# Agile Project Management within the BIM based Common Data Environment

## Master Thesis

**International Master of Science in Construction and Real Estate Management**

**Joint Study Programme of Metropolia UAS and HTW Berlin**

Submitted on 20.07.2018

**Razie Qaravi**

557535

First Supervisor: Prof. Dr.-Ing. Markus Krämer

Second Supervisor: Sunil Suwal

*[Acknowledgement]*

I would like to express my gratitude to my supervisor Prof. Dr.-Ing. Markus Krämer who has introduced me to the subject, guided me through all the steps, and widened my knowledge around it. I am also grateful to my second supervisor Mr. Sunil Suwal who has patiently helped me develop the research while staying within a logical framework in order to address the main research question. In addition, I am grateful to Pedro Aibeo who's help has been an inspiration to develop the method to address the research question and I am thankful to the interview participants as well, for without their cooperation the results of this paper could not have been evaluated.

**International Master of Science in Construction and Real Estate Management**

**Joint Study Programme of Metropolia Helsinki and HTW Berlin**

**Date** 24,04,2017

**Conceptual Formulation**

**Master Thesis for Ms. Razie Qaravi**

**Student number 557535**

**Topic:**

Teamwork design in BIM (The Efficient Method for the Construction Team to Exchange Data in the Design Process)

**Background**

These days technology has an important role in construction process in terms of time, cost and energy. Building Information Modeling (BIM) is a digital representation and a shared knowledge resource for information about a facility that forms a reliable basis for decisions during its lifecycle from concept to demolition in the construction industry.

Over the intervening 90 years, the practices of building have evolved greatly. The easy, close-working relationship between designers and builders has been largely disappeared. The easy mapping between an architect's intent and its realization by a builder cannot be assumed. The evolution to more complex construction methods and building systems, more complex programs (for example for airports, and hospitals) have made earlier tacit knowledge inadequate without far more explicit definition within buildings.(Rush, 1980). (New Methods of Architecture and Building)

Therefore, a growing number of soft wares, updated instruction, and visualization tools have been released regarding linking the architect's effort and design to the central data base which is linked to all the other constructional zones. In other words, these interactions between the design and other building stages lead to a more precise and accurate details where there will be no possibility for unexpected errors during the construction process.

All in all, It is well-known that BIM has made it easier for the involved experts to collaborate through specific soft wares and techniques using IFC as a data exchange platform; however, somehow we notice that there has not been a clear approach or instruction in which we could also collaborate in the very beginning of the design phase in which the most crucial decisions are being made with the architectural team; therefore, I propose a research on the subject to clarify this issue and if possible present an ideal theoretic package for the construction team as a way to communicate not in a back and forth order, but in a parallel time and pace as the design concept progresses. This idea provides architect with the opportunity of scrutinize the architectural details in the simulated model of the building to make a judgmental call on its possibility and feasibility. (Dhar, 2003)

There has been some realistic and helpful concepts such as BIM method, IPD, Knot Working and Project Big Room which I will refer to them in my research repetitively. In fact, they form the basis for my research. In this proposal I will briefly mention some of them to make my point;

Imagine applying the team locker room concept and dynamics to the design and construction of a building project, thus creating a "Project Big Room." Much like a football team in a locker room developing their game plan for an upcoming season, the entire project team (architect, engineers, contractors, and subcontractors) could use a similar philosophy and approach to design, plan, and construct a capital project. (Powell, ei pvm)

Knot working is a new way to work as a group for a short period of time to accomplish a task. It enables the client to take part in an early phase of design by actively commenting on and discussing solutions with designers, while obtaining realistic data from different design alternatives to help in decision-making. (Korpela, 2015)

There has been a presentation in Autodesk University in 2008 in which they: “demonstrate the challenges faced when coordinating large projects in multiple technologies and multiple offices where BIM documentation in Revit is the leading focus. During the review of this presentation later on, we will explore how approaching Revit with careful coordination of project managers, architects, engineers, and IT managers, combined with the reorganization of traditional team dynamics, can result in a successful Revit project.” (Autodesk, 2011)

Metropolia

Hochschule für Technik und Wirtschaft Berlin
University of Applied Sciences

**Research questions**

In this research I aim to answer these **questions**:

- What will be an ideal solution for an efficient collaboration within the construction team?
- What will be the realistic solution for an efficient collaboration within the construction team?
- Is there any tool better than the others for this purpose?
- Is there a possibility to invent an online platform or an application or software that covers all the required needs (in case the others that already exist in the market are not sufficient enough)?
- What is the possibility of enhancing the efficiency of the existing frameworks in terms of collaboration?

**Research objectives**

- To examine the assumption of an existing clear package for a teamwork in the very beginning step of the construction which is pre-design considerations in a full-efficient collaboration within the whole construction team which leads to a more efficient lean construction.
- To establish instructions for the architectural team to follow in order to work on the design simultaneously with all the other involved expertise' consultation tips.
- To draw conclusion about the applicability of the proposed ideal theory in this research to real practices.

