

# **BIM IN CONSTRUCTION MANAGEMENT**

Based on Trimble Solutions products



Bachelor's thesis

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ABSTRACT

The aim of this Bachelor's thesis is to introduce what Building Information Modelling (BIM) in the field of construction management is and how the BIM process has become an increasingly vital technology in the way buildings are designed, analyzed, constructed, and managed.

The main body of the thesis demonstrates how BIM creates a common language for all the parties involved in the construction project. It represents tools, workflows, and practices of BIM, as well as real-world examples based on Trimble Solutions products. Numerous products, software, and services used as an example in this research have been taken from Trimble Solutions owing to my personal admiration and experience in this company. Additionally, this thesis proves that in BIM the model is considerably more than just a virtual portrayal of a building.

In conclusion, although the goal of the thesis is to present proven methods of creating record of BIM, it is wise to mention that today there are probably other innovative technologies entering the marketplace. Moreover, different methods of project delivery shall be used for each project.

**Keywords** BIM, Construction Management, Trimble Solutions, implementation, tools

**Pages** 44 pages

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## 1 INTRODUCTION

BIM is an abbreviation for Building Information Modelling. It is an extremely collaborative technology that allows different investors, associates, and AEC (Architecture, Engineering, Construction) experts to cooperate on planning, design and construction of a project using one 3D model. In addition, owners have access to the data which can be used in operation and maintenance of the building. This information allows owners and stakeholders to arrive at solutions even after the structure is built.

In the old days, blueprints and drawings were used to indicate information about a specific building plan. That 2D method made it significantly hard to picture measurements and guidelines. After that CAD (Computer Aided Design) came, which guided drafter to see the benefit of plans in a digital environment. Following that, CAD developed into 3D, which carried more realistic visuals to drawings. Now, BIM is the reality, but it is something more than just a 3D model.

### 1.1 Basis for research

Today, projects in the field of the construction management are becoming progressively complex and ambitious, while at the same time tools, methods and workflows are being improved and developed. Moreover, clients of construction projects are setting various sets of demands, while most related laws and guidelines cannot experience such a fast change. Consequently, due to rapid development and progressive complexity in construction industry, systematic and professional management of construction projects is becoming increasingly fundamental. Worth mentioning, nowadays the use of 2D drawings are directly replaced by BIM technologies.

### 1.2 Objectives

The primary purpose of this study is to represent the importance of BIM in the construction management field as well as describe the implementation process in detail. This research identifies a process of testing, managing, and extracting important data during design and construction.

Finally, best-practice scenarios, lessons learned, and timelines are outlined.

## 2 BIM IN CONSTRUCTION MANAGEMENT

### 2.1 The potential of BIM technology

BIM is a comprehensive technology and process that has changed the way projects are carried out. Nowadays, an overwhelming amount of information is available concerning BIM: proven theories, an extensive variety of tools, and methods how BIM can solve most of the issues facing a construction manager. Even though most of this information is practical, it often overwhelms possible customers because the information appears to meld together. Misleading information can frustrate users and clients to the extent of not willing to use BIM again in the future. This will not only affect the future development of this technology, but its users' collaboration in BIM community. Figure 1 represents an example of a building designed and constructed using BIM technology.

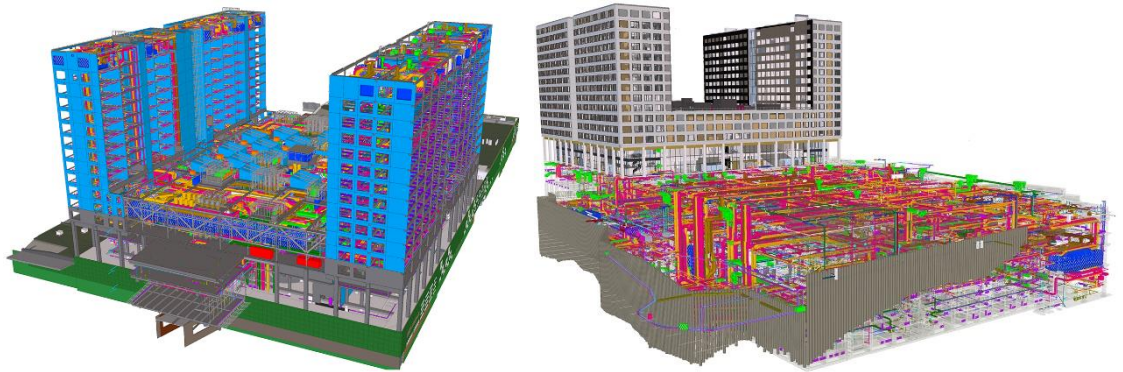


Figure 1 Tripla Pasila, winner and publics favourite of Tekla BIM Awards (Trimble Tekla Downloads, 2019)

BIM has started creating results for the AEC field all over the world. The goal for BIM and its clients is the most practical implementation that better enables this technology.

#### 2.1.1 BIM and the Individual

BIM is a “digital representation of the building process to facilitate exchange and interoperability of information in digital format” (Eastman, 1999). In fact, for a contractor BIM is a virtual representation of a structure containing intelligent objects, which is shared with other team members to reach the highest level of collaboration. Nowadays, this collaboration occurs not only among AEC parties, but also with sustainability experts, owners, and facility administrators.

It is important to understand, that BIM is not just a software, it is a process and software. Many individuals believe that once they have

invested in license of a specific piece of software and put someone in front of it – they are “doing BIM”. But they do not understand that building information modelling is mostly about being innovative and implementing something new. As soon as the company is putting this technology into use, other processes are transforming. Previously CAD technology made sense for certain things, but now it does not appear to be as efficient. As BIM is developing, so are methods and workflows of people using BIM. Computer technology development leads to improvement of site methods as well as BIM.

(Hardin, 2009, pp 3-4)

### 2.1.2 BIM and the Team

BIM has a significant impact on a team. Architects use this technology to work on their blueprints more systematically (no sketching anymore), to create documents needed from them. Designers use BIM to quickly generate a virtual perspective view and VR (virtual reality) to better introduce the project to the client or authorities. Engineers use BIM process to model mechanical, electrical and HVAC designs to assess building’s performance. Sustainability experts, engineers and architects are able to estimate day lighting, sun orientation and the life cycle of materials used as well as pollution caused during construction works.

(Hardin, 2009, p 4)

## 2.2 Delivery methods

All construction projects demand a sufficient amount of services such as: finance, plan, design, maintenance, operation. Construction project delivery methods involve ways to organize these services. As each delivery method generally involves the same group of professionals in the team, implementation of a project will differ. Steps taken will define how successful a project will be, that’s why the project delivery method is playing a crucial role in building information management.

Following sections will present six different types of project delivery: Design-Bid-Build (DBB), Design-Build (DB), Construction Management-at-risk (CM-at-risk), Integrated Project Delivery (IPD), Integrated Labor Delivery (ILD) and Multi-Prime (MP). These six delivery methods are described in regards of how information is shared among teams, and how project workflow differs, specifically in: preconstruction, collaboration methods, types of documents, clarification of information, and project closeout.

### 2.2.1 Design-Bid-Build (DBB)

Design-Bid-Build (DBB) is one of the most traditional project delivery methods. The basic idea behind this method is a linear operation. The owner is contacting the architect to produce the model and appointing engineers to develop mechanical, electrical, HVAC designs, and all technical specifications. After these have been done, the construction documentation part begins. Design team is responsible for producing needed documentation and handling it to several contractors to bid on. The role of the main contractor is to direct work with sub-contractors, determining their actions and bid delivery for the project. According to sub-contractor's estimates, main contractor sets the complete bid and delivers it to the owner. After this, all the future bids are declared either privately or publicly, which depends on the contract. Then, the owner awards the main contractor based on the offered price to complete the project. Figure 2 represents DBB Information flow.

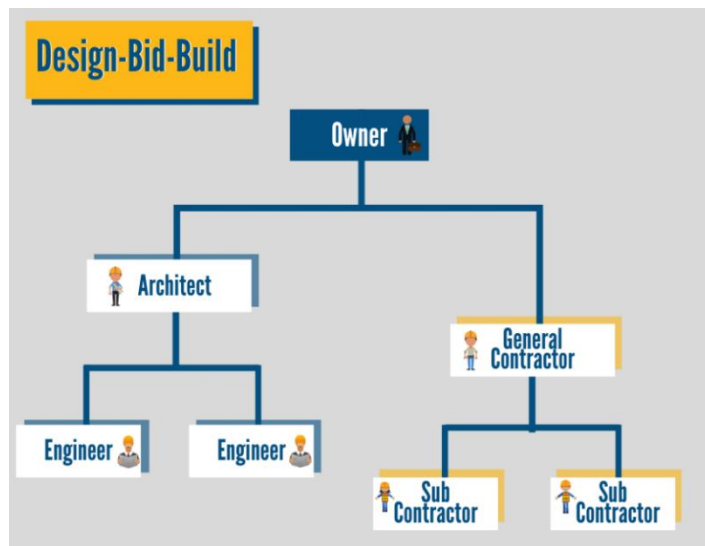


Figure 2 DBB Information flow  
(E-sub Construction Software, 2020)

- **Preconstruction**  
In DBB delivery method typically no information is shared between the architect and general contractor during schematic design development. Even though, contractor might participate during DBB as the owner's representative, his duties are only estimate checking, not bidding of the project. DBB allows engineers and architects to work more efficiently and produce integrated documents. The owner also gets the power to control the project, but only if he has sufficient amount of knowledge and experience to do so.

Talking about BIM, DBB is the most ineffective delivery method, due to ability limits it brings. In practice, BIM cannot be a practical tool in DBB, only with the exception of extracting quantities from the model for fast estimation purposes.

- Collaboration methods

Depending on the type of the contract, information is not shared with the rest of the construction team, until the construction documentation phase is fully completed. After drawings are distributed from the architect, contractor takes PDF and CAD files in order to conduct a take-off. Take-off is completed using document tracing software, manual take-off or digitizer.

Digitizer enables an estimator trace documents and quantify structures and facilities such as walls, floors, ceilings, doors, windows, and equipment, additionally flipping through drawings to estimate whether they portray the main idea implemented by architect and engineers.

The issue with the digitizer method of take-off is that the degree of interpretation left to the expert doing it is great, usually outstanding amount of misinterpreted information is put into the estimations. The other problem that overwhelms the process is time. Particularly in bigger, more complex projects, where it is important that information is right, this process takes a lot of time and exertion.

This method of delivery always requires significant amount of clarifications. Often, the big issues tend to be solved, but small ones that are not understood – are being pushed for later.

- Types of Documents

Documentation in DBB method are printed specifications and digital PDF, CAD files, and estimating programs such as Tekla Structures using Industry Foundation Classes (IFC) and Bluebeam may sufficiently speed up the tracing process. The design team does not always take the responsibility of sharing digital files in order to limit the possibility of any involuntary editing and misinterpreted information.

Although, the estimating software tends to save time, system relies on the expert, who will accurately quantify needed building's structures and set drawings, determine prices and approximations to labor, materials, equipment in regards of the project.

