How does BIM contribute to LEAN?
How Does BIM contributes to LEAN?

Title Page

Title: How does BIM contributes to lean?
Subtitle: With Focus on the Building Construction industry
Author: Thomas Felipe Johansen
Email: Thomas.fj88@gmail.com
Special advisor: Dr. James Harty
Date of hand-in: 26\textsuperscript{th} of March
Number of pages: 57
Number of characters including space: 71 914
Maximum Amount of pages: 30 pages based on 2400 characters on each page. Maximum allowed characters is 72 000 excluded Bibliography.
Number of copies: 3 plus digital copy on USB
Purpose of specialization report: This specialization report is a part of my 7\textsuperscript{th} semester and is a mandatory to accomplish a Bachelor of Architectural Technology and Construction Management at KEA – Copenhagen School of Design and Technology.
Declaration: I declare that this report is my work and that the sources are used right.
# Table of Contents

TITLE PAGE .................................................................................................................................................. 1

Table of Contents ......................................................................................................................................... 2
Table of Figures ........................................................................................................................................... 3

1 ABSTRACT .................................................................................................................................................. 5

2 INTRODUCTION ......................................................................................................................................... 6
   2.1 Tendencies in the Construction Business ......................................................................................... 7
       2.1.1 Study of productivity .................................................................................................................. 9

3 BIM ............................................................................................................................................................ 11
   3.1 Short History of BIM .......................................................................................................................... 11
   3.2 What is BIM? ...................................................................................................................................... 11
   3.3 Software and BIM Solutions .............................................................................................................. 13
   3.4 BIM Adoption .................................................................................................................................. 14
       3.4.1 North America .......................................................................................................................... 14
       3.4.2 North America vs. Europe ........................................................................................................ 15
       3.4.3 Future growth ........................................................................................................................... 17
       3.4.4 Comparing the ROI measures: Europe vs. North America ...................................................... 18
   3.5 Industry Foundation Classes (IFC) ..................................................................................................... 18
   3.6 Implementation Levels ..................................................................................................................... 21
       3.6.1 Benefits by the use of BIM ........................................................................................................ 26
       3.6.2 Improved Risk reduction: .......................................................................................................... 28
       3.6.3 Planning, communication and collaboration ............................................................................ 29

4 History of Lean Production ....................................................................................................................... 30

5 Five Steps of a Lean Implementation ........................................................................................................ 33
   5.1 Step 1, Specify the Value ................................................................................................................... 33
   5.2 Step 2, Identify the Value Stream ..................................................................................................... 34
   5.3 Flow ................................................................................................................................................... 35
   5.4 Push .................................................................................................................................................. 38
   5.5 Pull .................................................................................................................................................... 38
   5.6 The Strive for Perfection .................................................................................................................. 39

6 The Interaction .......................................................................................................................................... 40
   6.1 Directly Interaction ............................................................................................................................. 40
   6.2 Indirectly Interaction .......................................................................................................................... 41
       6.2.1 ICE-Meeting ............................................................................................................................. 42
       6.2.2 Own experience with ICE ........................................................................................................ 43
       6.2.3 Integrated Project Delivery (IPD) .............................................................................................. 44
   6.3 Directly and Indirectly Approach from BIM to Lean ........................................................................ 46
   6.4 The Communication .......................................................................................................................... 47

7 Conclusion ................................................................................................................................................. 49

Thomas Felipe Johansen | KEA - COPENHAGEN SCHOOL OF DESIGN AND TECHNOLOGY
How Does BIM contributes to LEAN?

BIBLIOGRAPHY

Table of Figures

Figure 2: Numbers from Statistics Norway shows a decline in the productivity of the construction industry is far less than previously assumed – (Boligprodusentene) ........ 7
Figure 2: Construction productivity – McKinsey (http://geospatial.blogs.com/geospatial/productivity/) ......................................................... 7
Figure 3: (“Mitt SSB: Statistikkbanken” 2015) ...................................................... 8
Figure 4: Shows the labor productivity index from 1964-2004 (Eastman 2008, 8)....... 9
Figure 5: (“D&J Tile Company, Inc. - Ceramic & Stone Contractors | Services,” n.d.).... 12
Figure 6: (Becerik-Gerber & Rice, 2010, p. 7) ...................................................... 13
Figure 7: (Becerik-Gerber & Rice, 2010, p. 8) ...................................................... 13
Figure 8: (Young Jr. 2009, 8) ........................................................................... 14
Figure 9: (“business_value_of_bim_in_europe_smr_final.pdf,” n.d., p. 7) .......... 15
Figure 10: (“business_value_of_bim_in_europe_smr_final.pdf,” n.d., p. 7) .......... 16
Figure 11: (“business_value_of_bim_in_europe_smr_final.pdf,” n.d., p. 11) .... 17
Figure 12: showing (“business_value_of_bim_in_europe_smr_final.pdf,” n.d., p. 7) ... 17
Figure 13: (“Why WE care about BIM…,” 2014, p. 1) ....................................... 21
Figure 14: (Dave et al. 2013, 11)(Bew 2010, 2)............................................... 22
Figure 15: (“Why WE Care about BIM…” 2014, 1).......................................... 23
Figure 16: (“BIM / 3D Modeling,” n.d.)........................................................... 24
Figure 17: (McGraw-Hill-Construction)(“Business Value of BIM in Europe SMR_final (2010),” n.d., p. 32)....................................................... 26
Figure 18: (“Business Value of BIM in Europe SMR_final (2010),” n.d., p. 33) .... 27
Figure 19: (The Future of the Building Industry (3/5): The Effort Curve (MacLeamy, 2010) ........................................................................ 27
Figure 20: Showing how the communication are between typical contractors in a project With 2D Drawings exchanged by paper, and a IFC model. (“What is BIM? - Construction BIM Forum Riga 2014,” 2014) ........................................ 29
Figure 21: The Figure shows a five step approach to lean thinking (self-made)...... 33
Figure 22: Illustrating the different shop fitting parts....................................... 36
Figure 23: This illustration shows how Clash detection contributes directly to lean goals throughout developing and technical phases of a project................................. 41
Figure 24: (Chachere, Kunz, Levitt 2004, p. 8) .................................................. 42
Figure 25: (“Facilities-Manager_NovDec-2014-Article-PDF.pdf” 2015, 12) .... 48
How Does BIM contributes to LEAN?
How Does BIM contribute to LEAN?

1 Abstract

Lean and Building Information Modeling (BIM) are two subjects relevant for the construction industry in 2015. BIM is often explained as the tool and lean as the philosophy and principle. They have both helped the construction industry to expand rapidly during the past 10 years. They are more often used together to strengthen the different phases a project goes through.

During my internship I worked for JM, one of the leading house and apartment developers in Scandinavia. They buy land, develop it, plan it as well sells it directly to their customers. When I started in JM my job was to participate as a part of a project-planning group working with a pilot project for implementing BIM. My task was to focus on BIM coordination between external and internal resources. I was able to observe, as well being a part of how a company tried to implement BIM, while they already used the lean principles. BIM is an interesting concept but what happens when a company wants to practice it together with lean? To have a clear path when implementing BIM is essential to succeed.

The experience I have gained during the last years of studying is essential for my BIM knowledge, and the principles behind it. However, there are many misunderstandings about BIM. Especially about what it really is, and what kind of impact it can have for the construction industry. I think everyone considering implementing BIM should be aware of the difficulties, as well the opportunities it can bring.
2 Introduction

Throughout this report I will explain what BIM is, and how it affects the construction and building industry. I will also go through the history of BIM and lean and explain the thought behind it. In addition to this the report will explain how BIM contributes directly and indirectly to lean, as well as how the building and construction industry can save time, money and resources by utilizing BIM effectively together with lean.

