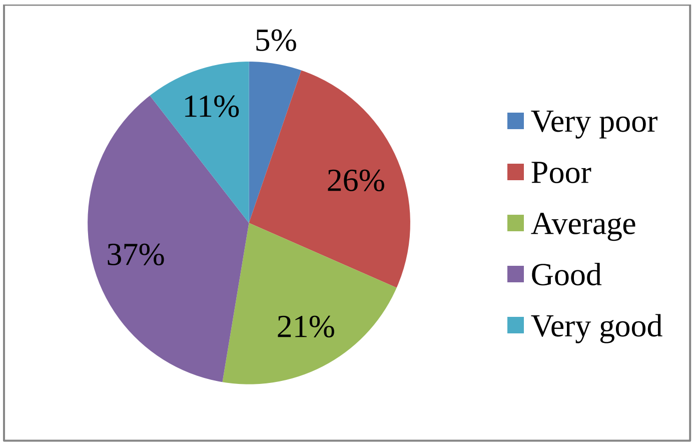

Figure 16: Self-assessment of BIM skill

When respondents were asked how many projects were carried out using BIM (figure 17) within their organisation, 21% of the respondents stated that BIM had been applied to 15-50 projects. The average number of BIM projects was 3.21. However, the average number of projects that the respondents were using BIM for was 8.47.

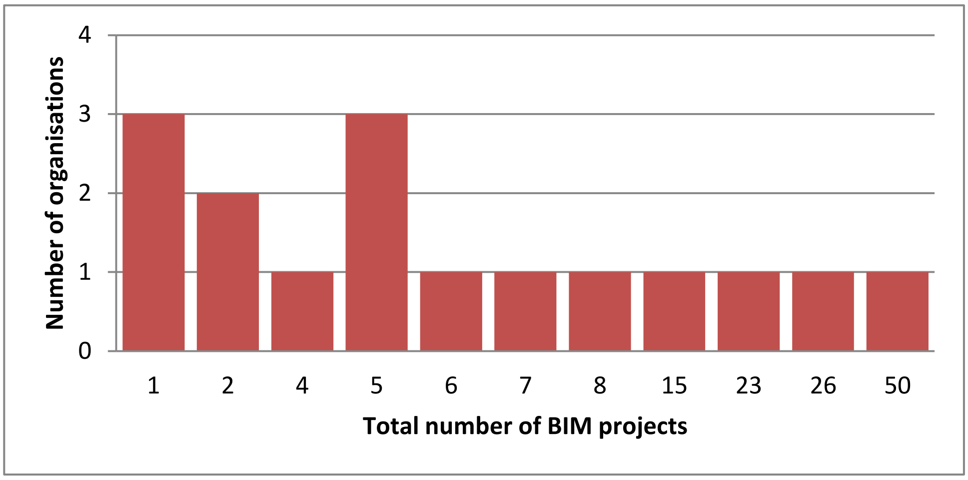

Figure 17: Frequency of projects using BIM within organisation

Due to the financial crisis in Iceland, it was considered appropriate to ask how many current projects are developed in BIM. Of organisations applying BIM, 31.6% have more than 5 current projects where BIM is applied (figure 18).

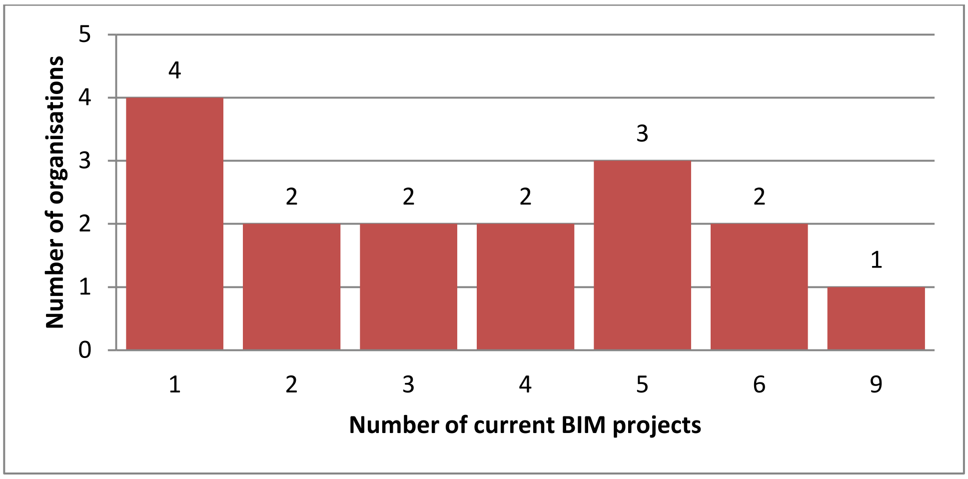

Figure 18: Number of current projects developed with BIM

Respondents applying BIM were then asked to state how likely they thought new projects would be developed using BIM. The answers were given on a five point Likert scale, the highest level being "strongly agree" and the lowest level being "strongly disagree". The majority of respondents, or 53%, were positive that BIM would be applied to new projects, 32% were neutral and 15% thought it unlikely (figure 19). This indicated that almost half of those already using BIM were positive that BIM would be used on new project; indicating that their experience with using BIM was positive.

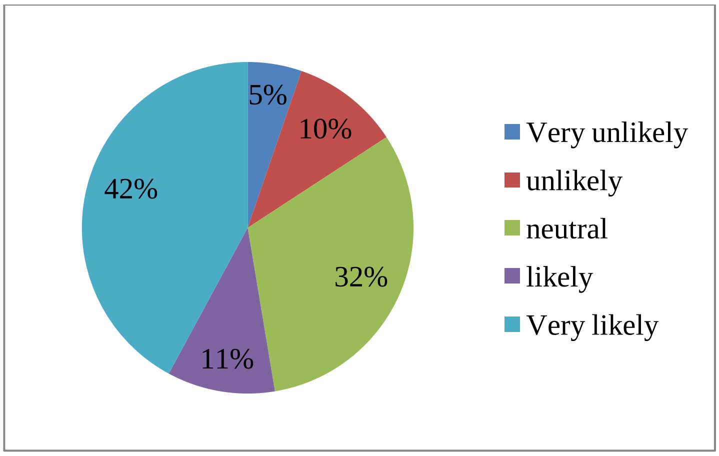

Figure 19: Likelihood of new projects being developed using BIM

Reasons for applying BIM

Questions in the form of statements designed to ascertain why BIM was implemented were presented. Respondents were asked to give their answer on a five point Likert scale, the highest level being "strongly agree" and the lowest lever being "strongly disagree".