In DBB architects and engineers have significantly more time to get involved in the project, comparing with contractor, who only has weeks to understand the site, systems, nuances, and reasoning behind the design to assign cost to the project.

- Project Closeout

In the end of DBB project, PDF and CAD files, drawings, specifications, and Request for Information (RFIs) are submitted into operations and maintenance (O&M) manual. This manual is handled to the building's owner and usually means the end of the construction project, as well as the end of contractor's responsibilities.

This delivery method can force a wedge between an architect and a contractor if construction documents are not accurate enough to maintain efficient work of a contractor. DBB is an accurate example of an old way of thinking, where use of rigid system of information management focuses on litigation avoidance. (Hardin, 2009, pp 6-11)

### 2.2.2 Design-Build (DB)

Design-Build (DB) project delivery method is a system where one entity performs both the design and construction phases under one single contract. In fact, the design-builder guarantees the construction company, that all the documents and blueprints produced are complete and absolutely correct (design-builder takes the risk). The competition process under DB method can involve one or more negotiating contracts or competitive selection according to price and duration offered.

Many people consider DB as a BIM solution. This type of delivery is much more united than Design-Bid-Build, moreover, it offers a strong basis for collaborative operations. When BIM is implemented in Design-Build projects, it truly represents its ability to cut costs, shorten schedules and improve quality. Additionally, it extends team's power to take into consideration such matters as sustainability during design and construction phases.

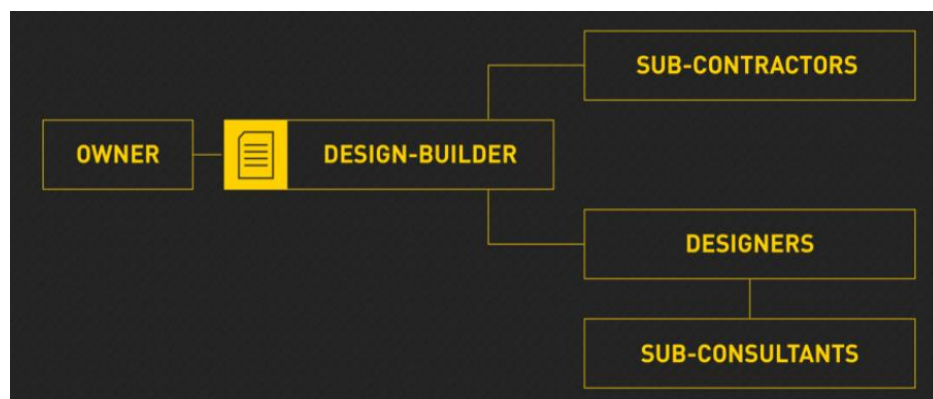


Figure 3 DB Information flow.  
(Korte, 2020)

- **Preconstruction**  
In DB delivery method contractor and architect are working under the same contract and called as the design-builder. The aim of such type of contract is to maintain accountability and have one source of project delivery. In this type of delivery (Figure 3), design-builder is the one who is responsible for organizing the process by merging the design, permit, and construction tasks. If the lead is on architect, the project is “design-led design-build”, if on contractor - the project is “contractor-led design-build”. In both cases, main party is responsible for completing the project in budget and on time.

DB shows to be one of the most efficient methods of delivering projects. However, there is a slight risk of inaccuracies due to simultaneous construction work and completion of design documentation. Quality control becomes secondary priority, because the main goal is to complete the project within a contractor-led agreement. The contractor's responsibility of managing trades and schedules becomes the main factor in the project, not aesthetics.

Consequently, in an architect-led design-build project, there is a risk of the focus being on the aesthetic and design, instead of construction related issues and finishing the project in time. The biggest problem with DB method is that one senior project member has the power over another one. For successful completion of a project using DB method, sufficient balance is playing a fundamental role.

- Collaboration methods

Information flow in DB delivery method starts with the design maintained by the architect and presented to the owner. Then, the design produced is handled to contractor, who makes first estimations and schedule of the project. While the contractor is estimating the first design proposal, the design becomes outdated and inaccurate, that is why architect's work of constant revising according to owner's changes and contractor's input takes place. This process continues until architect stays ahead of the contractor and contractor catches up to architect's design drawings.

During construction documentation phase in DB process 50 percent of documents are sent to authorities to secure building permit. When drawings are 100 percent finalized construction planning and development begins. Engineers, who produce mechanical, electrical, plumbing, and HVAC drawings are contracted directly with architect or contractor. When engineers start working on layouts, calculations and equipment based on architect's design, contractor assigns costs to engineer's input as well as starts the actual construction at site. Although, this type of delivery is a good opportunity for using BIM, it is also a challenge to continually bring up to date project with newer data from both architect and contractor.

- Types of Documents

In DB project documents include CAD and PDF files as well as printed lists of specifications and drawings. According to DB agreement, all digital documents are shared between both architectural and contractor teams, because both parties are involved in the project. Time to time, due to the nature of firm's legacy, architect or an engineer might ask project team to sign a non-disclosure agreement.

It is done to prevent accidental or non-accidental leak of company's database of information to public, competitors. Many companies deal

with this on a daily basis, and in order to avoid any problems, they print the drawing information to a hard copy and then delete the initial file from the shared folder.

Non-disclosure agreement has to be applied as well, if BIM is implemented in DB method and main contractor is working remotely on the design, when the actual department is in the office. BIM type documentation has to be discussed in the first team meeting if agreed to implement the technology to design build process.

- **Project Closeout**

At the end of DB project, the O&M is submitted as well as hard copies of all the drawings and specifications for future building maintenance.

BIM in DB process provides special opportunity to facility managers by letting them define what is possible to deliver at project closeout and how detailed information will be in final documentation. BIM is a significant tool for DB process, it proves that the project meets success and needed level of efficiencies if both teams involved in productive and balanced collaboration. (Hardin, 2009, pp 11-16)

### 2.2.3 Construction Management at Risk (CM-at-Risk)

Construction Management at Risk (CM-at-Risk) entails an obligation by the construction manager to complete the project within a guaranteed maximum price (GMP). Construction manager consults the owner during development and design phases and acts as the main contractor during construction phase. When the construction project is bound to GMP, construction manager performs in owner's interests, as well as controls project costs in a way not to exceed GMP, which consequently will lead to fee reduction and profit loss. Figure 4 represents CM-at-Risk Information flow.

CM-at-Risk method in a BIM process has two key fundamentals: a more united process equals to a more profitable one and significant value in leveraging BIM with the team.

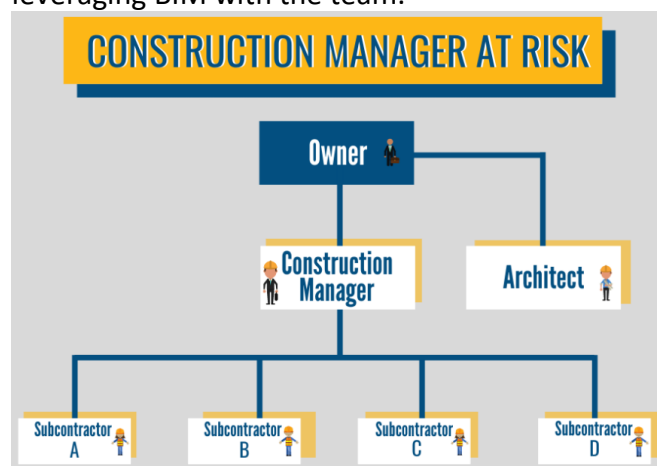


Figure 4 CM-at-Risk Information flow  
(E-sub Construction Software, 2020)

- Preconstruction

According to Information flow presented in Figure 4, it is wise to mention that CM-at-Risk project may provide collaborating service to both the construction manager and sub-contractors. Thanks to this type of project delivery, it allows all parties a possibility to get involved in the process and have an input into the design and documentation at an early stage. At the same time, CM-at-Risk system puts the risk on construction manager's shoulders of not being able to deliver the project within proposed time and GMP. That is why it is vital for this type of delivery to make construction manager sits at the same table with sub-contractors and design team.

During preconstruction phase Construction Manager's involvement is critical to the success of the project. Construction manager should continually inform design team regarding cost changes in documentation. CM-at-Risk delivery method makes the contractor closely involved with the cost-estimation process, because GMP delivery is demanded.

- Collaboration methods

Construction Manager of the project is responsible for delivering the deal within agreed budget. An architect who is contracted under the owner or the construction manager should satisfy the client in a digital and aesthetic way, as well as not exceed budget. In case the project is complex and unique in design, construction manager will deal with the cost and design at his best. This will lead to providing estimates to the owner, who can then make decisions in regard to design without affecting schedule too much. In fact, this is one of the main problems of CM-at-Risk making sure owner follows project's updates and all his requirements are met.

As it was stated, construction manager should be responsible for completing the project within agreed timeline and cost, even so, it shouldn't happen at the expense of practical design and balance. By balancing project and collaboration in information flow, CM-at-Risk may leverage team integration and BIM technologies. With the correct management of this delivery method, it can become an effective tool of bringing all the team members together and equally share responsibilities among them.

- Types of Documents

Traditional documentation for CM-at-Risk delivery are printed contracts, PDFs and CAD files. As the project constantly develops, as do costs, this may affect the way of transferring data. In most cases, file transferring protocol is established in a way that drawings are

simply sent via email to a distributor who tracks and archives those files for future use.

In this method, quick transfer of information is vital for BIM. Using a complex model sharing, multiple changes can be easily tracked, imported or replaced. BIM has a huge lead over CAD in CM-at-Risk.

The 3D construction of the model holds quantitative information that allows to be used early in establishment of estimates and design. To conclude, use of various CAD files can be quite overwhelming when it comes to updates, whereas use of BIM means use of a singular model which contains all the valid information.

- **Project Closeout**  
During project closeout, the owner receives all the documents as in other project delivery methods. Construction manager is the one who is responsible for handling and coordinating this information. In most cases, expectations of the project closeout are defined earlier and written in most of the contracts. (Hardin, 2009, pp 16-20)

#### 2.2.4 Integrated Project Delivery (IPD)

Integrated Project Delivery (IPD) is a newer type of project delivery method that has gained admiration and success as a unique solution. Even though, many companies have worked with integration during delivery of the project, this modern technology aims to bring construction to the latest level. This approach tends to integrate people, systems and business structures into a process which optimizes the efficiency during design and construction. Figure 5 represents IPD Information flow.