Examples of BIM utilizing lean could be throughout meetings, collaboration systems, tools and knowledge. One of my questions of interest are how the construction and building industry are able to save money, time and work effort by using BIM in combination with lean. I will also investigate what kind of factors supporting a BIM implementation. I’m also curious about how BIM are able to do the Building and construction industry more effective. Throughout the report I will investigate to the questions;

- What is BIM?
- What is lean?
- How are they related to each other?
- What are the benefits of using BIM and lean together?
- Why should the building and construction industry implement BIM?
- What kind of benefits will they earn by the use of BIM and lean together?

Lean thinking is a complicated principal and can easily be misunderstood because of all the strategies and principles behind it. However it’s a process that have proven its strengths, and enabled many different industries to create the right product for their customers without creating too much waste. I have therefore decided to explain the history of it, to give a perspective of how big the success factor of lean has been throughout history.

This report is based on research relating to the main subjects. I have primarily used different internet sources as my investigation method. In addition to this I have also used books, Journals, articles, interviews and the knowledge I have gathered during
How Does BIM contributes to LEAN?

my years as a student. Last but not least I have also used the experience I gained having an intern at JM. My target group will be companies that already utilize lean, but are curious about implementing BIM.

2.1 Tendencies in the construction business

The construction productivity of the main industries in the world was presented at the Global Infrastructure Leadership Forum. McKinsey has investigated the major trends in global infrastructure. In a report they explain that productivity has stagnated or declined in the European Union, Korea, Japan and U.S (Zeiss 2012, 1). This is shown in the figure 2, the trend shows that U.S has a steeper declined than Korea, Japan, and the European Union. The Norwegian trend shows an average compared with the European trend, see figure 1.

I think it’s strange to see the negative tendencies, when many construction companies use huge amount of recourses to increase their efficiency, as well implementing a variety of strategies and tools. All this has happened while a big part of the construction industry had worked to implement BIM. I decided to investigate the case closer, and made a graph showing the production index in Norway. The graph is based on numbers from “Statistisk Sentral Byrå” (SSB). I compared the Norwegian production
How Does BIM contributes to LEAN?

index of building and construction industry with oil production, mining, industrial industry and power because they are the most comparable industries in size. My findings show a positive trend for the building and construction industry with a bottom between 2008 and 2010 a consequence of the financial crisis.

Figure 3: ("Mitt SSB: Statistikkbanken" 2015)
2.1.1 Study of productivity

A study done by the Center for Integrated Facility Engineering (CIFE) explains that through research studies there have been associated extra costs with traditional design and construction industry (Eastman 2008, 8). Figure 4 illustrates the U.S Field construction industry in comparison with non-farm over a 40 years period. Throughout these years the productivity of the non-farm industry has increased with a approximately 140%. Meanwhile the construction industry has decreased productivity with only 10%.

![Figure 4: Shows the labor productivity index from 1964-2004](Eastman 2008, 8)

The reason to why the non-farm industry has such great productivity increase is the great use of offsite components, which utilize the factory conditions and specialized tools. That allowed the non-farm industry to decrease their costs and improved their quality. This is a result of using automated information systems, better supply chain management and improved collaboration tools.(Eastman 2008, 8) it could be several reasons to why the construction industry hasn’t been able to increase the productivity rate. Eastman mentions that one of the possibilities could be that the onsite construction is not benefited from automation. Instead the construction industry has used non-union immigrant to do the work. This has resulted in lower effort to replace the onsite workers. The construction industry also limits how quickly they are able to adopt new and innovative technology (ibid.:10,11). Eastman argues that the construction industries have difficulties with the exchange and management of
information as well incompatibility between the different systems making it difficult to share information rapidly. A study done by National Institute of Standard and Technology (NIST) compared current business activities and costs with hypothetical scenarios in which there was seamless information flow and no redundant data entry. NIST identified:

- **“Avoidance (redundant computer systems, inefficient business process management, redundant IT support staffing)”**
- **Mitigation (manual reentry of data, request for information management)**
- **Delay (costs for idle employees and other resources)”** (Eastman 2008, 11)

The conclusion is worth to notice, with an estimated loss on 15.8 billion dollars. (ibid.:11)

The construction industry has to re-think how they manage data and cooperate between each other. Is BIM the answer for better?
How Does BIM contributes to LEAN?

3 BIM

Today’s construction industry is influenced by the uncertainty around BIM. This could be because of the need to start doing the project development in new ways. It could also be the awareness of learning something you doesn’t know will work. For me, it seems like many companies are waiting for “another company” to try it out and see if it works or not. The problem here is if everyone does that, some firms will get the knowledgeable advantage. Another reason is that companies are afraid of not being able to master the “new way” and combining it with the “traditional way” of the project development. I will therefore roughly explain the history of how BIM has developed, and what BIM is as well as what it’s used for in the construction industry.

3.1 Short History of BIM

BIM is an abbreviation for Building Information Modeling. In the beginning everything was planned and sketched with a pencil and paper. The planning then moved over to digitalized models, with simple lines and circles, better known as Computer-aided design (CAD). While the computer technology continued developing, software and digitalized tools got more advanced. Instead of planning in 2D the architects, engineers and construction companies are able to do their work in 3D. It was then possible to create components instead of lines. This is what we now call 3D and one of the most essentials tools to visualize projects. After that the BIM came which revolutionized methods of collaboration and planning between the different professionals in the building and construction industry as well as digitalize analysis, and quantities.

3.2 What is BIM

My experience of what BIM really is, are varying. I have talked with many people about it, and heard several examples of what they mean BIM is. Some seems BIM as a drawing tool, others say it is a tool for illustrating buildings and some says it is to plan and build construction. I agree with all of these definitions, but BIM is so much more
How Does BIM contributes to LEAN?

than that. After some investigation of what BIM really is I came up with a couple of examples I think explains a lot.

BIM is not only a building in 3D, it’s also the parts and structures in the model that develops parallel to the project development. Every component in the building has intelligence as U-value definitions, load bearing capacity and schemes explaining area quantities, doors, windows and so on. Parties involved in the same project collaborate and communicate seamlessly trough the model as well sharing the knowledge between each other. Autodesk roughly describe BIM as intelligence based model used for planning, designing, building and managing buildings infrastructure."Autodesk” 2015)

The National Building Information Model Standard Project Committee defines BIM as:

“Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.

A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder."("BIM - Worthy of Clearer Definitions” 2015)
3.3 Software and BIM solutions

There is a huge variety of software and analysis tools on the market, some of them more used than others. The contractors utilize a wider specter of BIM solutions than the architecture companies which mostly use authoring tools. One-third of the Engineering companies use Tekla. Figure 6 illustrates how the U.S building industries has adopted the different software and BIM solutions. Autodesk has a clear advantage with the two most used software’s on the market. Revit has a usage percentage on 41.6% and Navisworks with 12.4%. The third most used software is Graphisoft Archicad (Becerik-Gerber and Rice 2010, 7)

Figure 7 are respondent to which tasks the BIM users use most. Architecture firms use BIM mainly for design-related functions. This includes building design and visualization. The contactors mostly use BIM for clash detection, visualization, and creation of as-built model. One fourth of the BIM users are utilizing direct fabrication. Almost one-fourth of the respondents utilize BIM for direct fabrication. (Becerik-Gerber and Rice 2010, 8)
How Does BIM contribute to LEAN?

3.4 BIM adoption

The McGraw Hill construction company have made a survey among thousands of Architecture, Engineering and Construction (AEC) participants in North America and globally. In this chapter I will present some of their key findings in the business value of BIM. Their findings show that the users of BIM highly value its benefits and that the majority implementing BIM sees positive numbers on their Return On Investment (ROI). It’s also stated that the benefits are greater than many users think, and experienced users are able to see more value in BIM.