Respondents agreed that the most salient reason for applying BIM was because it *"reflects changes instantly in all drawings and schedules"*. Other driving forces are: *"it automatically and dynamically creates views and schedules"*, *"reflects changes instantly"*, *"external blocks, X-ref management and multiple files are avoided"* and *"it* *is compatible with data exchange standards for interoperability"*. Respondent's answers indicated that *"Required by client"* and *"required by other project team member"* were not reasons for using BIM.

Table 8: Reasons for applying BIM

	N	Mean	Std. dev.
Reflects changes instantly in all drawings and schedules	19	3.89	0.937
Creates views and schedules dynamically and automatically	19	3.26	1.327
External Blocks, Xref management and multiple files are avoided	19	3.16	1.302
Compatible with data exchange standards for interoperability	19	3.05	0.970
Required by client	19	2.95	1.268
No need to work with layers	19	2.79	1.182
Required by other members of project team	19	2.11	0.875

This could indicate that the current BIM adoption in Iceland is driven by the users themselves. It seems that those respondents using BIM decided to do so because they saw the gain in productivity.

Respondents were given the opportunity to state other reasons, and those answers are presented here.

- *"BIM follows when using 3D software"*
- *"projects are partly designed in object-oriented design"*
- *"we saw great advantages in software computation"*
- *"company's willingness to be up front amongst peers (competitiveness)"*
- *"perfect model"*
- *"more productivity, more accurate documents, producing shop drawings of steel loads an option"*
- *"reduce failures"*
- *"in my opinion a project is not BIM unless everyone is participating in the BIM process. The company seeks to draw new projects in Revit and to produce information models which drawings are created from but it is difficult to call it BIM when client and contractors are not doing the same"*
- *"information sharing to clients after design, integration"*

The extent of BIM use

To ascertain to what extent respondents were using BIM, questions in the form of statements were presented. Respondents were asked to give their answer on a five point Likert scale, the highest level being "strongly agree" and the lowest level being "strongly disagree".

Respondents were most likely to use BIM when *"designing"*, *"producing work drawings"*, for *"visualization"* and *"energy simulation"*. They were unlikely to use it when performing *"scheduling"*, *"managing space"* and *"quantity take-offs"* (table 9). It should be noted that contractors were only 8.5% of the respondents who submitted the survey and none of them reported that they were using BIM, which should have affected these results. Respondents were neutral to other factors.

Table 9: Extent of BIM use

	N	Mean	Std. dev.
Designing	19	3.16	0.958
Producing work drawings	19	3.21	0.976
Visualization	19	3.11	0.994
Energy simulation	19	3.05	1.079
Producing general drawings	19	2.68	1.376
Producing detail drawings	19	2.63	1.116
Producing other drawings	19	2.63	1.165
Quantity take-offs	19	2.05	1.224
Managing space	19	1.95	0.970
Scheduling	19	1.53	0.697

Respondents were asked how often they measured BIM performance. Results showed that only 16% were measuring BIM performance on a regular basis (figure 20). This could indicate a low maturity level of BIM adoption.

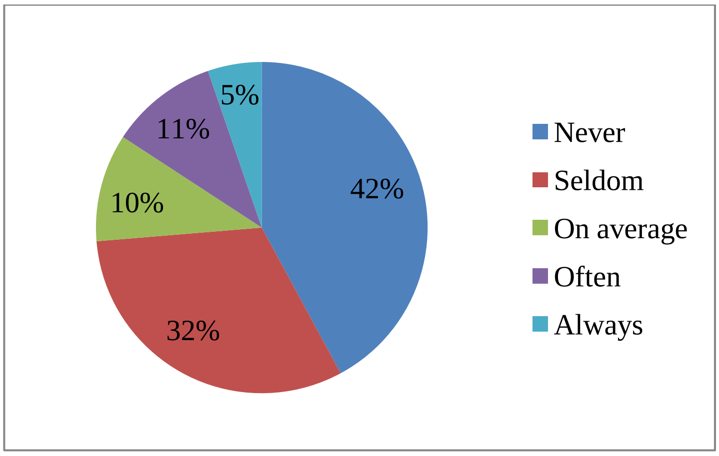

Figure 20: Frequency of BIM performance being measured

Of those respondents using BIM, 58% of them were satisfied with it (figure 21). These results are slightly above the results on the likelihood of BIM being applied to new projects (figure 19).

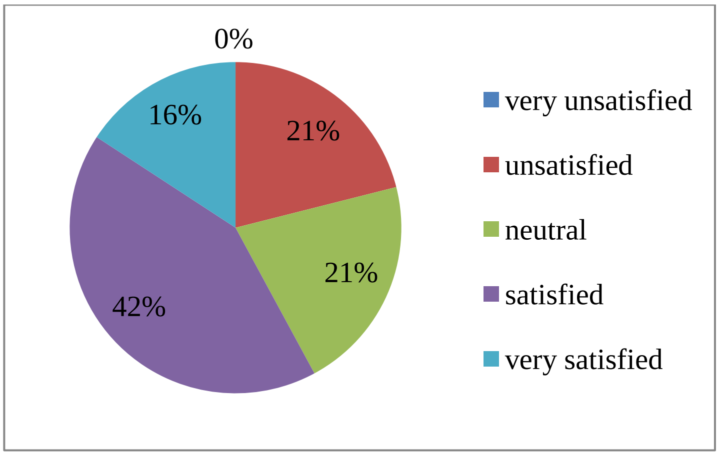

Figure 21: Satisfaction with BIM use

Respondents were given the opportunity to give open answers on what they believed was a weakness or limitation of the BIM software they were using. Answers are as follows:

- *"Steep learning curve"*
- *"no implementation in Iceland"*
- *"do not know"*
- *"none"*
- *"quantity take-off in engineering designs"*
- *"software too expensive"*
- *"standard issues"*
- *"communication between BIM software very limited"*
- *"incomplete Icelandic regulations"*
- *"expensive"*
- *"weak graphical visualisation"*

CAD software usage and skills

BIM is not as widely adopted as CAD software; therefore, it is important to know the uptake of CAD within the respondents' firms. All respondents were asked which CAD software they used and to rate their skills in using CAD software. As shown in figure 22, Autodesk AutoCAD was the software used by most respondents, or 66%. Other software that respondents used but were not mentioned were following: MagiCad, Tekla, Bluebeam, Vectorworks and ArchiCAD. Respondents reported no use of following CAD software: Accurender, Architrion, Arris, Bentley Structure, Bentley HVAC, Design Workshop, FormZ and GDS or MiniGDS.