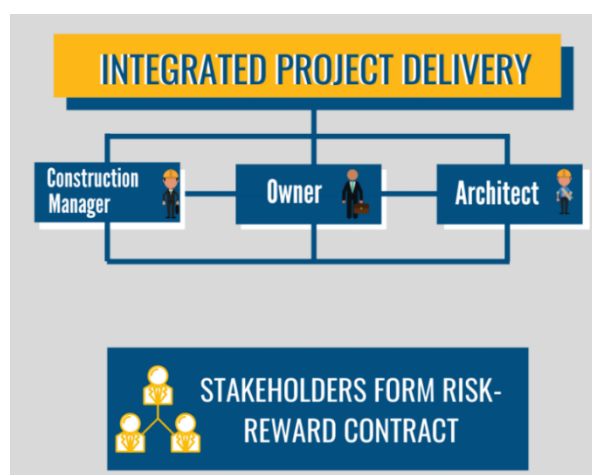


Figure 5 IPD Information flow  
(E-sub Construction Software, 2020)

- **Preconstruction**  
IPD delivery method is a complete integration of all project

participants that allows the team as a whole to focus on establishing newer technologies and defining successful outcomes. This delivery method sets the importance of collaborative processes, as well as potential of project balance through the use of BIM.

- Collaboration methods

During integration of BIM technology and use of new delivery method chances of reaching successful outcome and project balance are extremely high. In this type of delivery, a member of the project team or the team as a whole creates collaboration and value as well as savings for the project.

IPD encourages parties to share the risk and profit of a project through project goals, so the compensation will fluctuate depending on the result. That's why the team including the owner define the goal for the entire project budget at the very early stage. If the project cost is under the budget, the additional costs are issued to the team, if comes over the budget costs are reduced. In this concept, IPD brings a high level of communication and collaboration in the team as it might develop additional profits.

IPD involves all the team members, all parties are sharing knowledge and experience, which results in elimination of possible errors and cost overruns.

- Types of Documents

BIM technology manages an IPD and makes it a unique method. IPD relies on BIM technology not only because of integration purposes, but also due to quick and efficient ways of developing the project.

Documentation in this type of delivery is a complex of individual models from architects and engineers as well as BIM reports. BIM reports are used for estimates, clash detection, site coordination. Information can be updated and synchronized more quickly than in CAD because all the changes are shown in one model.

- Project Closeout

IPD method provides space for absolutely every party to integrate at their very best. The completed BIM project using IPD method provides the construction manager and other members with a more useful data than CAD. Other reports are handled digitally or mentioned in O&M manual. (Hardin, 2009, pp 20-23)

## 2.2.5 Advantages and Disadvantages of delivery methods

Delivery Methods	Advantages	Disadvantages
Design-Bid-Build	<ul style="list-style-type: none"> <li>• DBB process is easy for owners to manage and understand, because they can actively participate in the design process</li> <li>• Once the contractor makes a cost estimation, it is mostly reliable because it is based on almost completed design documents</li> <li>• Architects are more active in construction administration than in other project delivery methods and design actions are carried through construction</li> </ul>	<ul style="list-style-type: none"> <li>• Architect does not receive a full benefit of the contractor's advice on constructability and costs during design process</li> <li>• This approach's long process may be unacceptable for owners</li> <li>• As most contractors compete project with lowest bid, any alterations in design documents may lead to delays</li> </ul>
Design-Build	<ul style="list-style-type: none"> <li>• Integration between contractor and architect are better coordinated, it saves time. When owner provides information at an early stage, and design-builder is hired, owner involvement is minimized</li> <li>• Schedule delays and change of orders may be reduced because the architect and contractor coordinate activities together, moreover, conflicts are minimized as well</li> </ul>	<ul style="list-style-type: none"> <li>• Design, schedule, and construction are integrated, which makes it difficult for the owner to participation</li> <li>• Disagreements may arise with the owner regarding what was planned in the documents, and changes required by the owner may add costs</li> </ul>

CM-at-Risk	<ul style="list-style-type: none"> <li>• The architect can only move forward to the next phase of the project when the project estimates are ready, thus allowing the owner to control budget</li> <li>• Owner's risk is limited in the process, because project is done within GMP. GMP provides the owner an assurance that the project will meet the budget.</li> </ul>	<ul style="list-style-type: none"> <li>• CM-at-Risk delivery method is good for big projects, if the project is small it will not be the best option</li> <li>• The owner may be financially responsible for inconsistencies in the contract documents. It is recommended that the owner will participate in construction project</li> </ul>
Integrated Project Delivery	<ul style="list-style-type: none"> <li>• When team members are constantly sharing their ideas and experiences, everyone stays up to date. This will lead to reduction of delays and costs rise.</li> <li>• Integrated approach and good communication speeds up the project delivery time.</li> <li>• IPD spreads responsibilities among all the members, whereas traditional methods force contractors to take risk</li> </ul>	<ul style="list-style-type: none"> <li>• This method will not bring trust to the project. There is still need of maintaining good relationship between contractor, owner, architect and engineer</li> <li>• Not everyone is familiar with this delivery method, some people may refuse to working with such model</li> </ul>

Figure 6 Advantages and Disadvantages of delivery methods.

### 2.3 BIM implementation path

The way in which BIM is implemented plays a crucial role whether organization reaches success and desired goal or not. Strategy discussions, software, hardware, and budget identification, decisions on staff and many other matters need to be taken into account.

Following section outlines the most important aspects that are necessary in BIM implementation.

### 2.3.1 BIM Manager Identification

Selecting the right BIM manager who has strong professional skills and sufficient experience is one of the most important things to start with. This person has to be able to multitask and coordinate all the information flow between architects, engineers, sub-contractors, and the owner. In general, BIM manager has to have “old” skills, “new” skills, ability to solve issues, and following responsibilities:

- Project workflow and project management awareness.
- Arrangement of the project structure and transferring formats between architects, engineers, contractors, and estimators.
- Technical and practical knowledge of BIM software used, related systems and technologies.
- Communication and collaboration skills.
- Adequate decision-making in time of a mess.
- Mobility and flexibility.

The biggest advantage of hiring the professional BIM manager is that this person is able to make recommendations to the organization of what are the main values and what needs to be further investigated. That’s why BIM manager becomes a crucial part in the following six aspects of implementation. (Hardin, 2009, p 27)

### 2.3.2 Estimations of Cost and Time to Implement BIM to the project

The goal of this aspect is to give management a precise idea about the scale of funding needed for the software, hardware, staff needed. These estimations should include yearly costs, support costs, any other costs connected to software, as well as possible hardware costs such as disc space, servers, and network.

Implementing BIM in a company is a huge investment, which requires significant costs paid every year, on the other hand, possible savings balance the price paid for software and hardware.

In order to make the work more efficient, company should train personnel only on single piece of software at once. Implementation plan should state which software, why, and when should be used, in order to define the workflow.

### 2.3.3 Implementation plan.

Implementation plan contains of a software implementation plan, training timetable, hardware update timetable. This plan explains company's action to newer technology as well as how BIM is integrated across all the company's departments.

When big companies are located in different regions and countries, it is best to start implementation with main office that becomes a future hub of the system, whereas in smaller companies, using what is currently being created and developing an implementation plan based on department interviews would be the best option.

The goal of developing an implementation plan is to determine the efficiency of current tasks using BIM technology.

### 2.3.4 Manager`s continuous training

BIM manager has to keep up with all the software, resources, and technologies that company uses, understand its values and purposes. Continuous training of the person in charge will lead to company's awareness of what they are doing and why.

### 2.3.5 Resource creation

Creation of internal tutorials and guides is beneficial to construction management team, site personnel as well as new-comers who just joined the project. These materials can be presented on a company's private page, hard drive or other possible sources. Moreover, one or two day workshop will increase the efficiency and new-comer's environment.

### 2.3.6 Continuous Implementation Analysis

With the help of Metrics analysis, it is possible to follow the efficiency of new systems put in use, if its improving or worsening processes. Estimates will show what components of BIM are bringing the biggest value and which are making loses. BIM manager and staff can analyze whether this particular software works with the task and is there anything to improve.

### 2.3.7 Follow Software proposals and Trends

BIM manager and other staff shall stay aware of industry trends, new technologies and upcoming software. Increasing understanding of current market may benefit the development of the company and operation processes.

Company's staff is always interested in gaining a competitive superiority over the competitors as more clients are requesting use of BIM technologies. (Hardin, 2009, pp 28-33)

### **3 BIM IN PRECONSTRUCTION**

BIM-aware tools help to understand what the scale, site, building set-up, and the cost of the project are. Use of BIM technologies provided by Trimble sufficiently ease common processes such as collaboration among team members and streamline procedures.

As a design model often changes throughout the project, BIM is an important tool which helps coordinating take-off and cost variations. Using Trimble software gives an opportunity of having both analysis and modelling tools at the same time, that are critical for a successful BIM process.

#### **3.1 Project planning**

All successful projects begin with good planning. Although virtual and actual outcomes of BIM projects are sufficiently differ, goals remain the same. This is why it is important to define how to implement BIM as a tool before very beginning of the actual project. BIM is a massive technology, which will continue to develop and improve the construction industry, and as a consequence, construction professionals should spend enough attention to project's concept and details in real time.

Nowadays, many construction professionals aim to use BIM technology, but unfortunately, there are always risks in implementing these technologies in a project, which depends on the expertise level of employees. The biggest mistake contractors and design teams are making when they start using BIM is using too many tools at once. If the main goal is to use BIM estimating program for the first time, then it will lead to difficulty in clash detection for the first time as well. To keep away from these problems, it is necessary to avoid implementing too much too soon. It is a good idea to consider all projects as opportunities for BIM and new knowledge and implement tools responsibly.

Due to the fact that all the projects differ from each other, it is impossible to define a general BIM plan, which works with all of them. Instead, focusing on owner's expectations, team's experiences and project challenges will contribute to an efficient BIM project plan. Following elements are vital in planning a BIM project:

- Educate team regarding motives BIM technology is used, expected outcomes and how different software is brought together;
- All the team participants should understand the importance of their role in the project, as well as contribute throughout the process;
- It is important that junior staffs would be paired with more experienced employees, so that the hardest issues will be addressed earlier;
- Adapting the team to possible challenges throughout the work might increase their opportunities regarding alternative software and delivery methods;  
(Hardin, 2009, pp 38-40)

### 3.2 Contracts

The main goal of contract generation toward BIM users is to determine responsibilities and rights of all parties involved. In traditional BIM contract there are three parties involved: owner, design team and contractor. These professional are having different rights and benefits during BIM construction project. It is crucial to determine responsibilities early, since it affects contractor's ability to control and share information.

The selecting of contract language is truly important since work on these documents requires an experienced team of professional BIM users who are able to determine protocols for sharing and transferring project's data. (Hardin, 2009, p 40)

### 3.3 Ownership and responsibilities

Project team participants define the way information is shared in order to determine the working schedule, aim to deliver quality to the project, avoid misunderstanding, and coordinate tasks.

To successfully execute BIM, project team should design and map the BIM process in their company, after which create two plans: Information Exchange plan (IE) and Model Coordination plan. Further on, these plans are sent forward as an appendix to BIM contract language.