3.4.1 North America

63% of the North America users state that they see a positive ROI on the overall BIM investments. While 54% formally measures ROI. The users that measures their ROI gets positive returns in comparison to 53% who estimated ROI based on perception. The beginners doesn’t see as much positive ROI as the experts that see 87% positive ROI against 38% for the beginners. 93% of the overall BIM users believes that it’s a potential to gain more value from BIM in the future. (Young Jr. 2009, 6,8)

The report shows that only 13% of BIM users actually measure their ROI in projects. Does the different contractors and entrepreneurs just expect ROI no matter what, or do they trust the BIM reputation a 100%? Even if the use of BIM has a good reputation, a wrong implementation can be devastating for the ROI. The report also show, that those who didn’t measure their ROI, are open to do it in the future, while 39% of them explains that they probably will do it in the future and 27% says they haven’t decided if
How Does BIM contributes to LEAN?

they will measure it in the future. The users with more BIM expertise are those who indicate most that they will never measure their ROI, if they haven’t done it so far. The experts user state that they have made the decision to pursue BIM and don’t necessary need to proof the value of it. (Young Jr. 2009, 8)

The report also shows measures of the Level of business value of BIM by comparing the user differences between, contractors, owners, architects and engineers. 52% of the contractors are able to see the value in BIM. Contractors are also the majority of those who think more can be utilized from BIM. Today seven out of ten owners are expecting a positive ROI on BIM. 61% of the owners believe that they only utilize a small amount of the total BIM tool. This group are the most likely to believe this.

Six in ten architects are experience positive ROI on BIM, while a third of the architects claim returns in the 10-25% range versus half of the architect that claim greater than 25% ROI. It’s only 2% of them that feels they are currently experiencing the maximum value of BIM. The most pessimistic when it comes to the value of BIM are the engineers. 12% of them are seeing no meaningful value from BIM while three of five states that they only scratching the surface of the BIM value. (Young Jr. 2009, 9)

3.4.2 North America vs. Europe

All key numbers are found in the report McGraw-Hill Construction has made. The report is focusing on France, Germany and the United Kingdom. These three counties together represents 40% of the European none residential construction industry. Their findings are compared with the North American construction industry.
How Does BIM contributes to LEAN?

The BIM adoption in North America is higher than in Europe, as the report state the “Overall BIM adoption levels are lower in Western Europe vs. North America, but the longtime user community members are true BIM believers”. (Bernstein 2010, 6) That’s a sentence confirming my suspicion. However the study explains that the primary adopters are architects with 47% engineers with 38% and contractors with 24%. Take into account Europe vs. North America 34% of the Western European users have over 5 years of experience compared with only 18% in North America. Western European respondents are optimists about using BIM on their work in two years. (ibid.:6)

![BIM Adoption North America vs. Europe](image1)

![Years Using BIM](image2)

Figure 10 : (“business_value_of_bim_in_europe_smr_final.pdf,” n.d., p. 7)

Of the respondents are 60% frequently users, and use BIM at least in 30% of their projects. In only two years this number can increase to 75%. The contractors are the group that’s anticipating the steepest increase curve in the use of BIM, they expect the frequent user population to grow from 11% to 54% in just only two years.
3.4.3 Future growth

The McGraw-Hill construction report, also explains that the European BIM adoption is steady but flat averaging slightly 10% each of the subsequently years. It’s also showing a positive trend with close up to 20% BIM adoption since early 2009. Within the last three years 46% of the users have adopted BIM in Europe, in comparison with 66% in North America. (Bernstein 2010, 12)

The report shows that almost half of the users measure ROI on more than 25% of their projects were in North America as much as a third of BIM users measures their ROI on BIM. Figure 12 illustrates that only 18% of the BIM beginners reports that their formally measures the ROI, and that its 46% of them that that perceive ROI to be better than break-even, while 58% of the experts users measures their ROI while 80% of them experience positive ROI, and 25% citing greater than 100% ROI. (Bernstein 2010, 7)
3.4.4 Comparing the ROI measures: Europe vs. North America

“This improvement in ROI based on experience level is also consistent with the North American findings, although only 20% of the North American BIM experts reported over 100% ROI. Although architects in both markets report the greatest ROI, the markets diverge sharply when it comes to engineers and contractors.” (ibid.:7)

In Western Europe 70% of the engineers sees positive ROI, versus North America where only 46% experience the same ROI. Three quarters of the contractors in North America reports positive ROI compared to 40% cite ROI above break-even.

Those who have based their ROI on perceptions have a lower ROI then the users who formally measure it. 82% of the Western European users are getting positive ROI, and 46% of them are getting ROI of 25% or more. 49% of the Western European users consider themselves as experts or advanced, while 92% of them experience positive BIM ROI while 46% of the BIM beginners experience positive ROI. (Bernstein 2010, 19)

3.5 Industry Foundation Classes (IFC)

Before I started my internship, I didn’t know much about the Industry Foundation Classes (IFC), neither had I used it in practice. I had questioned my self how it’s possible to cooperate with all the different software’s and file formats. The industry mainly uses IFC to exchange and communicate data across platforms independently of each other. It sounds easier to use IFC than it really is. One element is to export the 3D graphics. Another is to export the data with correct coordinates, information and properties required for the project. There are several other software solutions to check the model with. Among these are Solibri Model Checker and Tekla BIMsight, which are both capable of doing sematic and rule-based clash analysis.

During my internship I used Autodesk Navisworks to rewrite the IFC files, visualize the models and do clash detections between MEP, as well as to navigate and find solutions to specific areas in the model. I was therefore dependent on having the different models placed on the right coordination’s. When I was supposed to merge the IFC files I noticed difficulties with the import and export. IFC files exported from different
software’s often had wrong x, y, and z coordinates. This was due to the fact that the
global and local coordinates are interpreted differently in Tekla, Revit, MicroStation
and ArchiCAD. I then ended up doing a lot of coordination work often resulting in an
agreement to just place the model in x,0 y,0 z,0 coordinates. The IFC format is
impossible to edit after its exported, as well as having unpredictable information
attached to it. Solutions for these kinds of problems are to be found on the market.
Simplebim is one of them, and I tried to use it during my internship. By filtering and
validating the IFC files before they was merged together. The program was easy to use,
but required a huge amount of effort to give the IFC files the right properties. The
program was also additional software to the ones JM already used. To add a program
to find a solution is one step in the wrong direction when the goal was to simplify the
merging process.

An important representative for the IFC format is Autodesk together with Graphisoft.
In the text under Autodesk explains what IFC is and how they support open data
exchange standards to improve project collaboration.

“Industry Foundation Classes (IFC) is an important standard for the exchange of BIM
data. The IFC data model contains both geometry and properties of ‘intelligent’
building elements and their relationships to other elements in a building model—
central concepts of BIM. The IFC standard is developed and maintained by
buildingSMART International (formerly the International Alliance for Interoperability or
IAI), which is a non-profit industry-led organization. As such, IFC is a neutral standard
and independent of any particular vendor’s software development plans.

The IAI was started in 1994 when Autodesk invited a group of organizations to examine
the potential for making different software applications work together.”(“BIM
Interoperability Standards | Autodesk” 2015)

In additional to Autodesk and Graphisoft they explain on their web page that they
have played an active role in the BuildingSMART since 1996. In similarity to Autodesk,
How Does BIM contributes to LEAN?

Graphisoft has supported the IFC standard. That enables the ArchiCAD to communicate with other disciplines of BIM, as well to coordinate a building or construction project entirely in 3D. By this is possible to export the project back to hundreds of other systems that support the IFC format. (“Knowledge Base from GRAPHISOFT” 2015).