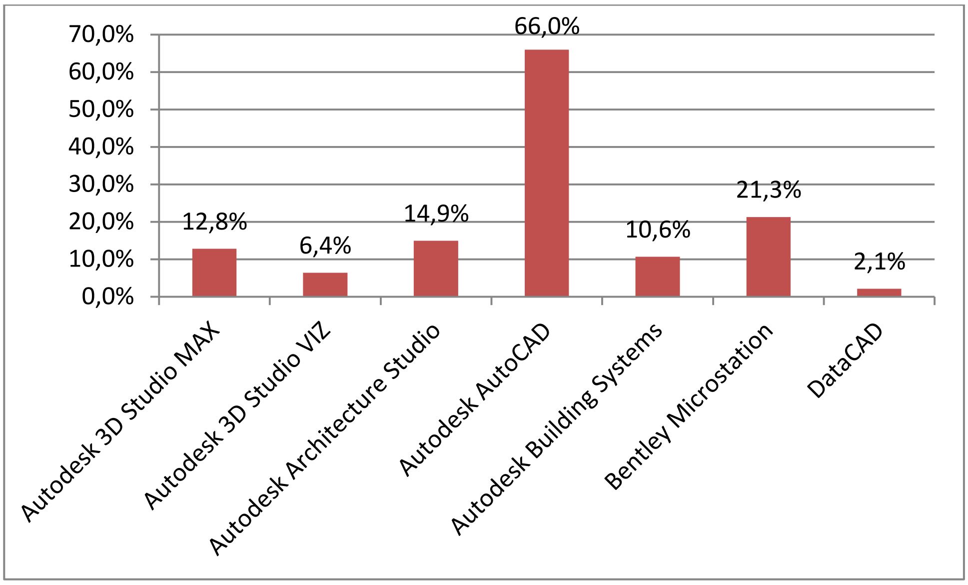

Figure 22: Frequency of CAD software in use

As shown in figure 23, 47% of respondents rated their skills on CAD software used within their organisation as above average.

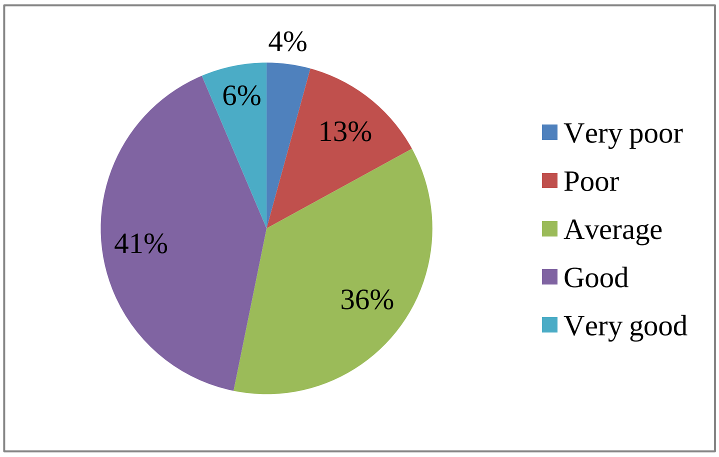

Figure 23: CAD software skills

4.2.4 Part 3: Reasons for not adapting BIM

Questions in part 3 were answered by those respondents who were not applying BIM and aimed to identify reasons as to why their organisation was not applying BIM to their projects and respondents' openness to applying BIM. Questions were in the form of statements, where the respondents were asked to give their answer on a five point Likert scale, the highest level being "strongly agree" and the lowest level being "strongly disagree". The statements were designed to identify the reasons why BIM was not being adopted, what it would take to convince them to adopt BIM and how likely they thought BIM would be adopted in the future.

Major reasons for not applying BIM (table 10) were the facts that *"BIM is lacking features or flexibility to create building model/drawing"*, and *"clients are not requiring BIM"*. This could indicate that if clients would require BIM, then BIM adoption would be greater. Respondents agreed on the fact that *"BIM is too expensive"*, *"other project team members are not requiring BIM"*, *"existing CAD system fulfils our need to design and draft"*, *"BIM does not reduce time used on drafting compared with the current drawing approach"* and *"no need to produce BIM"*. This could indicate that benefits from BIM are unknown to respondents and further promotion is required and that respondents are not expecting that the cost will be repaid in the future.

Table 10: Reasons for not applying BIM:

	N	Mean	Std. dev.
BIM is lacking features or flexibility to create building model/drawing	28	4.50	0.793
Clients are not requiring BIM	28	4.32	0.819
BIM is too expensive	28	3.89	0.937
Other project team memebers are not requiring BIM	28	3.54	0.999
Exiting CAD system fulfils our need to design and draft	28	3.26	1.327
BIM does not reduce time used on drafting compared with current drawing approach	28	3.16	1.302
No need to produce BIM	28	3.00	1.247
Lack of training in BIM software	28	2.79	1.182

Other reasons specified by respondents were:

- *"The software is way too expensive and complicated for such small projects as here in Iceland; better to make more of architectural quality than increasing management quality which does not work, compared to quality handbooks"*
- *"not suiting our company yet"*
- *"no discussions have been here on BIM"*

Table 11: Openness for implementing BIM

	N	Mean	Std. dev.
See a large productivity gain over CAD systems	28	4.07	0.940
If BIM would be required by clients	28	3.96	1.036
See downstream applications of BIM	28	3.86	0.756
If BIM would be required by other project team members	28	3.54	0.999
Would be offered support and training from BIM-Iceland	28	3.50	0.839
Would be offered support and training from BIM vendors	28	3.41	0.888

Respondents agreed on all reasons for applying BIM (table 11). They strongly agreed that they would implement BIM if they could *"see a large productivity gain over CAD systems"*. These results suggest that more effort should be put into promoting the advantages of BIM over conventional entity-based CAD software, and into enabling the application programming interfaces as well as into promoting information on interoperability. Respondents agreed that the client and other project team members can influence their move to BIM, and if they could *"see downstream applications of BIM"*. Respondents reported that they would be least affected if vendors or BIM-Iceland were offering support and training.