(Hardin, 2009, pp 45-47)

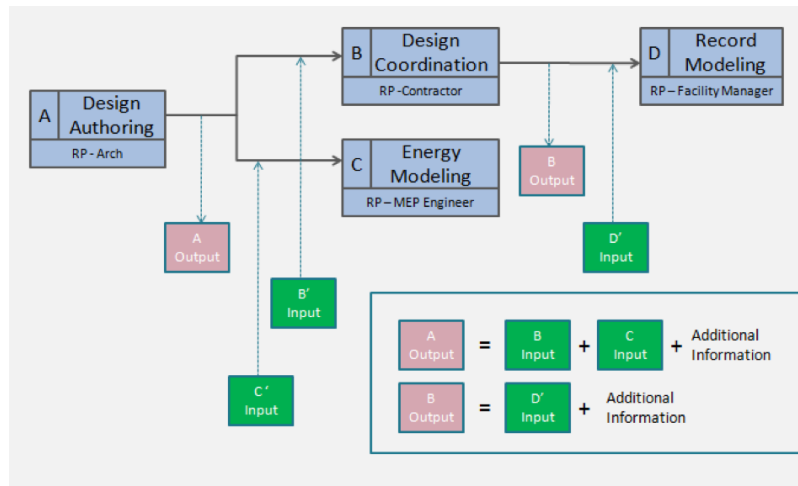


Figure 7 Map of BIM process.  
(PennState, 2020)

Every element of the project shouldn't be mentioned in the map of BIM process (Fig.6). Therefore, it is important to only define necessary stages for BIM implementation. Map of BIM process shows how information flows during preconstruction stage.

After process map developed, information exchange between parties should be identified. It is necessary for the team members and "sender" and the "receiver" of every information exchange to understand the content. An example of creating the information exchange plan is shown below (Fig. 7).

Information	Responsible Party
A Accurate Size & Location, include materials and object parameters.	A Architect
B General Size & Location, include parameter data	C Contractor
C Schematic Size & Location	CV Civil Engineer
	FM Facility Manager
	MEP MEP Engineer
	SE Structural Engineer
	TC Trade Contractors

Information Exchange Title	Design Authoring			3D Coordination			Energy Analysis		
	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Notes
Time of Exchange (SD, DD, CD, Construction)	N/A			DD			DD		
Model Receiver	N/A			C, TC			MEP		
Receiver File Format									
Application & Version									
Model Element Breakdown	Info	Resp Party	Notes	Info	Resp Party	Notes	Info	Resp Party	Notes
<b>B SHELL</b>									
<b>Superstructure</b>									
Floor Construction	B	A		B	A		B	A	
Roof Construction	B	A		B	A		B	A	
<b>Exterior Enclosure</b>									
Exterior Walls	B	A		A	A		B	A	R Value
Exterior Windows	B	A		B	A		A	A	R Value
Exterior Doors	B	A					C	A	
<b>Roofing</b>									
Roof Coverings	B	A							
Roof Openings	B	A		A	A		B	A	
<b>C INTERIORS</b>									
<b>Interior Construction</b>									
Partitions	B	A		B	A		B	A	
Interior Doors	B	A					C	A	
Fittings	B	A		B	A			A	
<b>Stairs</b>									
Stair Construction	B	A		B	A		B	A	
Stair Finishes									
<b>Interior Finishes</b>									
Wall Finishes							B	A	Reflectance
Floor Finishes							B	A	Reflectance
Ceiling Finishes							B	A	Reflectance
<b>D SERVICES</b>									

Figure 8 IE plan.  
(PennState, 2020)

Even though IE plan defines group responsibilities of larger tasks, team should also create a Model Coordination plan. This plan shows who is

responsible for development of the model and at what stage of project's completion. It has a clear idea of transferring the information at exact schedule and an understanding of who is responsible for inspecting that information throughout the project. This is the idea of Model Coordination plan.

Both of the mentioned plans are crucial since these documents build relationships in a project. However, these plans must stay flexible as different team members need different level of access to information. For example, a change in the design of a façade will require an engineer to redesign mechanical systems in order for it to work with the new idea. This extra work puts any mechanical design results behind where it would be if the engineer had continued with the original layout. This is why the level of preciseness is not as important as team members provide the data necessary for further development of the project.  
(Messner, Anumba, 2019, pp 31-34)

### 3.4 Digital information transfer

Data transfer among the construction parties is a long process. Nowadays projects tend to be contractor-led, and mostly contractors are running technology than architect's and engineer's software. With collaboration in mind, many companies are seeing the reason of creating information sharing methods before actual construction work.

Due to the big amount of stakeholders and unpredictable model updates, an archiving method can be developed. Archiving is a perfect tool when it comes to cost estimate checks or previous design changes. There are two main methods of using BIM:

- Parallel BIM model for individual use;
  - Composite BIM model for all parties;
- (Hardin, 2009, pp 52-53)

#### 3.4.1 Parallel BIM

The main feature of parallel BIM model is creation of independent model for contractors made by architects and engineers. Although this ensures that the model will correspond with contractor needs, there is still a possibility that the model will not represent exact views architect and engineer are having, since there can be a conflict between both regarding responsibilities and design.

Allowing the contractor to design the model will also lead to risks on the project. Architect's design view can be disturbed if the contractor will continue editing the model the way he sees the project. That's why architects and engineers should be responsible for their job by stamping

their designs.

Some construction managers believe that parallel modelling is the best solution when dealing with collaboration in BIM projects, at the same time they miss a chance of working together in a team and they fail to find solutions in use of software. There are some special cases when creating a temporary parallel model is a necessity, but as technology is developing its still better to use new tools in a software.

### 3.4.2 Single BIM

Single BIM method is creating a composite model for all the parties involved. This method requires deep understanding and experience of BIM software programs, since it allows multiple users work on their own models and link them together to create a composite model. Team members from around the globe or in the same office can work on the same BIM project and produce estimations, clash detection and other types of analysis. (Hardin, 2009, pp 53-54)

This thesis gives examples of software and tools based on Trimble products.

## 3.5 Estimation

Export of quantities, areas and volumes from a model is one of the most useful tasks BIM technology produces. Following sections explain which Trimble software allows extracting quantities and other necessary data to conduct accurate estimates.

### 3.5.1 Trimble GCEstimator

Before a building project breaks the ground, an enormous amount of work has already been done. Effective and accurate cost planning often determines the success of a project before construction even begins. Nowadays, cost planners face a number of evolving challenges from managing revisions to shifting costs schedules to tight deadlines, collaborating with a number of different stakeholders and decision makers.

Trimble GCEstimator suite is a cost-planning solution that provides help to cost planners. This software allows pulling estimates from 2D plans, 3D models or a blend of the two. Due to the reason that this estimator has been designed as a single all-in-one solution, it uses one central database, which better captures estimating practices and cost structures, allowing creation of detailed and granular reports. (BuildingPoint Florida, 2015)

Figure 8 represents the document controller view, it is a home central for

all of the documentation, whether it is a 2D drawing or a 3D model. On the left side there is a spreadsheet that lays out all of the documents. During the project life-cycle team constantly getting changes, addendums and bulletins to the drawings – these can be easily published as the project goes along.

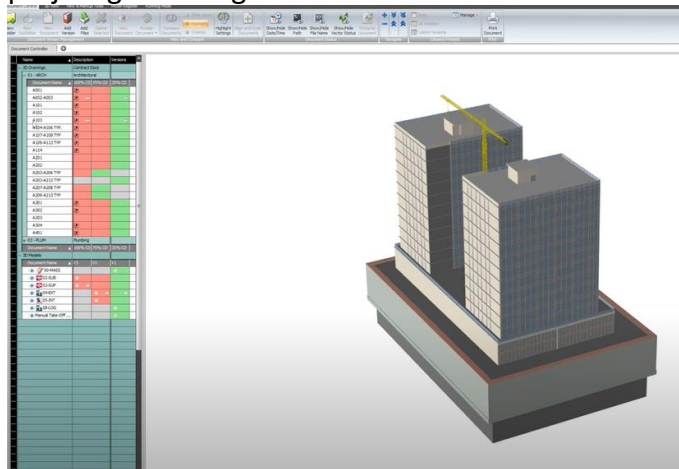


Figure 9 Trimble GCEstimator software layout. (BuildingPoint Pacific, 2016)

### 3.5.2 Trimble WinEst

Trimble WinEst is a data-driven estimating software solution that accelerates and standardizes the process of all phases of construction estimating. WinEst captures materials and labor productivity information in a database that the whole team works from. Every item in team's estimates have a standardized cost breakdown, which lately perform quantity takeoffs. (Trimble Owner Solutions, 2013)

Figure 9 below represents the sheet view, which allows summarizing and looking at different views of the estimate. It is possible to separate estimates into labor, materials, equipment or all details.

4 Level Code	Item Description	Takeoff Qty	Unit	Labor Total	Mat Total	Sub Total	Equip Total	Other Total	Grand Total
28									
29	210000 Fire Suppression					72,103.50			\$72,103.50
30									
31									
32	220000 Plumbing					30,000.00			\$30,000.00
33									
34									
35	230000 Heating, Ventilating, and Air-Conditioning (HVAC)					46,867.28			\$46,867.28
36									
37									
38	260000 Electrical					40,000.00			\$40,000.00
39									
40									
41	310000 Earthwork			8,723.75	5,733.00	1,817.01	3,992.45		\$20,266.20
42									
43									
44	320000 Exterior Improvements			28,328.23	35,133.59	5,900.10	20.43		\$69,382.35
45									
46									
47	330000 Utilities					300.43			\$300.43
48	331100 Fire Inspector	0.500	days						\$300.43
49	331113 Water - 235 Pipe Crew	0.500	days	1,175.00			606.00		\$1,781.00
50	331200 Fittings for Fire Dept Conn	1.000	each		272.95				\$272.95
51	334113 Storm Man PVC 50R-21 12"	100.000	lft		1,263.34				\$1,263.34
52	334113 Storm - 235 Pipe Crew	0.333	days	763.33			404.00		\$1,167.33
53	334113 Misc Fitting Plastic 12"	1.000	each		1.21				\$1.21
54	334113 Misc Item Plastic 12"	1.000	each		1.21				\$1.21
55	334400 Test & Flush	100.000	lft	100.00			11.00		\$111.00
56	334400 Backfill - Pca Gravel	24.050	ton		218.62	108.45			\$327.07
57	334613.13 Fine Grade for Foundation Drain	150.000	lft		45.00				\$45.00
58	334613.13 Excavate for Foundation Drains	11.111	cuyd		21.67		23.33		\$45.00
59	334613.13 Moisture Protection at Wall	45.720	sqft		18.97	11.89			\$30.86
60	334613.13 Backfill Drain Trench w/Native	5.555	cuyd		41.67		58.33		\$100.00
61	334613.13 Perforated Pipe - 4" ADS	150.000	lft		180.00	87.46			\$267.46
62	334613.13 ADS Fittings - 4"	150.000	lft		45.00	38.26			\$83.26
63	334613.13 Cleanout - 4" ADS	2.000	each		30.00	72.79			\$102.79
64	334613.13 Pipe Sleeve thru Footing 4"	2.000	each		18.00	10.40			\$28.40
65	334613.13 Filter Fabric	750.000	sqft		292.50	54.66			\$347.16
66				2,743.14	2,033.00	408.88	1,102.67		\$6,287.69
67									
68									
	<b>Grand Total</b>	<b>30,000.000</b>	<b>sqft</b>	<b>282,474.41</b>	<b>446,984.77</b>	<b>561,763.28</b>	<b>9,186.96</b>	<b>1,534.50</b>	<b>\$1,301,943.93</b>

Figure 10 Trimble WinEst software layout. (Trimble Owner Solutions, 2013)

### 3.5.3 Tekla EPM

Tekla EPM (Estimating and Production Management) is a tool which regulates estimating process, as well as allows construction manager see the construction site progress in real time. Tekla EPM includes all needed services, that contractor needs: estimation, project management within proposed schedule, materials streamline and production control. Tekla EPM is a part of Tekla PowerFab software suite. (Trimble Tekla Downloads, 2020)



Figure 11 Tekla EPM functionalities. (Trimble Tekla Downloads, 2020)

### 3.6 Site coordination

Virtual BIM site coordination plays an important role in improving construction and collaboration. Following sections give examples on what tools are helpful on site as well as outside its borders.