BuildingSMART IFC formats, are aiming to be a global standard for the use of BIM and exchange data. The IFC format exchange information and data in the IFC “language” that interprets the descriptions of the 3D building model elements (such as slabs, walls, columns, beams, windows, doors, etc.). All this done in an open format across different software applications that’s commonly used for, design, construction, procurement, maintenance and operations between various software applications during the design process. In comparison to Drawing eXchange Format (DXF) typically used in AutoCAD, IFC files also define the full properties of architectural objects, such as their 3D geometrical characteristics, materials and their relationship to other objects. This gives the users in the building and construction industry the opportunity to choose software independent on others in the project. All the communication goes through the IFC file while it’s still readable for everyone in the project. A benefit by using IFC format is that the construction industry can prevent that the formats doesn’t get controlled by one software vendor. (“Open Standards 101 | buildingSMART” 2014) / (“Knowledge Base from GRAPHISOFT” 2015)

A small conclusion to this is that IFC format forces the different software developers to compete and develop their software further. By this I mean different users don’t need to switch software for each project they participate in making them experts on one type of software. And I think that’s positive for everyone in the construction industry or in a project that they are able to save money by not having courses for every new software purchased.
3.6 Implementation levels

A BIM model can easily be associated with a 3D model. It’s much more than that. There are many different BIM Dimensions (The “D” associates the amount of information the model consist of) By implementing more information to the model, the letter I in BIM expands and results in a higher dimension dependent on what kind of information added 4D, 5D, 6D... In Addition to this, BIM contains several implementation levels. CAD is level 0, and it uses drawings, lines, arcs and text. CAD compared with BIM shows that these two headlines are quite different in purpose and function. CAD drawings for manufactures shows every single detail on a product, while BIM is developed to benefits everyone involved in the project development and show the graphics necessary. That helps the user to get an overall look on how much space the product requires. The minor details are usually shown on separate sheets or drawings dependent on the product. Robert S. Weygant describes a rule of thumb to not draw details you wouldn’t have seen in a distance on 3 to 4.6 meters (Weygant 2011, xi).

Level 1 consists of 2D and 3D models with objects and file based collaboration. In level 2 there is also a library management for models and objects while this is often seen as the minimum standard to archive, while level 3 its quite more complex having iBIM
How Does BIM contributes to LEAN?

Lifestyle Management, common dictionaries, data and processes underpinned by integrated and interoperable data through web based services.

Figure 13 and 14 illustrates the differences between level 0, 1, 2 and 3. The levels are also split into A and B, e.g. 2A and 2B which denotes the directionality of information sharing, i.e. one-way or multi-way. (“Why WE Care about BIM...” 2014, 1)

95% using the Level 0 use it to produce 2D drawings with a lack of coordination that increasing the costs by 25% through waste and rework. Level 1, 2, 2D and 3D has a much higher potential to remove errors and reduce waste by 50%. It’s also based on spatial coordination on BS1192:2007 the integrated interoperable BIM (M) are being used under level 3, it’s then possible to reduce risk throughout the process and to increase the profit by +2% through a collaborative process. (“Why WE Care about BIM...” 2014, 1)

BIM is continuously under development, quiet naturally everyone will not adopt the different systems and technologies at the same rate. The BIM adopters have to go through a managed process of change in their internal organizations as well the external processes and reconsider the way they interface with the supply base, clients and consultants. The majority of the BIM users in UK are still working in the level 1
How Does BIM contributes to LEAN?

process, when the more experienced users are sees significant benefits by moving over to level 2. (Bew 2010, 2) It shows that it’s important to improve the competence and try to reach level 2 “It is clear that organizations adopting BIM now will be those most likely to capitalize on this advantage as the market improves.” (ibid.:2)

Figure 15 : (“Why WE Care about BIM...” 2014, 1)

0D-BIM. can be categorized by use of Quantity take off, door and windows scheme (“BIM-Manual 1.1 - StatsBygg-BIMmanual1-1mVedl.pdf” 2015)

2D-BIM: These days’ programs and software’s are so well developed that a 3D drawing can automatically reflect the 2D drawing and opposite while it develops. This doesn’t mean that 2D drawings will be gone, 2D drawings are still the main drawing that’s used in a project developing and under the construction work.

3D-BIM can be used to coordinate plans and visuals. It can easily be a generated a 2D view that automatically evolves during the life of the project. This helps the participants to be updated at any time of the project resulting in fewer misunderstandings.

SCHEDULING: 4D-BIM “(four-dimensional building information modelling) is used for construction site planning related activities. This dimension makes it possible to

Thomas Felipe Johansen | KEA - COPENHAGEN SCHOOL OF DESIGN AND TECHNOLOGY
extract and visualize the progress of their activities throughout the lifetime of the project. The utilization of 4D-BIM technology can result in improved control over conflict detection, or over the complexity of changes occurring during the course of a construction project. 4D BIM provides methods for managing and visualizing site status information, change impacts as well as supporting communication in various situations such as informing site staff or warning about risks.” (“BIM 4D - Impararia BIM & PLM Reconciliator” 2014)

**ESTIMATING:** “5D-BIM (fifth-dimensional building information modelling) is used for budget tracking and cost analysis related activities. The fifth dimension of BIM associated with 3D and 4D (Time) allows participants to visualize the progress of their activities and related costs over time. The utilization of 5D-BIM technology can result in a greater accuracy and predictability of project’s estimates, scope changes and materials, equipment or manpower changes. 5D BIM provides methods for extracting and analyzing costs, evaluating scenarios and changes impacts.” (“BIM 5D - Impararia BIM & PLM Reconciliator” 2014)

**SUSTAINABILITY:** 6D-BIM allows the users to do energy analysis and heat frame calculations early in the design phase. It’s easy to visualize the problem areas by doing this, as shown in the figure 17. The model can illustrates cold “blue” and hot “red” areas in the structure that helps the contractor to improve the buildings characteristics; it could also be useful for the contractor or the construction company to do their documentation work for energy certification.

**FACILITY MANAGEMENT:** 7D-BIM is a model that includes information about the facility services of the building. This helps the facility manager to operate and maintain...
How Does BIM contributes to LEAN?

the building. This makes it easier to predict the life cycle costs and replacement parts needed throughout the buildings life cycle. The construction and building parts can also be traced back to the entrepreneur that installed it. In case the building is going to be extended or change user group, all the information needed is in the model (“BIM 7D - Impararia BIM & PLM Reconciliator” 2014).

**RISKS AND HAZARDS**: with 8D-BIM you can calculate the risks and hazards, throughout simulating an evacuation, and the smoke path during a fire. This helps to improve a safety plan early in the design phase (Kamardeen 2010).

**Changes manage data**: Allows the user to do modifications that will automatically replicate each view for every participant in the project. That happens because the model is stored on a central place where every member of the project has access. The model doesn’t only save the amount of work and creation of documentation faster. It also ensures the quality of the building parts and the coordinating in all the views.

**Building simulation**: It’s likely to think the model is just 3D, however it’s not. The model can be merged together with other models containing all different kind of information, such as electrical, plumping and mechanical information. The construction can then be simulated before the actual construction take place.

**Data management**: The non-visual information in the model can be generated by using BIM. It could be formation costs calculations to predict the outcome of the project, scheduling, managing man-power needed to erect the work.

All the information put in the model could also be useful after the construction work is finished. To implement the life cycle costs will help facility services to reduce the operation cost, which normally is much higher than the building cost. The model will be able to follow the building through its life cycle and reduce the operation management cost (Jernigan 2008).
3.6.1 Benefits by the use of BIM

BIM offers the user huge benefits compared with non-BIM development. A company doesn’t just implement BIM because someone heard of it. It got to be set in context with wishes and goals companies have. Every company wants to have a strong possession in the construction market. As well be able to have the capital to invest in new projects at a low risk. Using BIM can help companies to do quicker and better decisions in an early stage of the project development. “The client will then see the advantages that do not come from the traditional design process” (Jernigan 2008, 216). It will also be easier to maintain the sustainable requirements set by the government. Everything cost money even the implementation for a better. So what actually supports a BIM implementation?