**Method**

- Conduct a review of the literature on this subject as a feasibility study for this thesis and evaluate the needs for it.
- I am inspired by the idea of IPD (Integrated Project Delivery) in the integration consultation of all the involved parties during the project; I am hoping to find a solution to get take this idea as a base and take it into a further step in which the involvement is not only focused on the contracts but also on the design process.

- I am also greatly inspired by ideas such as Knot Working, and Big Room method.
- I am willing to prepare a questionnaire in order to have some actual data to base my theory on it, or even get some feedback about my idea.
- I am willing to consult my idea for the collaboration method with a technology specialist and run my sample in practice, if possible.

**Timescales**

- 24,04,2017 submission of the conceptual formulation
- 02,05,2017 starting the literature review
- 02,09,2017 data collection (first draft)
- 02,01,2018 data analysis (second draft)
- 02,05,2018 (final draft)
- 15,05,2018

**Resources**

I will be using information based on scientific articles which are related to my field of interest, books and my BIM and management related courses in this programme (such as Applied Product Modeling and International Site Management). I anticipate some costs for my research to take a further step to test my hypothesis in practice, but so far I do not have any financial support for that step, however this is the case for the optimistic and idealistic attitude for my research to reach that level and have a strong hypothesis which is worth the financial support and consultation from and expert. My questionnaire will probably contain questions regarding these matters,

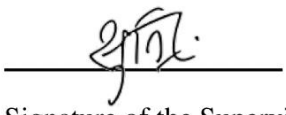
- Defining the characteristics of a comfortable and efficient framework in which the team will collaborate to reach the most efficiency and productivity that they wish.
- Defining the format of the most productive relationship between the coworkers in order to collaborate all the time.
- Defining the most convenient platform in which they will share everything including comments, votes, solutions, discussions and so on.

Metropolia

Hochschule für Technik und Wirtschaft Berlin
University of Applied Sciences

**References**


- Anon., 2011. s.l.: AutoDEsk0.
- Autodesk, 2011. Realizing the Benefits of BIM, s.l.: Autodesk.
- Dhar, G. W. Q. a., 2003.
- Korpela, J., 2015. Significance of knotworking from the client's point of view.
- Powell, S., ei pvm building design + construction. [Online].

Signature of the Supervisor

10. JULI 2018
Received by faculty

For the
Chairperson of the Examination Board

of the **Programme** ConREM
at the Hochschule für Technik und Wirtschaft Berlin

# REQUEST TO CHANGE THE TITLE OF THE FINAL THESIS

| | | | |
|---|---|---|---|
| Family Name: | Qaravi | First Name: | Razie |
| Telephone: | 15901397151 | Email: | razieqaravi@gmail.com |
| Street address: | Tempelhofer Ufer 1 B | Postal Code/City: | 10961 Berlin |
| 1st Supervisor: | Prof. Dr-Ing. Markus Krämer | 2nd Supervisor: | Sunil Suwal |

I wish to request for the following change to the title of my thesis.

**Previous title:**

Teamwork Design in BIM (the efficient method for the construction team to exchange data in the design process)

**New title to be confirmed:**

Agile Project Management within BIM based Common Data Environment

Please note that changing the title of the final thesis does not constitute a rejection of the topic as defined by § 21, no. 2 of HTW's Examination Framework Regulations!

**Agreement** of the 1st examiner:

**Agreement** of the 2nd examiner:

**Agreement of the examination board**:

Berlin, 30.06.2018

Signature of the candidate

*[Explanation for change of the title of the master thesis]*

The initial topic of this research has been Teamwork design in Building Information Modelling (The Efficient Method for the Construction Team to Exchange Data in the Design Process)**.** The literature review has widened the information regarding the team collaboration platforms in Building Information Modelling by clarifying the fact that the team collaboration is not a challenge specific to the design phase. A traditional phase-oriented process for the project management provides less flexibility to changes and follows a linear routine with every phase and detail specified in the beginning, whereas there might be some critical points in a project in which there is a need for re-alignment with business strategy and market's updated demands. In such critical situations a more flexible methodology like Agile could provide a more beneficial solution. In fact, the more the construction industry evolves towards complexity and technology the greater is the need for a more flexible and collaborative process.

Therefore, the integration of the Agile methodology with Building Information Modelling technology with a focus on the collaboration environment has been chosen as the topic of the research to substitute the initial topic.

## Abstract

This research is intended to extract the similarities of the Agile project management and the BIM project management methodologies and examine the possibility of adapting the Agile Scum framework into the Common Data Environment of a BIM project to which will be referred as the Scrum BIM Synthesis in this research.