#### 3.6.1 Trimble ProjectSight

Trimble ProjectSight application is built to support teams through a single unified platform. ProjectSight offers a variety of useful features that enable teams to mitigate risks, collaborate and stay on budget throughout every stage of the project. Beyond standard functionalities it identifies safety violations that were done by workers on site. These records may be used over time to monitor actions of each sub-contractor. It also helps to track job completed every day, daily activity of teams, as well as weather changes on site. In order to ensure that details are not missed, it is possible to create numerous of process checklists. (Trimble's ProjectSight, 2019)

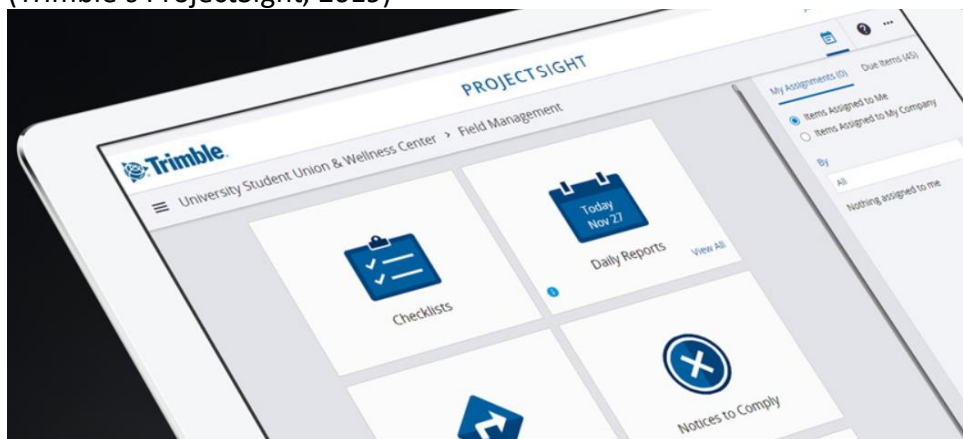


Figure 12 Trimble ProjectSight application on a tablet.  
(Trimble's ProjectSight, 2019)

#### 3.6.2 Trimble CrewSight

General contractors, sub-trades and owners benefit from knowing who, when and where workers are on job fields. CrewSight provides construction companies an automated way of capturing such data for compliance and productivity purposes.

This software creates an attendance records for workers as they enter and exit job sites, as well as identify who of the workers are on site in real time. Accessing such data improves compliance, safety, productivity and

effective workforce management. (Trimble Field Technology, 2020)



Figure 13 Trimble CrewSight operation.  
(Trimble Field Technology, 2020)

### 3.6.3 Trimble XR 10 hardhat and Microsoft HoloLens 2

Trimble XR 10 with HoloLens 2 enable solution in the world for frontline workers in environments requiring certified hardhat safety or personal protection equipment. This system has construction workflow features to empower the worker in the field to do their work right first time and using advanced Trimble software for design and construction the XR 10 lets the architect, engineers and contractors to bring the 3D constructible model detail and process all the way from office to field and on to the tool. (Trimble Buildings, 2019)



Figure 14 Mixed Reality in construction by HoloLens 2 by Microsoft and Trimble XR 10 hardhat.  
(Trimble Buildings, 2019)

## 4 BIM IN CONSTRUCTION

Many tasks are associated with construction phase, but scheduling, constructability and trade coordination are truly pushing BIM to be used.

In some companies, use of BIM during construction stage might mean implementation of new processes and tasks. As construction industry develops, so as projects getting to be more complex and difficult. Many software companies such as Trimble are developing BIM tools rapidly to catch demands of the industry.

#### 4.1 Scheduling Software

Before the first construction worker enters the field, the construction manager has to perform a significant amount of work – prepare a schedule. Schedule is a vital factor which costs a success to a project. The necessity of a schedule in regard of BIM is informing all parties and tracing the progress. Following sections will describe scheduling software engineered by Trimble.

##### 4.1.1 Vico Office Schedule Planner

Vico Office Schedule Planner creates a construction schedule by using BIM model elements and associating them with tasks and the corresponding materials, resources, and labor; all of which are optimized by location. (Intelligent BIM Solutions TV, 2014)

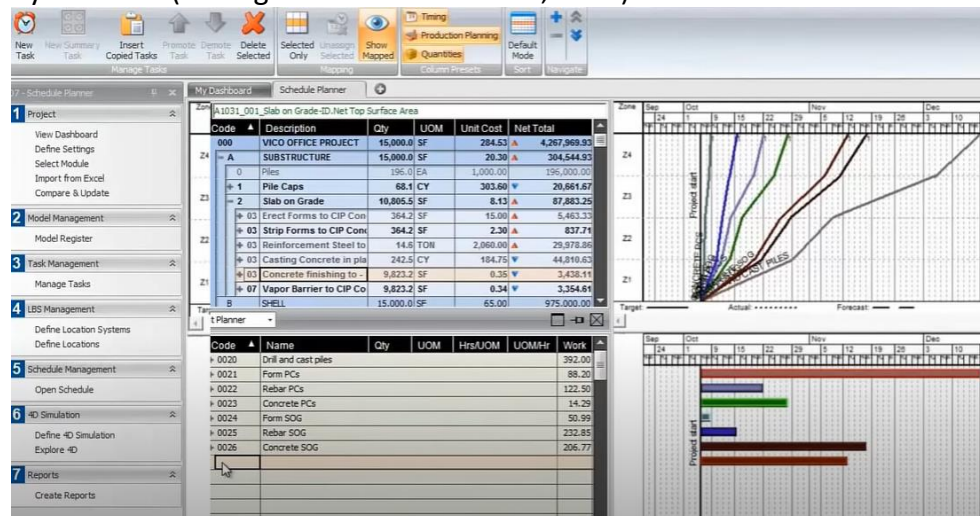


Figure 15 Vico Office Schedule Planner software layout. (Intelligent BIM Solutions TV, 2014)

##### 4.1.2 TILOS

TILOS software is used for planning of linear projects: roads, railways, pipelines, tunnels, bridges, overhead power cables. TILOS is a fully featured project control system with resources, cost and progress management.

Detailed information about current activities by location empowers production management opportunities and provides the transparency necessary to make sure on-time delivery of projects. Outputs from TILOS

are highly visual and might easily be deciphered by owners and construction workers alike. (Trimble Heavy Industry, 2020)

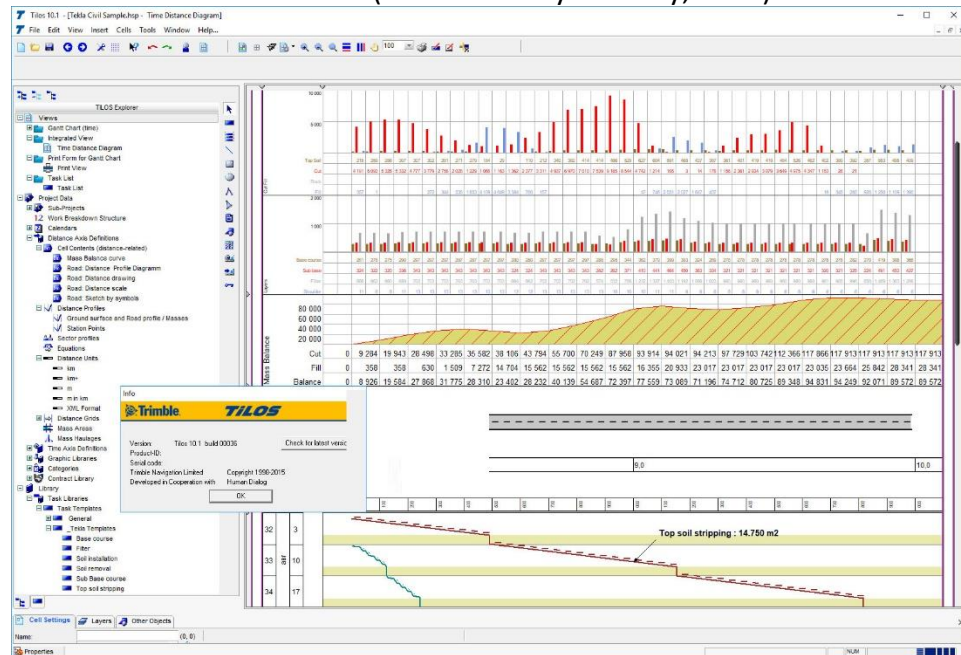


Figure 16 Trimble TILOS software layout. (Trimble Heavy Industry, 2020)

## 4.2 Constructability

Constructability refers to the evaluation whether the design can be constructed by workers on site and how it will be done.

To a construction manager, constructability problems directly affect cost, schedule, materials and labor. To an architect, constructability means the ability to construct the building according to the design. To an engineer, constructability means that the construction meets technical criteria set.

Constructability covers everything starting from logistics of materials to crane erection, it determines how the building is to be built and site organized. When architect is working on floor spaces, layout and safety issues, contractor determines logistics, formwork, control joints, slab edge conditions and pour sequences.

Current trends in construction promote constructability. Because the trend is towards an increasingly complicated architecture, designers and builders need to find even more innovative solutions, to realize these. The necessity to create successfully and safely is the reason why accurate data is critical already within the design phase.

Cost pressure is always present. Using constructible models, the building can be built cheaper, better and faster. Processes are planned and

scheduled and possible mishaps within the design phase detected before starting the construction.

The off-site building is another trend that makes accurate information crucial. It's gaining ground because the industry heads towards savings and the next level of automation. Even large units, like steel-roof assemblies and factory-built bathrooms, arrive prefabricated to the site to be installed just on time. Naturally, every such item must fit exactly and stay on the schedule while vast amounts of adjusting information must reach those people working on the project. (Hardin, 2009, pp 106-111)

"We have seen cases where the costs have been reduced by 50 % when using BIM. Having constructability issues sorted out before starting construction will inevitably lead to fewer errors." (Eastman, 2020)

#### 4.3 Project coordination

Trimble provides Trimble Connect software for contractors and construction managers that transforms the way construction is managed. By integrating workflows and using this software, it increases efficiency in managing quality, cost, time and safety.