In a report developed of McGraw Hill Construction, mentions benefit contributing the most value and the perceived value of BIM by phase. The key finding is that the design development and technical design are those two phases that contribute most value during a project. That helps to improve the collective understanding of the design intent and improve the overall project quality. The European and North American BIM users agree that the ability to make software and organization work together it’s an important factor in determine the BIM overall project value. The statistics data shown figure 18 and 19 could be the most important reasons to why a building or construction company should implement BIM. The report indicates that the collectively understandings, better work flows, faster communication, shared
knowledge, error reduction, and improved productivity rate on projects are increasing with use of BIM. Other improvement by implementing BIM is the knowledgeable team-advantage, and the ability to seamlessly share information from models with others in the team. This results in a significantly benefit for the overall project. (Bernstein 2010, 32)

In addition to this I will present another finding done by Hellmuth, Obata + Kassabaum (HOK) a global design, architecture, engineering and urban planning firm. Chairman and Chief Executive Officer Patrick MacLeamy, Fellow of the American Institute of Architects (FAIA), describes his vision for a buildingSMART design. It’s a strategy that enables architects to bring more value to projects by spending more time on design. By watching MacLeamy’s video he explains:

“When building owners hire architects they expect the work that’s done after design, is to document the design and see the building through to completion, is a sort of an atomically process.”

He further explains that
today’s architects spend about 75% of their time doing none design tasks and practicing which he calls defensive architecture. As a result of that the design suffers from lack of attention and not enough time is put in to theory vetting the design to be sure it absolutely suits the client’s purposes (MacLeamy 2010)

By comparing collective understandings of design intent, and the value perceived in the design development phase, shows that both of them are backed up with the illustration of the MacLeamy Curve. (See figure 19) The value of the design development and design intent has a higher effort rate earlier in the project, compared with the traditional methods of development, with a very small grade at the beginning. That makes it difficult to change the design after the documentation is done. The BuildingSMART is made to shifting effort forward in time. More effort on project development, tasks design alternatives and less effort on documentation. All this will be made possible by BIM. Patrick MacLeamy concludes “with better resolved design, the coordination will be more precise and free of errors. Leading to a smoother construction process and elimination of the litigation phase. The second conclusion he state is that the clients are happier and the buildings is much better (The Future of the Building Industry (3/5): The Effort Curve (MacLeamy 2010)

3.6.2 Improved Risk reduction:

BIM can reduce the risks by using virtual design early in the design, the projects can be safer developed and more able to withstand public scrutiny, politicians and climate related concerns. By using clash detection you are able to detect errors before the construction work has started, this reduce extra work and time consuming problem solving at the building site. The good quality to a low cost. The construction can be simulated before the construction stars at the building site. That will result in fewer misunderstandings, faster bidding process and improved efficiency of bidding. (Jernigan 2008, 217)
3.6.3 Planning, communication and collaboration.

Planning, communication and collaboration are important through a project. The traditional 2D drawings require a lot of communication which can be costly and time consuming. With IFC/BIM the communication delay, unnecessary work and misunderstandings can be reduced to a minor.

The illustration on figure 20 shows that every team member in the project has ownership to the model. During my internship I experienced the impotence of having everyone involved in an early stage of the project. That enables the right information of how the communication should be from the beginning of, instead of changing the communication method in a later phase of the project causing extra work. It also engages by saving the team members for communication effort and extra work.

To utilize the potential of BIM can have a strong impact on how the building and construction industry, plan, develop, manage, increase the sustainability, decrease the overall project cost and reduce the risks by using BIM. The statistics prove that BIM is well implemented in the building and construction industry, and that it’s a potential to gain more value from BIM in future.
How Does BIM contributes to LEAN?

4 History of Lean production

“Lean manufacturing” or “Lean enterprise” is a modern term for a practice originating several hundred years ago. Many associate what we call “lean thinking” with the Toyota manufacturing today.

Eli Whitney invented the first modern mechanical cotton gin. It’s a machine that separated the cotton fibers from their seeds. It allowed Whitney a greater productivity than a manual cotton separator. In 1799 Whitney signed a contract for the U.S Army that requested 10,000 muskets for only $13.40 each. He perfected the way of developing interchangeable part. This was a manufacturing breakthrough, compared to what King Henry III experienced in Venice 225 years earlier.

In 1896 Sakichi Toyoda invented Japan’s first self-powered loom named jidoka “Toyota Power Loom.” Subsequently, he incorporated numerous revolutionary inventions into his looms, as the weft-breakage automatically stopped the loom when a thread breakage was detected. He could then produce a huge amount of looms without defects and eliminate the amount of muda product created. The Japanese word for waste is muda. Throughout the report I will use the term muda in expressions of lean. Later on Sakichi invented the automatic loom called the “Type-G Toyoda Automatic Loom”. The loom was able to change the shuttle without stopping the operations. The jidoka concept or mechanical automation will later on become the ground pillar for what’s known as the Toyota Production System (TPS). It could also be defined as “automation with a human touch”.(“Toyota Global Site | Production System” 2015, 1)

Muda is described in many places as the most important word to know in connection with lean, it focuses on any human activities that absorbs resources and creates no value. It can also be set in context with correcting a certain product made in the production and products made that no one is willing to buy. An unnecessary product will then pile up the storage room, causing unwanted transportation costs and movement of employees. The people working downstream will have to wait because
How Does BIM contributes to LEAN?

the upstream activities do *muda* work. Products delivered late, products with production errors, and products which don’t live up to the customer’s requirement or needs.

Some years later Henry Ford was building the Ford Motor Company. He moved Ford motor to the Highland Park often referred to as the birth place of lean manufacturing. In 1911 Sakichi Toyoda traveled to the U.S in order to study Fords revolutionary way of manufacturing the model T. Toyoda then started to conceptualize what he learned in U.S. After many years developing the Just In time principle (JIT), the Just-in-Time concept was born in 1938. As Toyota writes on their web page:

"*Just-in-Time*” means making “only what is needed, when it is needed, and in the amount needed.” For example, to efficiently produce a large number of automobiles, which can consist of around 30,000 parts, it is necessary to create a detailed production plan that includes parts procurement. Supplying "what is needed, when it is needed, and in the amount needed" according to this production plan can eliminate waste, inconsistencies, and unreasonable requirements, resulting in improved productivity (“Toyota Global Site | Just-in-Time” 2015, 1)

<table>
<thead>
<tr>
<th>Just in time</th>
<th>Jidoka</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only make what we need, when we need it</td>
<td>Processes that detects errors and stops on their own</td>
</tr>
<tr>
<td>Downstream processes take what’s needed from upstream processes</td>
<td>Built in human intelligence</td>
</tr>
<tr>
<td>Thoroughly remove <em>Muda</em>/Respect people</td>
<td></td>
</tr>
</tbody>
</table>
How Does BIM contributes to LEAN?

Eiji Toyoda (1913 -2013) ensured the implementation of *jidoka* and the (JIT) was fulfilled. He also increased the workers’ productivity by the implementation of *jidoka* and (JIT) (“Toyota Global Site | The Origin of the Toyota Production System” 2004, 1).
How Does BIM contributes to LEAN?

5  Five steps of a LEAN implementation

Lean as we know it today is based upon four principles I will explain closer in this chapter. In the book Lean thinking: banish waste and create wealth in your corporation (Womack 2003a) subscribes an approach to implement lean with a five step principle as shown in the figure 21. The figure shows is an endless effort to reach the final costumer in a right way.