The first part of the research reviews the literature on Agile and BIM separately in order to obtain a thorough understanding of both, after which the main common interests of them have been extracted and further refined to form the Scrum BIM Synthesis. According to these shared interests, Common Data Environment would be a suitable context for their synthesis to take place.

Specific adjustments for the Common Data Environment structure and some refinements for the Scrum rules have been suggested in order to enable the adaption of Scrum within a BIM based Common Data Environment. These suggestions are made in the form of conceptual screenshots of the Scrum BIM Common Data Environment at specified points of the process, and in the form of redefined structure for the Scrum BIM Common Data Environment as well. Furthermore, the metrics to control the Scrum process that are obtained from the literature review have been tailored for monitoring and controlling the Scrum BIM process and ranked by the interviewees to bring out the five most effective and applicable metrics to the Scrum BIM Common Data Environment.

Through the result evaluation process for which a few interviews have been conducted the suggested collaboration platform has been further defined and the practical challenges of implementing it have been examined.

## Table of contents

# Table of Figures

# List of Tabulations

# List of Abbreviations

| | |
|---|---|
| CDE | Common Data Environment |
| BIM | Building Information Modelling |
| IT | Information Technology |
| AEC | Architectural Engineering Construction |
| FM | Facility Management |
| PD | Project Development [1] |
| 3D | Three Dimensional |
| EIR | Employer’s Information Requirements |
| PIM | Project Information Model |
| AIM | Asset Information Model |
| BCF | BIM Collaboration Format |
| IFC | Industry Foundation Classes |
| PMI | Project Management Institute |
| PMBOK | Project Management Body of Knowledge |
| SP | Story Points [2] |
| MA | Mutual Assessment |
| PBI | Product Backlog Item |

[1] Only in this paper with the purpose of facilitating the drafted tables including the phrase.
[2] Story Points are sprint tasks committed to being completed during a sprint picked up from the product backlog. The phrase is widely used in Agile Software Development.

# 1. Introduction

Over the last decades the construction practices have evolved significantly. The evolution to more complex construction methods has made the earlier knowledge inadequate without far more explicit methodology. Therefore, the construction industry has been highly affected by the wave of transition towards explicitly. Complex projects require different problem-solving treatments since there are too many inter-related control points with opportunities for small decisions which might result in exponential failures.

Building Information Modelling (BIM) followed by a growing number of software, updated file formats, information exchange platforms and visualization tools have been introduced regarding linking the individual efforts to a central database to improve the interactions within the team members which results in more precise and accurate details with lower possibility for unexpected errors during the construction process.[3] BIM as a technology-based process has made it easier for the involved experts to collaborate using a virtual 3d Model of the building in advance to its construction to manage data [4] and efforts linked to the Digital 3D Model in and around a central data-based platform which is a Common Data Environment including all the graphical and nongraphical information regarding the building process.[5]

However somehow there is a lack of flexibility towards business realities and ability to adapt constant feedbacks from internal and external stakeholders such as the client and the end-user in to the building process which might require a continues design in a back and forth manner with the full involvement of the stakeholders. In other words, for such flexibilities, considering an Agile method seems to be far more practical than following a Waterfall Progress[6] which is a pre-defined and pre-designed method with all the details planned in the beginning, resulting in less flexibility for changes throughout the process. Somehow the necessity of this consideration has been neglected*,* whereas withholding

[3] (Autodesk, 2017).
[4] (British Standard, 2013).
[5] (PCI, 2009).
[6] The PMBOK does not precicely prescribe a development approach, however the Waterfall methodology is the most common and accepted approach Scrum framework could also be adapted into it with a few adjustments and a few definitions are made clear.

to constantly direct the project towards the business demand with total involvement of all the stakeholders in the project process jeopardize the project resources due to a non-aligned process with the business demand driven strategy, end-user needs, and investment interests.

Agile methodology suggesting a feedback loops in the design process appeared in the IT industry as a solution to match the speed of the project with demand development, highlighting the fact that the business demand development requires the project team to align itself with the updated business strategy according to the stakeholders'[7] feedbacks received after each Sprint[8]. Although there has been some theoretical research around the BIM Agile integration[9], Somehow there has not been a clear technical approach to implement this methodology into a BIM construction project which functions in and around a Common Data Environment. Therefore, this thesis proposes a research to address this concern and if possible present an efficient method for this matter.

The research begins with stating the research question, objectives and assumptions in the first chapter followed by methodology which is explained in the second chapter. Chapter three includes the gathered information from the literature review which is divided in to three sub-chapters for BIM, Agile, and BIM Scrum literature. Chapter four is offering the treatment for the stated research question by providing a table for the Scrum BIM synthesis and further on provide a conceptual screenshot to treat the highlighted cross-sectioned categories of the table. The results of this treatment will be evaluated through interviewing experts of the filed. And the overall conclusion will be covered in chapter sixth.