Trimble Connect focuses on three key areas: all phases and trades are connected, models and workflows are content-enabled, and constructible models drive smart workflows.

Trimble Connect allows the information to flow for successful, on-time project completion. Cutting edge technology enables connectivity across all project phases, platforms and devices-allowing users to view, share and access information from anywhere in real time. For example: structural steel member sizes might need to change during the design or pre-construction process. As a result, many quantities, drawings or CNC files (path files, containing instructions for cutting a 3D part using milling machine) would be affected. With connected workflows, changes happen automatically, so you can update material orders and keep building for on-time delivery. The "constructible" process goes beyond BIM by building with constructible data. This data can be used for everything from layout with Robotic Total Stations to holographic information in a Mixed Reality hard hat. (Trimble MEP, 2020)



Figure 17 Trimble Connect use on site.(Trimble MEP, 2020)

## 5 BIM IN UPDATES

BIM is a useful tool during preconstruction and early construction phases through constant updating. The flow of information increases from the end of preconstruction and the beginning of construction phases of a project. The success of the project is a direct result of how well the rapid flow of information is controlled, tracked and distributed. Usually, it involves one person, who is responsible for managing the information coming in and then sharing it with the rest of the team. This role might be played by the project manager, support member or other personnel. Managing documentation is another responsibility of the team. It is important to understand from where documentation is coming from, date it was created, question involved, and responsible party for its resolution. Often, lack of this information adds additional layer of complications to the project.

BIM during updating and developing phases might face following challenges:

**Issue:** Lack of personnel experience with BIM, leading to additional time to become efficient and productive.

**Solution:** Create open classroom, guide or manual for users, to share experiences and learn fast. Moreover, make sure that new personnel are aware of study resources.

**Issue:** Company uses old processes as a standard instead of new ones which result better and faster outcome.

**Solution:** Use of old processes as a basis and combining it with newer technology is not practical. Instead, use new processes as a standard.

**Issue:** Existing project schedule has limited time for BIM tasks.

**Solution:** Log the amount of hours needed for future jobs and pick tools that are more important and which are not as needed.

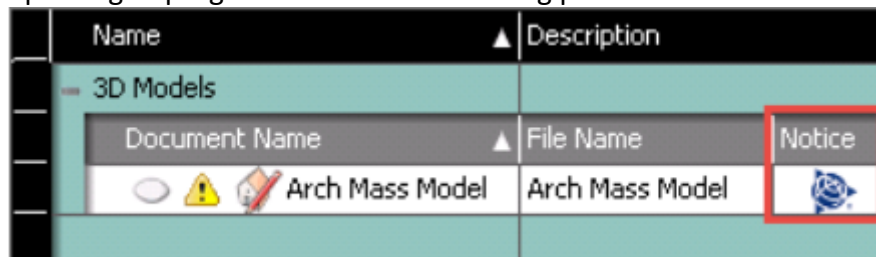
(Hardin, 2009, pp 142-144)

## 5.1 Model updates

Project design model is constantly updating throughout the sharing and transferring phases. Depending on the delivery method of the project, there are different ways of BIM information updates. Every company has to choose their own strategy and way of performing these updates, since it directly affects the speed of information transfer.

(Hardin, 2009, p 159)

In case of using Trimble Connect as the main project coordination software, there is a very simple way of updating the model through Vico Office. Trimble Connect is a cloud-based application which allows updating in-progress models without long procedures.




Name	Description	
3D Models		
Document Name	File Name	Notice
Arch Mass Model	Arch Mass Model	

Figure 18 Document Control panel interface.

(Vico Software Support, 2020)

Every time, there is a need to upload a new version of the model to Trimble Connect, Vico Office software can help indicate model changes made in Document Register.

1. Open Document Control panel.
2. Right-click the model where the changes made. The Notice column appears when the changes were updated in Trimble Connect.
3. Choose “Go to Trimble Connect” file option if needed.

(Vico Software Support, 2020)

## 5.2 Clash detection

One of the main procedures, leading to successful information movement is clash detection. Clash detection improves the degree of accuracy and enables combining multiple project models in one BIM file.

The idea of clash detection is identifying whether two or more building components are interfering with one another.

The following tutorial explains how to conduct clash checking in Trimble Connect.

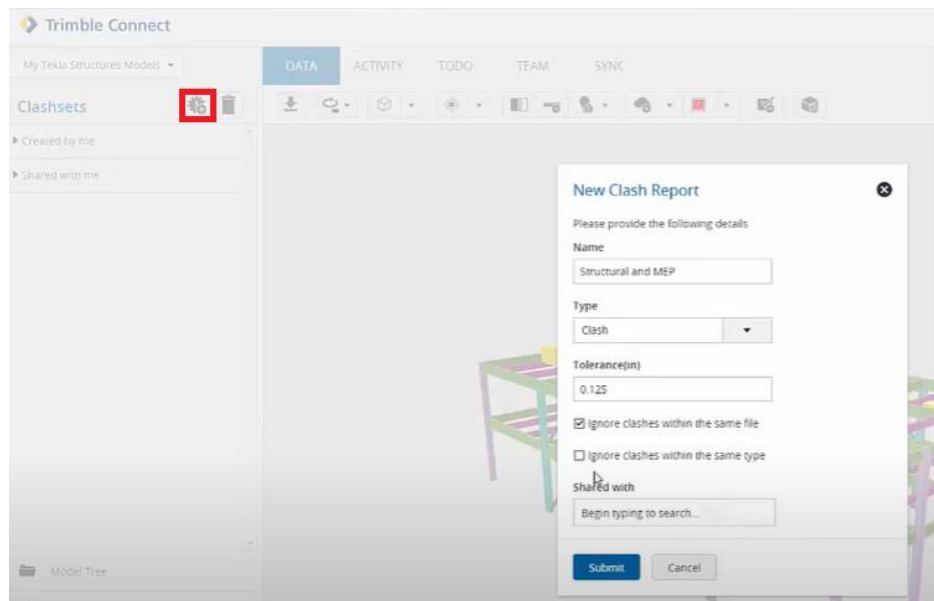


Figure 19 New Clash Report panel in Trimble Connect.  
(BuildingPoint Mid-America, 2019)

1. Press the red framed button to create a new clash check report.
2. Give it a name.
3. Specify the type of clashes to be “Clash” only or “Clearance” only.
4. Set a tolerance.
5. In order to ignore any clashes that are within the same file and see clashes between the two different files tick the first option.
6. And assign this clash report if needed.

After pressing “Submit”, the clash checking is going to be evaluated in the background.

To review the clash sets created, select the name of the model at the at the initial left section, then clashes will be highlighted in the model, as well as in the details there are a total of 12 clashes.

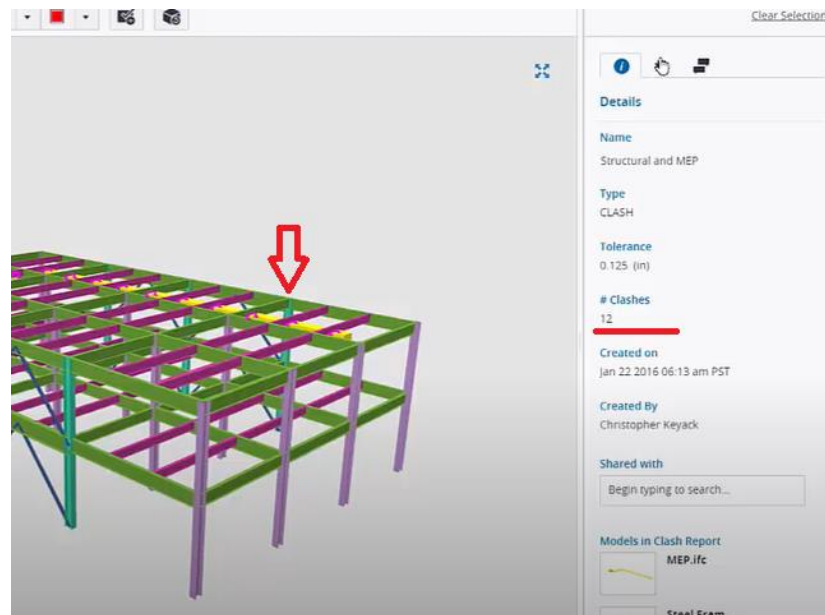


Figure 20 Clash check interface in Trimble Connect.  
(BuildngPoint Mid-America, 2019)

If we go to the individual clashes, there are different clashes available on the list. When selecting the clash, it will zoom the view into that location and then hide the other objects. (BuildngPoint Mid-America, 2019)

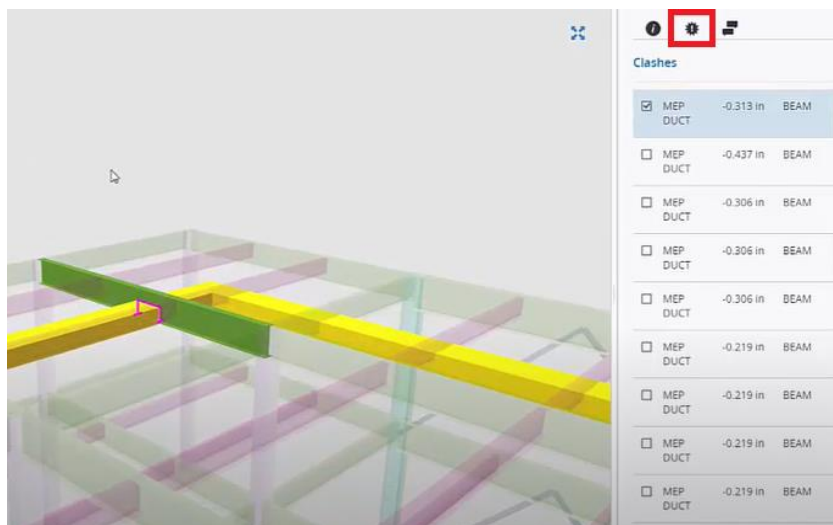


Figure 21 Clash view in Trimble Connect.  
(BuildngPoint Mid-America, 2019)

## 6 BIM IN CONSTRUCTION ADMINISTRATION

BIM is an incredibly powerful tool during construction administration phase. BIM process provides tools and methods that enable sufficient project coordination on a job site.

## 6.1 BIM and RFI

Request for Information (RFI) is a tool, which helps to find resolution and clarify issues. Usually, RFI is created by subcontractors and sent to general contractor, and then to design team to review. RFI submission and approval phases may be improved by using BIM Collaboration Format (BCF), which allows users to share encoded messages among different platforms about the errors appeared.

(Hardin, 2009, pp 184-185)

### 6.1.1 Tekla EPM RFI Report

First way of creating RFI report is with the help of Tekla EPM tool. It is possible to create a RFI report containing all the details, which afterward can be viewed, printed, or exported. Following tutorial gives a clear vision of how it works with EPM tool.