![Figure 21: The Figure shows a five step approach to lean thinking (self-made)](image)

5.1 Step 1, specify the value

Womack highlights that “The critical starting point of lean thinking is value. Value can only be defined by the ultimate costumer. And it’s only meaningful when expresses in terms of a specific product (a good or a service, and often both at once) which meets the customer's needs at a specific price at a specific time. (Womack 2003a, 16)

Throughout the text it’s clarifies the purpose, to re think of how we interpret our company to look how it can reduce the internal costs, by rather focusing on the costumers needs. The examples shown in the book also express that this should be done throughout adjusting the products as well the different services a client require.
How Does BIM contributes to LEAN?

To form the production basis the construction company has to identify the product value seen from the customer’s point of view. That could be several different things; if a company only offers one type of apartments they assume the costumer feels secure with. The company can easily get stuck with doing the same thing over and over again. The difficult part is get out of this comfort zone with old philosophies and production methods. To reduce *muda* the company has to adopt the lean thinking. They have to change their old processing behavior and start focusing on the customers need. The customers don’t really care what kind of machinery or tools the construction company uses to build the apartment, but how the final product is. Focusing on the final product and rethink how they manufacture the product gives them the ability to remove internal *muda*, reduce the costs and overburden work that’s not important for the final costumer (Womack 2003a, 16). To figure out the costumers needs, the production company can use several different methods to make a survey, by utilizing internal and external statistic data, inquire schemes, do interviews, follow up the costumers inquires and establish a focus group that investigates future customers need and interests.

5.2 Step 2, Identify the Value stream

(Womack 2003a, 19) explains that “The value stream is the set of all the specific actions required to bring a specific product (whether a good, a service, or, increasingly, a combination of the two) through the three critical management tasks of any business: problem-solving task running from concept through detailed design and engineering to production launch, the information management task running from order-taking through detailed scheduling to delivery, and the physical transformation task proceeding from raw materials to a finished product in the hands of the customer. Identifying the entire value stream for each product (or in some cases for each product family) is the next step in lean thinking, a step which firms have rarely attempted but which almost always exposes enormous, indeed staggering, amounts of muda.” After a
How Does BIM contribute to LEAN?

closer look I could recognize that there are three types of actions along the value stream:
1. Activities that directly adds value for the final customers
2. Activities that doesn’t directly add value for the customers, but have to be there for the manufacture ability to create the product
3. An activity that doesn’t add value for the customers at all, these activities can be removed immediately after they are mapped

There are several reasons to why companies have difficulties to define the right value for their customers. In many cases constructions companies “keep the cards close to their chest”, and do not inform what they do to other contractors or business partners in the same project, and opposite. The companies have to look at the whole project as an overall process. And give transparency through all the different phases of the project. This could be done by involving everyone in the project and set a plan for how the cooperation should be, as for example IPD (that I will explain more detailed later in the report). And then eliminate the non-valuable tasks and processes.

5.3 Flow

“The lean alternative is to redefine the work of functions, departments and firms so they can make a positive contribution to value creation and to speak to the real needs of employees at every point along the stream so it is actually in their interest to make value flow”. (Womack 2003a, 24)

After the customer’s value is defined, the production values are mapped and the muda is defined, it’s time to move further in the lean thinking. All the remaining values have to be converted to flow where the value creating activities are done quickly and in a coordinated order. With the old production principles the different tasks is grouped and categories, in additional to this the activities is organized in separate departments and the products was based on producing huge quantities at one time, what described
How Does BIM contributes to LEAN?

as “batches” (Womack 2003a, 16) the argument for this type of production was to reduce the coactive work and to change the work tasks more efficient. A production like this causes huge storage space for raw materials, as well as finished products causing the company to lose their flexibility towards the customers. Another disadvantage is the waiting time for the next step in the production. In the end this doesn’t make the costumers happier because the flow is based on the “push” principle.

An example of this is when I worked with shop fittings five years ago. In the beginning I worked with an experienced guy. He had used the same methods for twenty years without any form for improvements. When he mounted a huge numbers of shelves along the walls, consisting of an L-column standing on the floor, distance stay, shelf brackets, a bottom shelf, back plate, side and front covers. All of these different modules had to be mounted in a specific order to complete the task. However, He mounted one certain part first, before he moved over to the next part (in the right order). One thing he hadn’t thought about is the huge amount of distance he had to walk for each operation. Instead of merging the different operations and do them at the same time, he had to walk 30 X 7 times equals 210 meters to accomplish his operation in comparison with maybe 30 X 2 times. Instead of following old habits he could have saved time, costs and walking effort “muda”. As a final result of how he worked, the clients in some cases had to wait to place their products until he had mounted the last part, the most essential of them all; the bottom shelf.

The first persons to realize the potential flow was Henry Ford. He was able to reduce the amount of effort by 90% only during the fall 1913. To do this he changed the work habits so that the production always had continues flow between the different stations in the production. Later on the he lined up the machinery so the parts needed for the car started with raw materials and ended up as a finish product ready to be shipped.
How Does BIM contributes to LEAN?

The production method was effectively but had a disadvantage when the quantities were small. After World War 2, Taiichi Ohno and his team, “concluded that the real challenge was to create continuous flow in small-lot production when dozens or hundreds of copies of a product were needed, not millions” (Womack 2003a, 23) They manage to archive the flow even with a small production volume. They did that by rescaling the machinery to a smaller scale and to produce different variations in a smaller volume. In the book lean thinking J.P. Womack use term “right-sizing” to describe what Ohno and his team did; “by learning to quickly change over tools from one product to the next and by "right-sizing" (miniaturizing) machines so that processing steps of different types (say, molding, painting, and assembly) could be conducted immediately adjacent to each other with the object undergoing manufacture being kept in continuous flow.” (Womack 2003a, 23)

Flow is then a counterintuitive to the traditional methods instead of creating batches and different departments in the production. The flow principle creates continues flow through all the departments in the production, decreasing the waiting time between the different tasks. This will reduce the time it takes to switch from one production task to another. This is time that doesn’t add value to the final product. Flow in itself doesn’t add quite much flexibility so it’s than important to add takt that’s maybe the most difficult part of the lean system. It’s how fast you need to produce a product to meet the costumer’s interest. It allows the producer to balance the work content to achieve continuously flow and respond flexibly to changes in the market place. The outcome of these two principles is that the storage space doesn’t fill up, transportation costs are reduced, and the production are more flexible to a switch demand. If we look at BIM in the context with flow it could be to standardize drawing methods, creating an object library, using standard sheets, and templates. This results in the creation of flow in the projects, as well enables possibilities to re-use the objects library in another project. The outcome of this will then result in the elimination of
unnecessary work the final customer doesn’t see as valuable (Womack 2003b) explains that the *flow* principle can be utilized by every kind of companies and activities, but using *flow* when a product is not demanded will result in more *muda*.

### 5.4 Push

*Push* is the more traditional way of creating goods before the customer demands it and then hope it will sell. By using the *push* principle customers will always be able to get the goods in a short period of time. Imagine this scenario; “factory one” mass produces one certain type of insulation meant to be sold over a long time period. This means that “factory one” are *pushing* the product on to customers. Before that period is over, “factory two” develops a new and better insulation the customer prefers. The demand for the insulation “factory one” made will decrease, as a consequence, “factory one” will have to store the overproduced insulation that may never reach the customers, in worst case they have to condemn the overproduced insulation, causing *muda* and overburden work. The advantage with push principle is that the customers always have available goods to buy. The downside with this method is when the demand decrease the *push* method will produce *muda*.

### 5.5 Pull

The easiest way to explain Pull is that nothing is produced before a customer demand pull goods or services through the manufacturing process. It will then reduce the risk of overproduction that can cause waste. If “factory one” had used the pull principle, they would only need to produce the insulation after the customer demands it, they would only have to produce what’s necessary. They could then easily have stopped the production when “factory two” got the market advantage. The gain “factory one” can get with the *pull* principle is capability of controlling the production quantity dependent on the market demand and then produce only what’s necessary when needed. This will minimize over production, inventory, working capital and a risk reduction for “factory one” and contributing directly to lean. The disadvantage is that
How Does BIM contributes to LEAN?

the costumers have to order the product and then wait for it to be made and delivered.