Table 12: Likelyhood of BIM being applied in the future

	N	Mean	Std. dev.
Next 10 years	28	3.68	1.156
Next 5 years	28	2.96	1.261
Next year	28	2.11	1.113

Respondents' openness for adapting BIM (table 12) was positive within 10 years, and neutral that BIM will be applied within the next 5 years. They disagreed on whether BIM will be applied within the following year.

4.2.5 Part 4: Organisations adopting lean construction practices

This part aims to identify those firms and organisations practicing lean construction principles. Respondents reporting not being practicing lean construction were directed to the next part. As reviewed in chapter 2, previous research has shown synergies between lean construction principles and BIM. Other previous research has put forward a maturity framework for BIM implementation. When BIM is implemented, the implementation process goes through three different maturity stages, where the ultimate goal is integrated project delivery. When the implementation process reaches that stage, it has already made workflow leaner, and waste has been reduced. It was therefore necessary to ascertain if the Icelandic AEC sector is practicing lean construction, which can be an indication to how mature the implementation process is.

To explore the extent to which lean construction was being practiced, respondents were asked to report on the tools from lean construction that they were using. Next, they were asked to state their level of agreement, on a five point Likert scale, on their experience with lean construction.

Only one firm stated that it was adopting lean construction practices, and that it was using two kinds of tools: PDCA cycle and Percentage Planned Complete Charts. The respondent agreed that *"schedules are on time"*, *"workload is more even"*, *"increased customer satisfaction"*, *"more value for money"* and *"mistakes from previous projects* *tend not to reoccur"*. The respondent was neutral about *"better co-ordination within team"* and *"work-related accidents have decreased"*.

This respondent also reported on not using Last Planner, which is the most widespread tool in lean construction. This could indicate that the organisation is not practicing much in the way of lean construction principles.

4.2.6 Part 5: Data Exchange Standards

All respondents were asked to rate their knowledge of Data Exchange Standards, due to its impact on interoperability issues (table 13). BIM is considered to have potential for being a platform to solve interoperability issues. Being able to share data is essential to downstream applications of the building information. By measuring respondents' knowledge on Data Exchange Standards, a bigger picture was given on how respondents were seeing BIM and its capabilities.

Table 13 Knowledge Data Exchange Standards

	N	Mean	Std. dev.
DXF	47	2.51	1.249
IFC	47	1.68	1.086
IGES	47	1.30	0.548
STEP	47	1.23	0.476

The respondents' knowledge of Data Exchange Standards was in generally low, which can be an indication of their lack of knowledge of interoperability issues.

4.3 Limitations

The respondent rate was 47% and the number of utilised answers 47. No answers were deleted or rejected. The sample is small, with a total of 103 firms and organisations. The results reflect on the status with-in the organisations and firms asked, and are not to be generalized to the Icelandic AEC sector.

5 Conclusion

The purpose of this research was to explore the implementation process of BIM in Iceland and the extent to which BIM is being used in Iceland, as well as identifying if firms and other organisations within the Icelandic AEC sector are applying BIM to their projects and the extent. Additionally, the objective was to ascertain where the Icelandic AEC industry stands compared with others and to identify if there are gaps in the implementation process of BIM in Iceland. In this chapter the research objectives are reviewed and compared to the theory set forth in chapter two.

5.1 Final conclusion

5.1.1 What has been done to support BIM being adopted within the Icelandic AEC sector?

The comparison matrix and review of BIM-Iceland in chapter 4, demonstrate that many projects have been initiated to support BIM adoption within the Icelandic AEC sector. The support BIM has received is in compliance with what theories state is important, although it seems as if the support might not be fully complete as yet. BIM-Iceland was the initiative to support BIM implementation, but has now come to an end. What is planned in the near future is beyond the author's knowledge. According to the literature review provided in chapter 2, on BIM adoption planning, the initiative should be considered as an on-going project, to be improved and developed permanently. A lot of good initiatives have come through BIM-Iceland, and GCCA is also doing their best to support BIM adoption. The support is in its early stages, and will hopefully contribute to an even better adoption rate in the future.

5.1.2 Is there a gap in the implementation process in Iceland?

Gaps were identified from the comparison work and survey conducted. The fact that BIM is not required by GCCA, but sought after tender indicates a gap between the government and GCCA. BIM is being used for their projects, but regulations on BIM requirements are lacking. As reviewed in chapter 2, by Hardin (2009), one of the steps in successfully integrating BIM is: support the manager by starting a department. This role is specific to each discipline. A government initiative supporting BIM implementation should therefore establish a department to support firms and organisations to adopt BIM.

The survey results suggested that BIM was not being applied by contractors. This could indicate that more promotion of BIM was needed, and focused on this discipline.

5.1.3 To what extent is BIM being applied within the Icelandic AEC sector?

The survey aimed at identifying the extent to which BIM was being applied within the Icelandic AEC sector. The results showed that BIM was indeed being applied with-in the Icelandic AEC sector. Around 40% of respondents reporting they are applying BIM. The maturity level is probably not very high, as indicated by respondents' report that they were not measuring BIM performance on a regular basis, were not practising lean construction, and the reporting of the low level of uptake by contractors.

Architects are the primary adopters, where 53% reported they are using BIM software (figure 14), followed by engineers (50%) and owners (50%). Of contractors, none of the respondents reported they were using BIM software. According to McGraw-Hill Construction (2010), architects are the primary adopters (47%) in Western Europe, with engineers (38%) and contractors (24%) lagging behind. The low uptake of BIM by contractors could have been influenced by the financial crisis in Iceland.

BIM is mostly applied when designing, producing work drawings, visualisation and energy simulation. Applying BIM for scheduling and quantity take-offs was at a low level. This was in compliance with the disciplines that were applying BIM. This also indicated a low level of maturity of BIM adoption.

As reviewed in chapter 2, BIM stages are divided into three different stages. It is concluded that the Icelandic AEC sector most likely had not reached stage 3. When in stage 3, semantically-rich integrated models are created, shared and maintained collaboratively across project lifecycle phases. At this stage, model deliverables extend beyond semantic object properties to include business intelligence, lean construction principles, green policies and whole lifecycle costing (Succar, 2009). The results report that this was not the situation. The low knowledge and uptake of lean construction and the low level of BIM uptake within contractors indicated that the Icelandic AEC sector has not reached maturity stage 3.The Icelandic AEC sector is more likely to lie somewhere in between stages 1 and 2.