1. In RFI dialog box, click on RFI tab;
2. In the menu select the "Reports" section;
3. If there is a need to create RFI report, at the bottom of "Project Management Report Filters" select only "RFI" check box.

If there is a need of creating RFI's including specific types of request, at the "Project Management Report Filters" box select needed settings and press "Select";

4. Depending on the filter type selected at the previous section, move the request properties that need to be included in the "Included" list, or assign maximum and minimum amount of requests that need to be included;
  5. Click "OK";
  6. Click "Make the Report".
- (Tekla EPM, 2020)

### 6.1.2 Tekla Structures RFI Manager

Tekla Structures RFI Manager is a tool which helps to create and link RFIs to specific objects, colorize the model based on the RFI status, publish to a HTML (Hyper Text Markup Language), FTP site or zip up and mail.

Picture below shows the main interface of the RFI Manager and couple of RFI reports that already have been created.

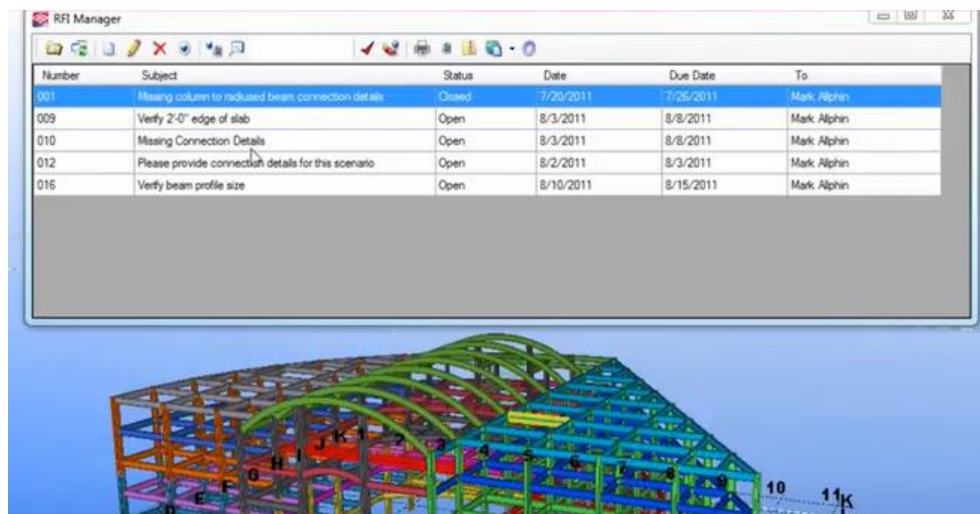


Figure 22 RFI Manager interface in Tekla Structures.  
(Tekla Software, 2015)

After opening the selected RFI report, it shows that the column misses the connection. Speaking about RFI Form, it allows us to give a specific number to a RFI report, assign the status (done, closed, overdue), tag the date the report is created and when is the due date, attach images and include attachments. (Tekla Software, 2015)

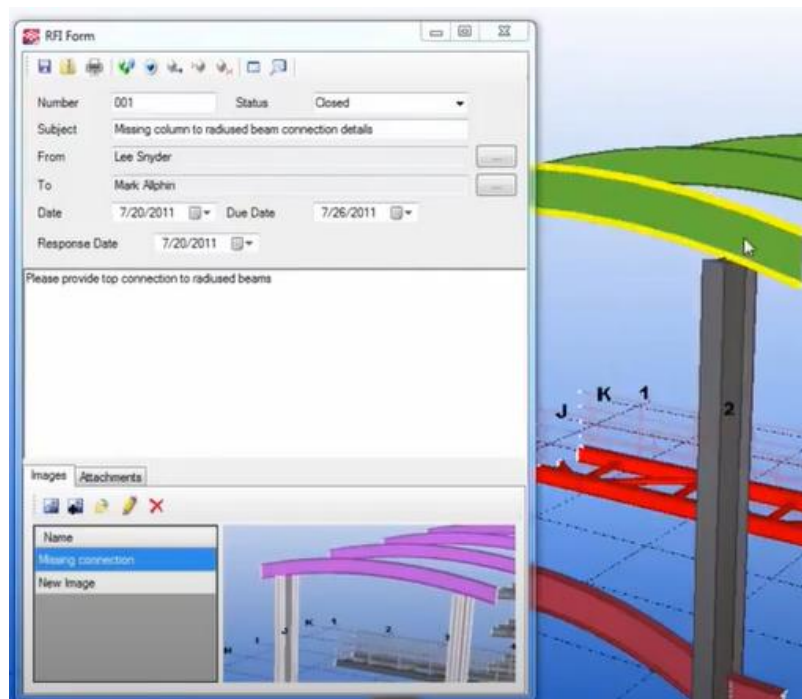


Figure 23 RFI Report Form containing all the details.  
(Tekla Software, 2015)

## 6.2 Training the Chief Supervisor

Chief Supervisor (CS) training should be relevant and concentrated. CS needs to know how to create on-site RFI documents, improve job efficiency and quality in the field, use BIM for punch lists and project completion. Moreover, it is important for CS to know how to maintain clash detection on-site, as well as being flexible with BIM.

The best timing for training is when CS completes BIM course and starts getting familiar with a project. If possible, it is wise to group new user with experienced users who can educate others. This methodology is very effective when a senior employee introduces new processes and programs to a newcomer.

Field supervisors must have following qualities to successfully run BIM:

- Software understanding.
- An understanding how this software will help the project to be BIM coordinated.
- Knowledge of how it is possible to save time.
- Being able to use internal support system.

(Hardin, 2009, pp 193-194)

In order to implement a good base for training CS, it is recommended to use official Trimble sources. There are many online courses available, which are suitable for different level of expertise and can be found at software web pages or video sharing platforms of Trimble.

## 6.3 Construction Trailer set-up

Use of BIM technology on site depends on a set-up level of a Construction Trailer because major portion of information flow is sent from the job field. Generally, a good construction trailer must have a conference area, plans and specifications board and a Virtual Trailer.

### 6.3.1 Conference area

Conference area of a construction trailer is usually a place where meetings are conducted. These meetings might be scheduled, or immediate if an issue arises. The purpose of scheduled meetings is delegating responsibilities and work to be completed within the right time. Construction supervisor strongly relies on a construction manager as well as working schedule produced.

### 6.3.2 Plans and specifications board

The main purpose of plans and specification board is to keep all the members updated with drawings and changes, since sometimes information happen to be missing or wrong on physical drawings. All of

the information is usually printed and put on board, which allows fast data distribution among people. The Chief Supervisor is usually responsible for updating the board and printing all the necessary documents received from the construction manager. Now the flow of information is oriented to the field, as the project reaches the phase, where engineers and architects are done with their work.

### 6.3.3 Virtual Trailer

Virtual Trailer is an online communication platform which is created among different project members. The difference between Virtual Trailer and a Conference area is the amount of people participating during the session. The biggest advantage of this type of communication is that all the members who might be helpful and necessary to interact with can be easily met and reached in this platform, whether a person is on site or at the office. (Hardin, 2009, pp 209-214)

## 7 BIM IN SUSTAINABILITY

Constant development of construction industry changes the way people produce construction products using natural materials. Use of natural resources has led to a price increase of materials over the past years. (Hardin, 2009, p 230) For example, from January 2019 to June 2020, softwood lumber prices have dramatically increased. After 10.8% decrease in April, softwood lumber costs have risen 16.5% and are now at the highest measure. (ProSales, 2020)

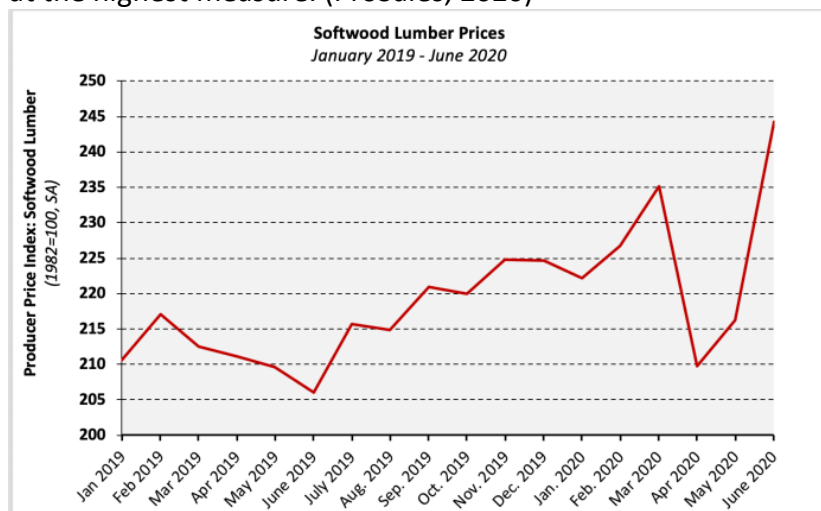


Figure 24 Softwood Lumber Prices chart.  
(National Association of Home Builders)

Green Buildings rise in popularity, their construction minimizes site grading, alternative materials are used, the waste is recycled rather than sent to landfills. Through collaboration and integrated analysis, BIM gives

the potential to deliver a more innovative, green, and cost-effective buildings. Architect may input geographical data to a BIM file, so the design team will have a full picture of possible issues related to climate, surrounding systems and resources. Engineers can also use BIM file in order to reduce energy demands, through 3D model estimate light reflectance. Contractors may analyze building site situation, coordinate logistics to eliminate extra pollution.

## 7.1 LEED

To begin with, there is a need of more integration and correlation between contracting and design teams. In general, it involves number of sustainable project tools that analyses the building. In order to begin a green process, the contractor need to become familiar with eco-friendly subject, as well as study rating system such as LEED (Leadership in Energy and Environmental Design). (Hardin, 2009, p 231)

LEED is a Green Building rating system that was released publicly by US Green Building Council in 2000. LEED provides third-party verification for design, construction and operations of superior green buildings. There are five primary LEED rating system reference guides and each is geared toward a specific project type.



Figure 25 Primary LEED reference guides.  
(LEED training, 2010)

The LEED reference guide for building design and construction is appropriate for most new construction, in addition to school projects and major renovations.

The LEED reference guide for interior design and construction focuses primarily on commercial interior projects.

The LEED for homes covers high performance residences that are less than four levels.

The LEED for neighborhood development is set up to pair green buildings with smart growth urbanism.

The LEED for existing building's operations and maintenance a system that helps building owners minimize environmental impacts by maximizing operational efficiency. (LEED training, 2010)

## 7.2 Green Construction

Green construction aims to reduce negative environmental effects on the planning, construction and operation stages. The aim isn't only to

minimize damage but to make buildings that have a positive impact on the environment. Construction is one among the biggest contributors to greenhouse gas emissions.

Below there are some examples of 2020's most innovative structural engineering and construction projects using BIM technology.

(Constructible, 2018)

### 7.2.1 Norwegian Randselva Bridge

Companies: SWECO Structural Engineering, PNC, Armando Rito, Isachen;



Figure 26 Randselva Bridge.  
(Constructible, 2020)

Randselva bridge is the world's longest bridge which was built without drawings, not even a single PDF file.