The JIT supports pull directly by making sure the goods are produced only when needed, at the right in the right volume the customer demands.

5.6 The strive for Perfection

To succeed with the 5th step in the lean thinking, a transparent system is maybe the most important step to improve. “...in a lean system everyone—subcontractors, first-tier suppliers, system integrators (often called assemblers), distributors, customers, employees can see everything, and so it's easy to discover better ways to create value” (Womack 2003a, 26). When all the muda and the unnecessary work are eliminated the company is one step closer to perfect their product and production for what the customer looks for. So how is a construction company then able to improve their perfection? (Womack 2003a) explains that its two types of methods used for improvement, kaizen a Japanese word that means change for the better, a method consistent of continually improvements, while kaikaku is the more radical improvements often done in the beginning. The productivity can double in two to three years if the firm gradually utilizing kaikaku as well as halve the inventories, errors and lead times. The kaizen and the kaikaku combined can result in endless improvements. Meaning, when all the steps is completed you start over again to improve the perfection even more (figure 21) This contributes to BIM by
6 The interaction

In this chapter I will explain how the use of BIM creates values together lean in the building and construction industry. I will come up with examples of how BIM tools are used as well explaining about meeting methods and tools.

6.1 Directly interaction

The most natural place to start is to see how clash detection contributes directly to lean. There are three types of clashes;

1. Hard clashes are two or more objects unintentionally penetrate another.
2. Clearance clash where two or more object closer than it should be.
3. Time clashes happened when two potential object are occupying the same space. (Tommelein and Gholami 2015, 3) Clash detection is done by merging all IFC files exported from the different professionals in the project, and the building is reviewed for hard, clearance or time clashes. It can especially be useful to check the MEP up against each other, because it’s often complicated to check this visually or with 2D layers put on top of each other. Still we don’t have to forget the importance to check the architectural and the structural models as well. To check the models virtually can result in huge cost savings early, as well as late in the project. It makes it easier to solve problems before the costs accrue. Another aspect of clash detection is the ability to choose the errors that may become critical issues in later phase of the project. To achieve reduction of unnecessary extra work, all the uncertainty in the planning low as possible. This will result in better flow and contribute to the zero defects as a part of the lean principles. This gives results in the developing, technical and the construction phase. The focus areas should then reflect the amount of work effort necessary for improvement. In figure 24 I have set up my explanation of how Clash detection contributes directly to lean goals.
How Does BIM contributes to LEAN?

6.2 Indirectly interaction

BIM also contributes indirectly to lean goals. This was evident during my internship period where I was allowed to attend a conference. The conference was named “Den kloke tegning” held by Via Nova. One of the stakeholder presented Integrated Concurrent Engineering (ICE) meeting originally develop by NASA to reduce project development time, and improve the communication between the different professionals in the project group. Me and my colleague at JM thought the idea behind it was clever and easy to test. We later on presented the idea for the project team, and it was quickly decided to do a test the ICE principle in an already established pilot project for BIM.
### 6.2.1 ICE-Meeting

An ICE group mainly consists of engineers with multidisciplinary expertise. Among these; architects, a project leader and MEP consultants. Everyone needs to bring a computer to the meeting. The meeting should be led by the project leader, who also is also responsible for making a plan for the meeting without directing it too much. Meaning that the project leader have to set up headings that has to be discussed with the flexibility for others to come with inputs as well. The meeting should have a flat management organization enabling the participants to do what they should do till they have, or get any question. This can easily end up seaming a little chaotic, but, that’s one of the good outcomes. People are allowed to do and cooperate with the necessary partners to solve the different points. The meeting rooms can be formed after individually needs with facilities as; smart board, the opportunity work with the model, screens showing relevant information, internet connection, and the possibilities to have video conferences. It all depends on what’s necessary to reach an optimal result for the company. The IFC model is the base for the ICE-meeting. To a certain point it’s where you can see the progression, as well the model will reflect the errors and cases during the session. To succeed with the meetings everyone is depend on everybody in the project group to be able to get quick

![Diagram](image-url)
How Does BIM contributes to LEAN?

answers while a question is set. Instead of waiting a day or two for a mail or telephone response the contact are directly and accurate towards the other project members, reducing the time down to seconds instead of days. This is also where the clash report is presented. The BIM coordinator can then check the model for improvements or new clashes during the session. It’s typically in small spaces like shafts and technical room you want everything to fit before the construction start. It could also be that a collision is fixed but affects another professional field. This is then easy to fix because everyone in the project are available. On another side the disadvantage with ICE is the ability to attend, if one of the professionals doesn’t attend the decisions can be taken without the person able to affect the decision, or maybe come up with another or better solution.

So the objectives for an ICE-meeting is to develop, show and explain the product, work out plans and commitments for the team, solve construction errors, discuss solutions all that done in an fast and effective way of communication.

6.2.2 Own experience with ICE

In my case the ICE meeting was an addition to the ongoing BIM pilot project. But I quickly saw the advantages to solve problems quickly on place. During a couple of rounds we manage to solve over 100 collisions some important and some not. I also learned that the most effective way to hold the meeting was to let the professionals cooperate naturally between each other to a certain point.

The ICE-meetings have been very effective when it comes to solving cases that are related to the 3D-model, as well as those cases that we haven’t been able to finish discussing in the project meetings. One of the main points during the ICE-meetings has been to go through the status of different clashes and to solve them together between the different professions. The project I was involved in had a lot of collisions when I started the clash detection. Earlier in the process the collisions had been solved through e-mail and phone conversations between the different professionals. However this was a tedious process sometimes taking weeks. During an ICE-meeting
we were able succeed in solving 60-90 clashes in just a couple of hours. Having the ICE-meetings therefore made a great difference in the process of finding clashes. The main aim of the meetings is to give the participants the chance to communicate directly with one another. This enables us to solve different clashes in the 3D-model immediately, correct the mistakes and upload them to the server as we’re having the meeting. This in particular has been a successful method to do it for JM while it still continues developing thorough out their BIM pilot project.

The challenges with ICE-meetings are that you’re dependent on having everyone in the project available for the meetings. If one professional can’t attend the meeting it will be insufficient and the risk to waste others time. The fact that a meeting is quite expensive to hold the cost benefits can decrease drastically if the meeting is ineffective. And you can end up by having a huge cost holding ICE-meetings, and still haven’t managed to solve problems showing up in the production. So it’s important with a good agenda for the meeting as well making sure the facility services work as they are supposed to.

6.2.3 Integrated Project Delivery (IPD)

IPD is a relative new method of cooperation between the owners, contractors and designers in a project that are using BIM, where BIM is a component part of an IPD.

“IPD should be understood as a comprehensive process which addresses the entire sequence of programming, design, construction and building operations within the industry”(...)“Lean construction is a production control system that seeks to apply principles of the “Toyota Way” of manufacturing to the construction process. Just as BIM is a tool that is useful, but not in itself sufficient for implementing IPD, lean construction is a set of tools in support of IPD but is not the entire process.”(Parrot and Bomba 2010, 7)

This is done by setting up the collaboration and contracts between the involved members in an early stage of the project. The contracts make everyone equals in the project. The team shares the risks and rewards where a failure or success is depend on
the others project members’ performance. The IPD method is then relying on the principles of equality, trust, respect and openness. A successful project will result in a profitable share or a satisfying construction or building. Those kinds of agreements seek to motivate the team and align their self-interest with the project interests, and eliminate the adversarial attitude between contractors and designers. IPD secures a transparent project where all the professionals share the risks and hazards.