5.1.4 What is the driving force of the implementation process in Iceland?

BIM users were not basing their decision on whether to adopt BIM because of clients' requirements. They reported that the main reasons for adopting BIM was because of BIM capabilities. This indicates that the driving force of BIM adoption has not been a client driven process, despite GCCA initiative and the BIM-Iceland project. Clients requiring BIM on a project immediately increase the value of BIM to users. These results indicate that BIM users and non-users are looking for owners to take the initiative to require BIM.

The fact that respondents reported they have good skills, were applying BIM, even if clients were not asking for it, and were open to BIM, could indicate that the next step lies in the hands of clients to set higher requirements towards BIM.

The primary reason given by non-BIM users was the lack of features or flexibility to create building model/drawing. Next, most often respondents reported that clients were not requiring BIM and that BIM was too expensive. They also reported that lack of training was the lowest ranking reason for not applying BIM.

When asked if they would apply BIM, they reported that if they could see a large productivity gain over CAD systems, BIM would be required by clients and they would see downstream applications of BIM and would be positive about applying it. They reported that training in BIM software would increase their willingness to adopt BIM: there would be a preference for BIM-Iceland rather than vendors. Respondents were open when asked if BIM is to be applied in the future, although they did not think it would happen within next year. The fact that GCCA was not yet requiring BIM, but striving for it after tender, is in compliance with what was concluded on being the driving force of BIM implementation in Iceland.

This indicates that with more promotion of BIM productivity gains over CAD systems and higher requirements for BIM from clients would probably support BIM adoption even more.

It is concluded that the implementation process in Iceland is not driven by clients today, but more likely driven by BIM capabilities and benefits.

5.1.5 To what extent is lean construction being practiced within the Icelandic AEC sector?

The fact that only one firm reported of practising lean construction indicates a low uptake of lean construction within the Icelandic AEC sector. It also indicates a low maturity scale of BIM adoption in the Icelandic AEC sector. 11 respondents know what it is, so that indicates awareness.

5.2 Summary

This research work indicated that regulations were lacking, to fully support implementation of BIM in Iceland. Public organisations were striving for BIM, though they could require it. Denmark has regulations on BIM requirements. Norway and at least two states in the United States require . In Iceland there was established a project, BIM-Iceland, to support BIM adoption in the Icelandic AEC sector. Denmark, Norway and the United States have established an organisation to support BIM adoption within their countries.

The adoption rate of BIM was 40%. Compared to studies from the United States and Western Europe, Iceland was slightly behind. The results indicated that BIM was not being used by contractors, which indicated a low level of BIM maturity.

The survey results suggested that the implementation process in Iceland was driven by perceived rewards. The users themselves are the driving force of the implementation process, not the client.

The survey results showed that the Icelandic AEC sector is slightly aware of lean construction, but were not practising it, although one firm stated they were practising lean construction.

5.3 Contribution

To be able to decide on what steps should be taken, it is important to know where the implementation process stands. The results have hopefully given an indication as to the direction the implementation process in Iceland is going, and what steps should be considered next.

5.4 Further research

This research work recognises that further studies are needed to be able to fully determine the maturity stage of BIM within the Icelandic AEC sector. A deeper analysis of construction projects in Iceland where BIM is applied would benefit the implementation process to determine how the process is being adopted and what steps should be considered.

In order to gain holistic view of BIM adoption there is a need to conduct similar research work, to be able to measure if there has been progress, and if there has been a shift on the driving forces of BIM within the Icelandic AEC sector.

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Appendices

Appendix A: Introduction letter

HÁSKÓLINN Í REYKJAVÍK
REYKJAVIK UNIVERSITY

10. Október 2011

Kæri viðtakandi,

Ingibjörg Birna Kjartansdóttir heiti ég og er nemandi í meistaranámi í framkvæmdastjórnun á byggingasviði, við tækni- og verkfræðideild Háskólans í Reykjavík. Meðfylgjandi er rannsókn sem er hluti af meistaraverkefni mínu. Tilgangur rannsóknarinnar er að varpa ljósi á hve langt innleiðingarferli Building Information Modeling (BIM) er komið á Íslandi og hvort það sé tenging á milli fyrirtækja sem nýta sér BIM og Lean Construction. Niðurstöðurnar verða kynntar í janúar.

Rannsóknin er nafnlaus og því órekjanleg til einstakra fyrirtækja og stofnanna við úrvinnslu gagna.

Það tekur u.þ.b. 10-15 mín. að svara rannsókninni. Vinsamlegast lesið leiðbeiningar vel. Aðeins á að merkja við eina tölu á skalanum við hverja spurningu. Athugið að ekki þarf að svara öllum spurningum.

Vinsamlegast smellið á eftirfarandi hlekk til þess að opna rannsóknina.

http://www.createsurvey.com/s/UvziO4/?

Rannsóknin er opin til 21. október, 2011.

Með von um jákvæð viðbrögð,

Ingibjörg Birna Kjartansdóttir,
meistaranemi í framkvæmdastjórnun á byggingasviði, HR.
Netfang: ingibjorgk10@hr.is
Sími: 866 9332

Appenix B: Survey in its full length

PART 1: Þekking á hugtökunum BIM og LEAN Construction. (General information and knowledge on BIM and LEAN Construction)

1. Þekkir þú til BIM (Building Information Modelling)? Have you heard of BIM (Building Information Modelling)
   - ☐ Já (Yes)
   - ☐ Nei (No)

2. BIM skilgreint sem: (BIM is defined as:)
   - ☐ Nýtt forrit þar sem er hannað og teiknað í þrívídd.
   - ☐ Tölvustutt byggingarlíkan sem geymir upplýsingar um byggingu yfir líftíma hennar. – right answer
   - ☐ Nýleg aðferðafræði sem auðveldar magntöku.
   - ☐ Nýtt forrit sem auðveldar stjórnun á framkvæmdum sem og útreikningi á orkunotkun mannvirkis.

3. Þekkir þú til Lean Construction? (Have you heard of Lean Construction:)
   - ☐ Já (Yes)
   - ☐ Nei (No)

4. Lean Construction er (Lean Construction is defined as):
   - ☐ að hanna og stjórna þeim ferlum sem þarf til að afhenda umbeðna byggingu á tilsettum tíma, eftir ósk viðskiptavinar. – right answer
   - ☐ að byggja byggingar eftir einingum.
   - ☐ að skipuleggja framkvæmdir vel fram í tímann.
   - ☐ að losa úrgang af vinnusvæði sem fyrst og/eða endurnýta hann.