95% of all data, including over 200 pour phases, is sent to the contractor with IFC files. The BIM model contained over 200,000 rebars and 250 post-tensioning cables. Design team used Tekla Model Sharing to communicate across four countries. (Constructible, 2020)

### 7.2.2 Japanese Saga Natatorium

Companies: Yantai Daizo Design Co., Ltd, China

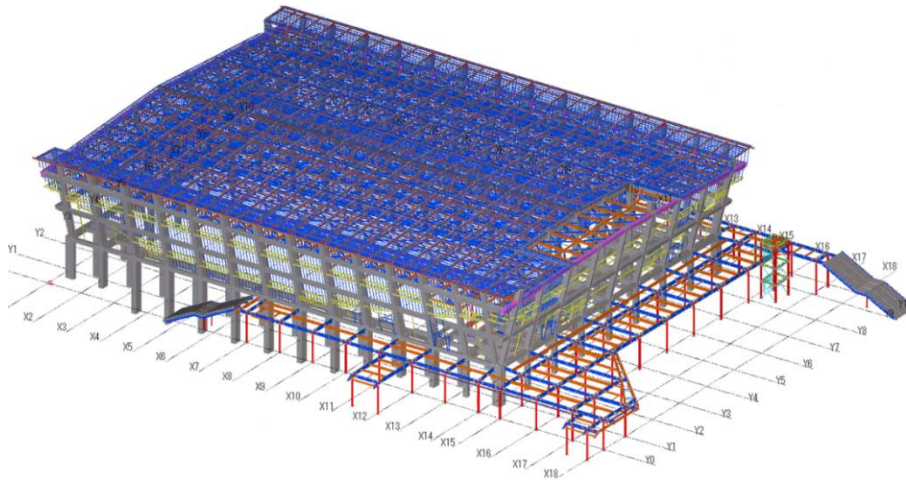


Figure 27 Saga Natatorium.  
(Constructible, 2020)

Tokyo 2020 Olympics Pool model was completed in 10 months just by five people. Design team used Tekla automatic connection function to create nodes and components in the model. Throughout the entire project, they used parametric blocks and an API (Application Programming Interface) to develop new nodes. (Constructible, 2020)

### 7.2.3 Russian Lion and Eagle Transmission Tower

Companies: Belenergomash BZEM, LLC



Figure 28 Lion and Eagle Transmission Tower.  
(Constructible, 2020)

This idea set a record to support power lines in the form of heraldic symbol of a city. Internal ERP (Enterprise Resource Planning) systems

used for updating and tracking of elements together with Tekla Structures. Tekla BIM Sight used at the construction field. (Constructible, 2020)

### 7.3 Salvaging and Recycling

Unfortunately, buildings do not last forever. Buildings often become outdated as design systems keep developing, materials lose its quality within time and weather conditions (asbestos, mold) and environment outside changes in temperature and density. Worth mentioning, many materials of a structure can be replaced or repurposed during renovation process.

Salvaging and recycling building materials minimizes the cost of disposal and transportation. Moreover, these practices reduce the demand for new resources, which cuts transportation and production needs. (Hardin, 2009, p 259)

#### 7.3.1 Salvaging

Salvaging reclaimed materials is a cost-saving and environmentally responsible action. Salvaging is one of eco-ways to re-establish building materials.

Many environmental organizations promote the sustainable reuse of building materials. Even though market is driven by economics, demolition contractors are seeing a potential profit in salvaging of demolished materials.

Using salvaged building materials instead of new ones can benefit the environment in many ways. This practice helps saving forests and other natural resources, whereas reducing the amount of waste sent to landfill sites. There will also be less energy spent to extract and transport new building materials.

Some materials and appliances should not be repurposed due to safety regulations. For example, old plumbing might contain lead which can leach to water, while old appliances might not be suitable due to latest safety standards. (Mcmanus, 2020)

#### 7.3.2 Recycling

When material salvaging is not feasible, material recycling becomes an industry standard.

Recycling saves an enormous amount of energy, and it decreases the consumption of natural resources to produce new construction materials. As landfills are constantly filling up, it pushes people to develop alternative ways to manage construction waste. Recycled building materials can be reused or repurposed to something new.

Green building practices are gaining an admiration, many developers are trying to achieve LEED certification. Recycling and other environmentally sustainable processes will lead to earning of more points under the LEED system. (Hardin, 2009, p 262)

## 8 BIM IN FACILITY MANAGEMENT

The use of BIM technology is critical and beneficial even after the successful completion of a construction project. The main advantage of BIM in Facility Management is the ability to improve space management. With the help of BIM technology facility managers have a better understanding of operational and maintenance cost, that will later lead to cutting unnecessary fees.

### 8.1 Building`s operating cost

A building`s operating cost during its life-cycle is approximately 75% of the initial cost to build, and the initial 25% investment to build it. Nowadays, building`s operating and management costs are annually increasing. Moreover, these investments are considered to be necessary. Additionally, high environmental costs related to pollution reduction is something that facility owners are facing on the daily basis. Today, many owners and companies are investing to green practices to reduce these additional payments. (Hardin, 2009, p 264)

It is very unfortunate, that nowadays some companies are mostly focusing on the first design and construction costs, rather than future maintenance operations. To avoid this, and moreover help the facility manager with future expenses as well as reducing them – Trimble Manhattan One is the solution.

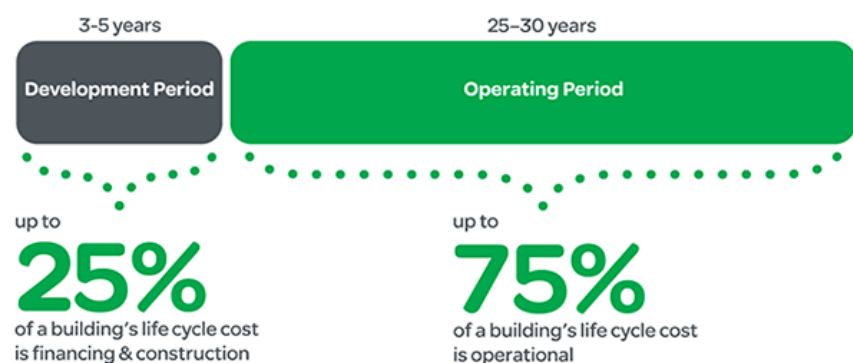


Figure 29 Average life-cycle cost of a building.  
(Schneider Electric, 2020)

### 8.1.1 Trimble Manhattan

Trimble Manhattan is a real estate management software which helps with managing the building's lifecycle, planning, and optimizing real estate and workplace portfolio. Manhattan has different modules for different functions: property information, manage projects and maintenance, manage financial leases.

This software can be used by an owner or occupier to maximize resource utilization while reducing the total cost of occupancy, an investor to maximize portfolio performance and improve decision making, and a service provider to help deliver high levels of service, lower costs and increase income. (Trimble Real Estate & Workplace Solutions, 2019)



Figure 30 Functionalities of Trimble Manhattan software.  
(Trimble Real Estate & Workplace Solutions, 2019)

## 8.2 BIM and the Owner

One of the biggest problems after a project closeout is the huge amount of end-of-project documentation and files owners are left with. The bigger and more complex the project is, the more information owners have to deal with.

Trimble Manhattan software supports the owner by ensuring that all the documentation and files received from the design and construction crew are collected and stored for future use. Moreover, the software captures, monitors, processes and analyzes real-time maintenance data to determine what asset should be maintained or replaced by using combination of sensors and indoor positioning technology.

### 8.3 BIM Implementation

BIM has a potential and facility manager who are always looking to step up and apply the technology to cover operating and maintenance needs.

In order to implement BIM, a facility manager examines the building and finds out what systems are needed to put into use to achieve the desired level of efficiencies. There are risks which are highly possible to realize when migrating from old facility management processes to BIM processes. Most challenges relate to BIM implementation.

There is a need to communicate and understand advantages of BIM for facility management, which are mentioned above. However, the facility manager should have sufficient skills to be in a position of maintaining the BIM for building's model. Facility managers wishing to implement BIM in the near future should adapt to any possible challenges. For example, one of the main concerns is the limited compatibility between BIM and facility management technologies, which can be worsened by the difference among the lifecycle types of BIM and facility management technologies.

The lifecycle of a BIM technology is approximately 12 - 24 months, when the lifecycle of a facility management system ranges between 10 - 20 years and the building lifespan can be up to 100 years. It means that data standards and interoperability will remain critical for implementing BIM. Therefore, facility managers willing to implement BIM immediately to the project should nevertheless take a long-term view.

(Tereno, Anumba, Asadi, 2018)

## 9 THE FUTURE OF BIM

Technology development is constantly leading the construction industry to transform into something even more highly collaborative and digital. However, urban planning is one of the spheres that has not considerably moved forward. The way to design individual buildings has dramatically changed with the BIM approach, but the plans for broadening urban planning still fall behind. (Constructible CIM, 2018)

### 9.1 CIM

In the last 15 to 20 years the impact of information communication technologies has led people to live in cities. There are over 40 billion connected devices worldwide. People collect more data than ever before. And with all this data and processing power we have incredibly smart computers. But meanwhile with all the technology, the way that we plan cities is still firmly stuck in the 20<sup>th</sup> century.

CIM (City Information Modelling) is a 3D live simulation of the city, which connects with BIM and other information sources and allows architects, planners and other construction professionals to collaborate in city projects and designs.

When considering the way cities are planned today, it can take 4-5 years to produce the plan, and by the time these plans are done – they are out of date. When having the city information model, architects and developers will be able to test their proposals and designs, before building the buildings.

CIM will be valuable for different parties in the city. Citizens will be able to understand what is going on in their neighborhood, developers can use CIM to test their planning applications, and politicians as part of their manifestos can provide a simulation of what they believe their policies will achieve and show how it will play out in CIM.  
(Future Cities Catapult, 2017)

## 9.2 Relationship between BIM and CIM

BIM uses 3D modelling functionality, and it also goes beyond traditional CAD abilities, by including data about every part of the lifespan of a building. The possibility that different characteristics can be linked together gives a potential expansion - where various individual projects can be linked into a large project model. CIM goes beyond BIM projects, providing links to urban planning, community services, and simulations of how people move and interact with a city.

CIM is still being developed, but there is little hesitation that it will have a huge impact on designing and running the cities in the future.  
(Constructible CIM, 2018)

## 10 CONCLUSION

The purpose of the thesis was to prove that BIM technology is beneficial in the Construction Management field. This topic was chosen to show that Trimble Solutions offers a variety of software, platforms, and tools that connect physical and digital phases of any construction project.

This thesis has determined goals and objectives that are clearly useful and valuable to all the building specialists who work with BIM during the Construction Management phase. The focus on good communication and elimination of challenges makes the BIM implementation a practical, long term solution.

Finally, Construction Management is a very complex process, which needs to be adequately planned, estimated, and maintained, whereas specialists have to keep high level of cooperation, expertise and flexibility.

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