With the traditional method the owner engage designers that handed over to several of designs to the contractors that attempted to execute the design with varying degrees of design involvement. This causes a fragmented process that encourages the different professionals to avoid taking the necessary responsibility. With an IPD approach these fragmented processes are joined and causing a complex teaming agreement, involving everyone in the project (Parrot and Bomba 2010, 3). The integrated form of agreement requires the project team to make reliable promises as a basis for planning and executing the project. The condition for those promises is:

- “Satisfaction that is clear to both parties—performer and customer
- The performer/promissor is competent to perform the task and has access to needed resources (tools, equipment, instructions)
- The performer/promissor has estimated the time to perform the task and has internally allocated adequate resources and blocked the time on its internal schedule.
- The performer/promissor is sincere when making the promise that it can reasonably be fulfilled.
- The performer/promissor is prepared to accept the legal and reasonable consequences of not performing as promised and will promptly advise the team if confidence in meeting the promise is lost.” (Forbes 2011, 181)

In the page The Impact of IPD on Insuring Project Risks article found on owners perspective’s web page shows and that IPD forces a transparent attitude throughout a
project with an insurance agreed. This contributes directly to lean by doing it easier to create value, in the stipe for perfection.

“The drafters of the IPD project agreement are key members of the insurance team. Developing the insurance program requires particular attention to the objectives of the contract, limitations of liability, allocation of risk, indemnification, and financial responsibilities, as well as incentives and rewards. If an underwriter sees a transparent and collaborative contract among the IPD team, they will be able to justify cost effective coverage enhancements. A significant portion of insurance cost is budgeting for defense or claims expenses.” (Hurley and Sier 2011, chap. Contract Clarity/Transparency)

The IPD process contributes directly to BIM by utilizing the capabilities. This project team gets a greater understanding of how the model will be developed, accessed and used. They will also know more about the information that is shared and exchanged between the team members. This will then cause reduction in errors within the documents, as well a conflict reduction between trades before purchasing systems and products. If the project understanding is imprecise the model can be used incorrectly or for unintended purposes. (The American Institute of Architects 2007, 10, 17)

6.3 Directly and indirectly approach from BIM to lean

As mentioned in chapter 3.6, 5D and 6D BIM contributes to cost and energy frame analysis. They eliminate unnecessary redoing if something’s are calculated wrong, compared the old method that was mainly done by hand or with independent programs. It was easier then easier to do mistakes, without anyone seeing it. A 5D and 6D BIM model can also contain mistakes; software or a cloud based solutions like Autodesk Navisworks and Green building studio will seek them out and show the areas with errors. It also eliminates the risk of calculating one building part two times. To fulfill the calculations mentioned above, a change in the design process is maybe needed to improve the design practice by rapidly repetitions (Dave et al. 2013).
How Does BIM contributes to LEAN?

6.4 The communication

The collaboration between all the participants in a project is central to both BIM and lean. In many cases it can be difficult to utilize the model and get access to the addition documentation at one place. A cloud solution is therefore an option in many cases. There a dozen of them with almost the same optional features delivered. Docia BIM2Share is one of the many that offer to host BIM projects, on a cloud, and provides a server for the model including the necessary Revit license. *BIM2Share breaks down the barriers between the design team model and the project extranet. The interface provides an onscreen overview of the BIM-model, internal servers and your extranet* (“Byggeweb - Solutions - Project Management - Docia BIM - BIM2Share” 2015). The service also provides document flow by keeping track on dates, revisions, phases, authors and ownerships. Once a document is uploaded it’s accessible for everyone in the project.

However it’s meant for BIM by it providing the companies with many of the principles lean is about. The illustration below shows the direct and indirect contribution from BIM to lean and opposite.
How Does BIM contributes to LEAN?

1. BIM
   - Lean goals: reduced waste and increased value

2. BIM
   - Lean processes
   - Lean goals: reduced waste and increased value

3. BIM
   - Auxiliary information systems
   - Lean processes
   - Lean goals: reduced waste and increased value

4. Lean processes
   - BIM adoption and use

Figure 25: ("Facilities-Manager_NovDec-2014-Article-PDF.pdf" 2015, 12)

Note:
1. BIM contributes directly to Lean goals.
2. BIM enables Lean processes, which contributes indirectly to Lean goals.
3. Auxiliary information systems, enabled by BIM, contribute directly and indirectly to Lean goals.
4. Lean processes facilitate the adoption and use of BIM.
7 Conclusion

After the report is written it’s easy to argue why the building and construction industry should implement BIM, and utilize the benefits it provides. A BIM implementation is strongly supported by the findings done by McGraw Hill Construction Company, they shows that the majority of BIM users in Europe and North America see positive ROI. Proving that BIM have positive effects on the different phases in a project, saving time, reducing errors, improving the collective understanding of design intent, as well as the overall project quality. I have also shown how BIM reduce conflict and changes during construction, improved the cost control/predictability and reduce a number of requests between the team members.

BIM proves to be a powerful tool that helps companies in the decision making, as well as anticipate different outcomes for the project.

A BIM model should be used through the buildings life cycle. This gives the model a “life” after the development and construction phase is finished. Helping the facility management to do their job efficiently as well reducing the facility management cost.

One of my findings was that the huge variety of BIM software’s could be a week point. The idea to make an open IFC format that everyone can utilize is good; it makes the different professionals independent in the choice of which program to use. This makes it easier to connect BIM with lean, and enables the opportunity to seamlessly cooperate and share information. The negative side of IFC is that the format isn’t fully capable of preserving the information needed to fulfill the lean thinking, and it requires an extra effort to make it work properly. This is against the lean principles of reducing unnecessary work, and movements involved during the project development phases. It can also inhibit the capability to produce the right product at the right time, by delaying the process. Lean is reliable on valid data to let the information and knowledge flow seamlessly between the project participants.
How Does BIM contributes to LEAN?

The buildingSMART design is a good motivator for why the IFC format should be used in the future, by increasing the effort rate in an earlier stage of a project. In a “perfect world” this sounds easy. However, if the different professionals in a project used the same software and validation tools, as well having the same aim for the project outcome this should have been quite simple. On the other hand that’s not the truth. I have also described how the software variation is huge showing that the different professionals use different software solutions.

BIM is an easy adjustable tool, which has a wide specter of possibilities, by analyzing point one in “the five steps of a lean implementation” by focusing on the costumers needs should be done throughout adjusting the products as well the different services a client require. To utilize BIM the right way and use the properties BIM software’s provides. This helps the construction industry to adjust the product quickly internally in the software BIM and adjust the services a client requires.

As I also manage to analyze that many of the opportunities BIM can provide are directly or indirectly connected with lean thinking.

5D and 6D BIM helps to eliminate unnecessary work, I was critical to t this is compared with the old method of projecting.

When companies use BIM and IFC formats it contributes to identify the values stream. As mentioned under the value stream chapter, many companies “keep the card close to their chest” and doesn’t allow transparency in the projects. With the use of IFC and IPD a transparent projects is essential to cooperate as well as succeed.

I was also able to do a finding in the flow chapter. I found out that to create object library, using standard sheets, and templates will result in the creation of flow in the projects, as well enables possibilities to re-use the objects library in another project, saving time and money.

My Results of finding, is that BIM has revolutionized the building and construction industry, together with the lean principles. By utilizing both of them and have a clear
How Does BIM contributes to LEAN?

definition of goal while the BIM is implemented. Will give huge advantages when it comes to reducing *muda* and increase the profits.
How Does BIM contributes to LEAN?

Acknowledgments

I will thank Mats Kjellberg, Kim Andre Moe, and Kenneth Nicolaisen for giving me the opportunity to work with BIM and lean during my internship.

I will also thank my special advisor Dr. James Harty for the feedback and inspiration during my writing of the report.
How Does BIM contribute to LEAN?

Bibliography


How Does BIM contributes to LEAN?