Hversu sammála/ósammála ertu eftirfarandi fullyrðingu. *Fimm punkta skali frá 1 (mjög ósammála) til 5 (mjög sammála).*
How strongly do you agree on following statement. *Five point scale from 1 (strongly disagree) to 5 (strongly agree).*

5. BIM og Lean Construction vinna vel saman. (BIM and Lean Construction work great together.)

Mjög ósammála	1	2	3	4	5	Mjög sammála

6. Ég mun koma til með að teikna upp næsta verkefni hjá þínu fyrirtæki?
It will be in my hands to produce drawings for next project within my company? **?**

Mjög ósammála	1	2	3	4	5	Mjög sammála

7. Hefur þú heyrt um BIM-Ísland? (Have you heard of BIM-Iceland?)
- ☐ Já (Vinsamlegast svarið næstu spurningu)
- ☐ Nei (Vinsamlegast sleppið næstu spurningu)

8. Hversu ánægður/óánægður ertu með störf BIM-Ísland? (How satisfied are you with the services BIM-Iceland have provided?)

Mjög óánægður	1	2	3	4	5	Mjög ánægður

PART 2: Fyrirtæki sem nota BIM (Companies using BIM).

9. Fyrirtækið mitt notast við BIM forrit?
My company uses BIM software?
- ☐ Já
- ☐ Nei (Vinsamlegast farið í næsta hluta)

10. Mitt fyrirtæki notast við eftirfarandi BIM forrit (má merkja við fleira en eitt) **(**Which BIM software does your company use? (you may mark with more than one))
- ☐ Autodesk Revit
- ☐ Autodesk Architecture Desktop
- ☐ Graphisoft ArchiCAD
- ☐ Bentley Microstation TriForma
- ☐ Bentley Architecture
- ☐ Nemetschek AllPlan
- ☐ Annað, vinsamlegast tilgreinið (Other, please specify)*:*

  ____

11. Gefðu sjálfum þér einkunn fyrir hversu litla/mikla þekkingu þú telur þig hafa á því BIM forriti/forritum sem unnið er með hjá þínu fyrirtæki. *Fimm punkta kvarði frá 1 (mjög lítil) til 5 (mjög mikil).*
Give yourself an overall grade on your knowledge on the BIM software your company is using. *Five point scale from 1 (very poor) to 5 (very good).*

Mjög litla	1	2	3	4	5	Mjög mikla

12. Hversu mörg verkefni í heildina hafa verið teiknuð í BIM innan þíns fyrirtækis? (How many projects all together have been developed with BIM within your company?)

____

13. Hversu mörg BIM-verkefni eru í gangi í dag hjá fyrirtækinu þínu? (How many current projects does your company have?)

____

Hversu sammála/ósammála ertu eftirfarandi fullyrðingum. *Fimm punkta skali frá 1 (mjög ósammála) til 5 (mjög sammála).*
How strongly do you agree on following statement. *Five point scale from 1 (strongly disagree) to 5 (strongly agree).*

14. Ný verkefni hjá mínu fyrirtæki verða teiknuð í BIM. (New projects at my company are produced after BIM)

Mjög ósammála	1	2	3	4	5	Mjög sammála

15. BIM var innleitt hjá mínu fyrirtæki af því að: (Reasons for using BIM:)

a. Teikningar og töflur eru útbúnar án fyrirhafnar (Creates views, schedules dynamically and automatically).

Mjög ósammála	1	2	3	4	5	Mjög sammála

b. Breytingar koma inn strax í allar teikningar og lista (Reflects changes instantly in all drawings and schedules).

Mjög ósammála	1	2	3	4	5	Mjög sammála

c. Engin þörf er á að vinna með lagskiptingu (No need to work with layers).

Mjög ósammála	1	2	3	4	5	Mjög sammála

d. Komist er hjá því að vinna með margar skrár, blokkir (external blocks) og vísanir í aðrar skrár (Xref) (External blocks, Xref management and multiple files are avoided).

Mjög ósammála	1	2	3	4	5	Mjög sammála

e. Sambærilegt við upplýsingastaðla sem styðja samverkunarhæfni (Compatible with data exchange standards for interoperability).

Mjög ósammála	1	2	3	4	5	Mjög sammála

f. Krafist af viðskiptavini (Required by client).

Mjög ósammála	1	2	3	4	5	Mjög sammála

g. Krafist af öðrum meðlimum teymis (Required by other project team members).

Mjög ósammála	1	2	3	4	5	Mjög sammála

h. Aðrar ástæður, ekki taldar upp hér að framan, vinsamlegast tilgreinið (Other reasons, not listed above, please specify): ___________________________

Hversu sammála/ósammála ert þú eftirfarandi fullyrðingum, varðandi fyrirtæki þitt? *Fimm punkta skali frá 1 (aldrei) til 5 (alltaf).*
How strongly do you agree/disagree on following statement on your company? *Five point scale from 1 (never) to 5 (always).*

16. Mitt fyrirtæki notar BIM: (At my company BIM is used when:)

a. Við hönnun (Designing).

Aldrei	1	2	3	4	5	Alltaf

b. Við teikningu aðaluppdrátta (Producing general drawings).

Aldrei	1	2	3	4	5	Alltaf

c. Við teikningu vinnuteikninga (Producing work drawings).

Aldrei	1	2	3	4	5	Alltaf

d. Við teikningu deila (Producing detail drawings).

Aldrei	1	2	3	4	5	Alltaf

e. Við teikningu annarra teikninga (Producing other drawings).

Aldrei	1	2	3	4	5	Alltaf

f. Við rýmisstjórnun (Manage space).

Aldrei	1	2	3	4	5	Alltaf

g. Við áætlanagerð (Scheduling).

Aldrei	1	2	3	4	5	Alltaf

h. Til að spá fyrir um orkunotkun . (Energy simulation).

Aldrei	1	2	3	4	5	Alltaf

i. Við framsetningu. (Visualization).

Aldrei	1	2	3	4	5	Alltaf

j. Við magntöku. (Quantity take-off).

Aldrei	1	2	3	4	5	Alltaf

17. Mitt fyrirtæki mælir frammistöðu BIM verkefna sinna. (My company measures BIM performance?).

Aldrei	1	2	3	4	5	Alltaf

18. Hvaða CAD forrit notast fyrirtæki þitt við, eða hefur notast við? Má merkja við **fleiri en einn** möguleika. (Which of the following CAD system(s) is your company using?)

- ☐ Autodesk 3D Studio MAX
- ☐ Autodesk 3D Studio VIZ
- ☐ Autodesk Architecture Studio
- ☐ Autodesk AutoCAD
- ☐ Autodesk Building Systems
- ☐ Accurender
- ☐ Architrion
- ☐ Arris
- ☐ Bentley Structure
- ☐ Bentley HVAC
- ☐ Bentley MicroStation
- ☐ DataCAD
- ☐ Design Workshop
- ☐ FormZ
- ☐ GDS or MiniGDS
- ☐ IntelliCAD
- ☐ Nemetschek MiniCAD
- ☐ Nemetschek VectorWorks
- ☐ PowerCADD
- ☐ SketchUp
- ☐ TurboCAD
- ☐ Annað, vinsamlegast tilgreinið: *(Other, please specify)*

____

19. Gefðu sjálfum þér einkunn fyrir kunnáttu þína á því CAD forriti/um sem þitt fyrirtæki notar. *Fimm punkta skali frá 1 (mjög lítil) til 5 (mjög mikil).*
Give yourself an overall grade on your CAD knowledge. *Five point scale from 1 (very poor) to 5 (very good)*

Mjög lítil	1	2	3	4	5	Mjög mikil

20. Hversu óánægður/ánægður ertu með að notkun á BIM? *Fimm punkta skali frá 1 (mjög óánægður) til 5 (mjög ánægður).*
How unsatisfied/satisfied are you with using BIM? *Five point scale from 1 (very unsatisfied) to 5 (very satisfied).*

Mjög óánægður	1	2	3	4	5	Mjög ánægður

21. Hvað finnst þér vera veikleiki eða takmörkun, ef einhver, í BIM forritinu sem þú notar?
What do you think is a weakness or limitation in the BIM software you are using, if any?

____
____
____
____

PART 3: Fyrirtæki sem nota <u>ekki</u> BIM (Companies <u>not</u> using BIM):

Hversu sammála/ósammála ert þú eftirfarandi fullyrðingum, varðandi fyrirtæki þitt? *Fimm punkta skali frá 1 (aldrei) til 5 (alltaf).*
How strongly do you agree/disagree on following statement on your company? *Five point scale from 1 (never) to 5 (always).*

22. BIM er ekki notað í mínu fyrirtæki af því að? (BIM is not being used in my company because)

a. Engin ástæða til þess (No need to produce BIM).

Mjög ósammála	1	2	3	4	5	Mjög sammála

b. Þau CAD forrit sem fyrir eru, uppfylla þarfir okkar til að teikna og hanna (Existing CAD system fulfills our need to design and draft).

Mjög ósammála	1	2	3	4	5	Mjög sammála

c. BIM er of dýrt (BIM is too expensive).

Mjög ósammála	1	2	3	4	5	Mjög sammála

d. Skortur á þjálfun/kennslu á BIM forritum (Lack of training in BIM software).

Mjög ósammála	1	2	3	4	5	Mjög sammála

e. Tími hönnunar og teiknivinnu minnkar ekki við notkun BIM, miðað við þá aðferð sem notuð er hjá mínu fyrirtæki í dag. (BIM does not reduce time used on drafting compared with current drawing approach).

Mjög ósammála	1	2	3	4	5	Mjög sammála

f. BIM skortir eiginleika/sveigjanleika til að búa til byggingarmódel eða teikningu (BIM lacks features or flexibility to create a building model/drawing).

Mjög ósammála	1	2	3	4	5	Mjög sammála

g. Viðskiptavinir biðja ekki um BIM *(*Clients are not requiring BIM).

Mjög ósammála	1	2	3	4	5	Mjög sammála

h. Aðrir meðlimir teymisins biðja ekki um notkun á BIM (Other team members are not requiring BIM).

Mjög ósammála	1	2	3	4	5	Mjög sammála

i. Aðra ástæður, vinsamlegast tilgreinið (Other reasons, please specify):
____
____
____
____

23. Fyrirtæki mitt myndi innleiða BIM ef: *Fimm punkta skali frá 1 (aldrei) til 5 (alltaf).*
My company would implement BIM if: *Five point scale from 1 (never) to 5 (always).*

a. Stjórnendur/eigendur sæju aukinn framleiðslu gróða fram yfir venjuleg CAD forrit (See large productivity gain over CAD systems):

Mjög ósammála	1	2	3	4	5	Mjög sammála

b. Stjórnendur/eigendur myndu sjá notkunarmöguleika BIM (t.d. mat á byggingareiginleikum, aðgengi, hljómburð, kostnað og sjálfbærni) See downstream applications of BIM (e.g. assessment of buildability, accessibility, acoustics, costs, sustainability).

Mjög ósammála	1	2	3	4	5	Mjög sammála

c. Fyrirtækinu yrði boðinn stuðningur og þjálfun frá sölu-/þjónustuaðilum BIM forrita (Would be offered support and training from BIM vendors):

Mjög ósammála	1	2	3	4	5	Mjög sammála

d. Fyrirtækinu yrði boðinn stuðningur og þjálfun frá BIM-Ísland (Would be offered support and training from BIM-Iceland):

Mjög ósammála	1	2	3	4	5	Mjög sammála

e. Viðskiptavinir krefðust þess að unnið sé eftir BIM (If BIM would be required from clients):

Mjög ósammála	1	2	3	4	5	Mjög sammála

f. Finndu fyrir vaxandi kröfu frá öðrum meðlimum teymisins að vinna í BIM (If BIM would be required by other team members).

Mjög ósammála	1	2	3	4	5	Mjög sammála

g. Aðrar ástæður, vinsamlegast tilgreinið (Any other reasons, please specify):____

24. Hversu líklegt/ólíklegt telur þú að fyrirtæki þitt komi til með að innleiða BIM *Fimm punkta skali frá 1 (aldrei) til 5 (alltaf).*
(How likely/unlikely do you think your company will implement BIM): *Five point scale from 1 (never) to 5 (always).*

a. Næsta árið? (Next year?)

Mjög ólíklegt	1	2	3	4	5	Mjög líklegt

b. Næstu 5 ár? (Next 5 years?)

Mjög ólíklegt	1	2	3	4	5	Mjög líklegt

c. Næstu 10 ár? (Next 10 years?)

Mjög ólíklegt	1	2	3	4	5	Mjög líklegt

HLUTI 3: Fyrirtæki sem notast við aðferðafræði Lean Construction *(Companies adopting Lean Construction practices).*

25. Fyrirtækið mitt notast við Lean aðferðafræði (My company adopts Lean Construction practices).

- ☐ Já (Yes)
- ☐ Nei (No)

26. Mitt fyrirtæki notast við eftirfarandi verkfæri úr Lean Construction (Má merka við **fleiri en einn** svarmöguleika) (My company uses following Lean tools)?

- ☐ Last Planner System (LPS)
- ☐ Just in Time *(JIT)*

- ☐ Kan-ban
- ☐ Skuldbindingar skjal *(Commitment Charts)*
- ☐ Skipuleggja-Gera-Athuga-Aðhafast *(Plan-Do-Check-Act)*
- ☐ Hlutfall áætlunar lokið skjal *(Percentage Plan Completed Charts)*
- ☐ Annað, vinsamlegast tilgreinið *(Other, please specify)*:

  ____

Hversu sammála/ósammála ert þú eftirfarandi fullyrðingum, varðandi fyrirtæki þitt? *Fimm punkta skali frá 1 (aldrei) til 5 (alltaf).*
How strongly do you agree/disagree on following statement on your company? *Five point scale from 1 (never) to 5 (always).*

27. Við notkun á verkfærum frá Lean hugmyndafræðinni hef ég orðið var við að: By adopting Lean Construction practices:

a. Að áætlanir standast frekar (Schedules (time schedules) are on time).

Mjög ósammála	1	2	3	4	5	Mjög sammála

b. Jafnara vinnuálag í verkefninu (Workload is more even within the project).

Mjög ósammála	1	2	3	4	5	Mjög sammála

c. Aukið samræmi innan teymis (Better co-ordination within team).

Mjög ósammála	1	2	3	4	5	Mjög sammála

d. Aukna ánægju viðskiptavinar *(*Increased client satisfaction).

Mjög ósammála	1	2	3	4	5	Mjög sammála

e. Að vinnutengdum slysum hefur fækkað (Workrelated accidents have decreased)

Mjög ósammála	1	2	3	4	5	Mjög sammála

f. Meira virði fyrir peninga (More value for money).

Mjög ósammála	1	2	3	4	5	Mjög sammála

g. Mistök fyrri verkefna endurtaka sig síður (Mistakes from previous projects tend not to recurr)

Mjög ósammála	1	2	3	4	5	Mjög sammála

Hluti 4: Upplýsingastaðlar: (Information Exchange Standards)

Hversu sammála/ósammála ert þú eftirfarandi fullyrðingum, varðandi fyrirtæki þitt? *Fimm punkta skali frá 1 (mjög litla) til 5 (mjög mikla).*
How strongly do you agree/disagree on following statement on your company? *Five point scale from 1 (very little) to 5 (very much).*

28. Hversu litla/mikla þekkingu býrð þú yfir á eftirfarandi CAD gagnasamskipta stöðlum? How little/much knowledge do you have on following CAD Data Exchange Standards?

a. Drawing Exchange Format (DXF)

Mjög litla	1	2	3	4	5	Mjög mikla

b. Industry Foundation Class (IFC)

Mjög litla	1	2	3	4	5	Mjög mikla

c. Initial Graphics Exchange Specification (IGES)

Mjög litla	1	2	3	4	5	Mjög mikla

d. Standard for the Technical Exchange of Product Data (STEP)

Mjög litla	1	2	3	4	5	Mjög mikla

HLUTI 5: Bakgrunnur svarenda *(Respondents background).*

29. Inn á hvaða sviði er þitt fyrirtæki? Within which field is your company?

- ☐ Arkitekt (Architect)
- ☐ Verktaki (Contractor)
- ☐ Verkfræði (Engineering)
- ☐ Ráðgjöf (Consulting Engineering)
- ☐ Fasteignastjórnun (Facility Management)
- ☐ Menntun (Education)
- ☐ Eigandi/Viðskiptavinur (Owner/Client)
- ☐ Skipulag (Planning)
- ☐ Annað, vinsamlegast tilgreinið: Other please specify:

  ____

30. Hver er fjöldi stöðugilda í fyrirtækinu? How many employees are there in your company?

- ☐ 10 eða færra
- ☐ 11-20
- ☐ 21 eða stærra

Appendix C: Letter to respondents with results summary

HÁSKÓLINN Í REYKJAVÍK
REYKJAVIK UNIVERSITY

27. Desember 2011

Kæri viðtakandi,

Með bréfi þessu vil ég þakka þér fyrir þáttöku þína í rannsókn minni í október síðastliðnum og einnig vil ég kynna stuttlega niðurstöður hennar. Verkefnið er hluti af meistaraverkefni mínu við framkvæmdastjórnun á byggingasviði við Háskólann í Reykjavík. Tilgangur rannsóknarinnar var að varpa ljósi á stöðu innleiðingarferlis Building Information Modelling (BIM) á Íslandi og hvort tenging sé á milli BIM og lean construction.

Innleiðingarferli opinberra stofnanna á Íslandi og í nágrannalöndum voru skoðuð sem og Bandaríkjanna og þau borin saman. Niðurstöðurnar gáfu í skyn að bil sé í innleiðingarferlinu á Íslandi, þar sem engar reglugerðir um notkun BIM eru í gildi. Opinberar stofnanir geta því aðeins sóst eftir að BIM sé notað, en ekki krafist þess.

Framkvæmd var könnun innan fyrirtækja og stofnanna innan íslenska byggingariðnaðarins með því markmiði að varpa ljósi á hverjir notast við BIM og lean construction og að hvaða marki. Af þátttakendum segjast 40% nota BIM, mest arkitektar og verkfræðingar. Niðurstöðurnar gefa í skyn að þroskastig BIM á Íslandi liggi á milli þroskastigs 1 og 2, þar sem enginn verktaki sagðist notast við BIM og aðeins eitt fyrirtæki notast við lean construction.

Verkefnið í heild sinni er hægt að nálgast á vefslóðinni www.skemman.is eftir 12. Janúar 2012.

Með þakklæti og virðingu,

Ingibjörg Birna Kjartansdóttir,
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