[7] Internal and external stakeholders including the owner or the client, the end-user, the investors and the project management team itself.
[8] A phase defined in the PMBOK could be equal to a Scrum Release and the sub-phases can be dividied into one or more sprints. The assumption is to consider each sub-phase of sprint as a complete cycle of design, development and test.
[9] Will be discussed in 3.3 BIM Scrum, (P.34).

### 1.1 Research Question

Given this background and the aforementioned concern, the research question of this thesis is as follows:

- How can an Agile method be implemented into the Common Data Environment of a BIM project in order to benefit from the flexibility to the business realities and sheer involvement of the stakeholders by enabling a continuous design[10] according to the feedback loops[11]?

The research question can be divided into more objective questions as follows:

1. What are the criteria to adapt the Agile methodology throughout the lifecycle of a BIM based project? Which points of the project require total involvement of stakeholders and receiving their feedbacks to improve?

2. Which tools of the Agile method are applicable to the BIM project using a CDE as the communication and data exchange platform? And in which parts of Agile methodology could CDE be beneficent?

3. Can Common Data Environment be used in an Agile context as the environment in which the Agile meetings[12] take place and the information before the Sprint such as backlogs or after the meeting such as the Sprint Demo can be shared?

4. Is there a way to draw a conclusion about the applicability of this paper to real practices? Does this method and the taken steps and the achieved conclusion make sense to experienced experts of the discussed fields?

---

[10] Back and forth via feedback loops.
[11] A sequential and phase-defined process in which there is no flexibility to change when the previous step is done. According to HOAI the pre-planning, planning, construction, monitoring and cost management and all follow a sequence in which the further the process progresses, the more detailed it gets, and the less change is possible.
[12] Scrum Sprints.

### 1.2 Research Objective

The aim of this research is to address the aforementioned questions[13]; hence, the goal is to do as follows:

- Determining the applicability of a BIM Agile synthesis within the Common Data Environment for all the stakeholders to benefit from.

In order to achieve this aim, the following steps are considered to be taken:

1. To review the literature about BIM project management as well as Agile metrics and the Scrum method[14] framework in the Information Technology (IT) industry[15]
2. Adapting Scrum into the BIM Common Data Environment
3. Determining the metrics that could be used to monitor the Scrums within a BIM project in a Common Data Environment
4. To interview experts in the field of IT and BIM Project Management to evaluate the conducted synthesis method and the resultant conceptual Common Data Environment screenshots, and to collect reliable data regarding the chosen metrics to control the method.

[13] Mentioned earlier on 1.1 Research Question, (P.3).
[14] The Scrum approach to agile software development marks a dramatic departure from waterfall management by emphasizing on collaboration, functioning software, team self-management, and the flexibility to adapt to emerging business realities. Scramble throws all the waterfall traditional phases in the blender and divides the work to fixed length integration mixtures of all ingredients called sprints (scrummethodology, 2016).
[15] Quantitative and qualitative.

### 1.3 Research Assumptions

BIM is a widely defined method which consists of tools and techniques for addressing the problems related to sharing of information and collaboration throughout the lifecycle of the building. To achieve the answers of the initial research question it would be appropriate to narrow it down to the area in which brainstorming meetings are held in response to an Agile up coming. In other words, at any point of the project in which re-alignments with the business strategy and the client demand are required such as the milestones of the project.

Other criteria for the Agile methodology to be applied into a project could be the number of participants. Complex projects with high number and variety of stakeholders[16] require a different method to have them all involved in the process and take their feedbacks into consideration.

Even though the literature review covers the entire process of the BIM project, but the methodology targets the Scrum BIM synthesis regarding the constant deep involvement of the team through CDE. Furthermore, the desired method to do this enables further specification into the approach by categorizing BIM and Scrum into phase-oriented divisions in the same table that presents both and cross section the overlapping phases to address their synthesis complexities more precisely.

[16] The stakeholders, main client, consultant, contractor and the subcontractors are all the numerous participants of a project who will be far better structured and organized following Agile Guidelines discussed further in this paper.

## 2. Research Method

This chapter describes the methodology implied to answer the research question which per already mentioned[17] is as follows:

- How can an Agile method be implemented into the Common Data Environment of a BIM project in order to benefit from flexibility to the business realities and sheer involvement of the stakeholders by enabling e continuous design[18] according to the feedback loops[19] ?

The methodology consists of the following research steps as indicated in Figure 1. The initial research step is the selection of sources of information in which all the literature topics that could contribute to the development of the research are identified. Data collection for this project consists of the literature review described in Chapter Three. The gathered necessary information contributes to the Agile BIM integration approach which is described in Chapter Four. The outcome of this suggested Agile BIM integration is to be evaluated through some interviews in Chapter Five. The summary of the last two chapters will shape the conclusion chapter in which the whole outcome is summarized.

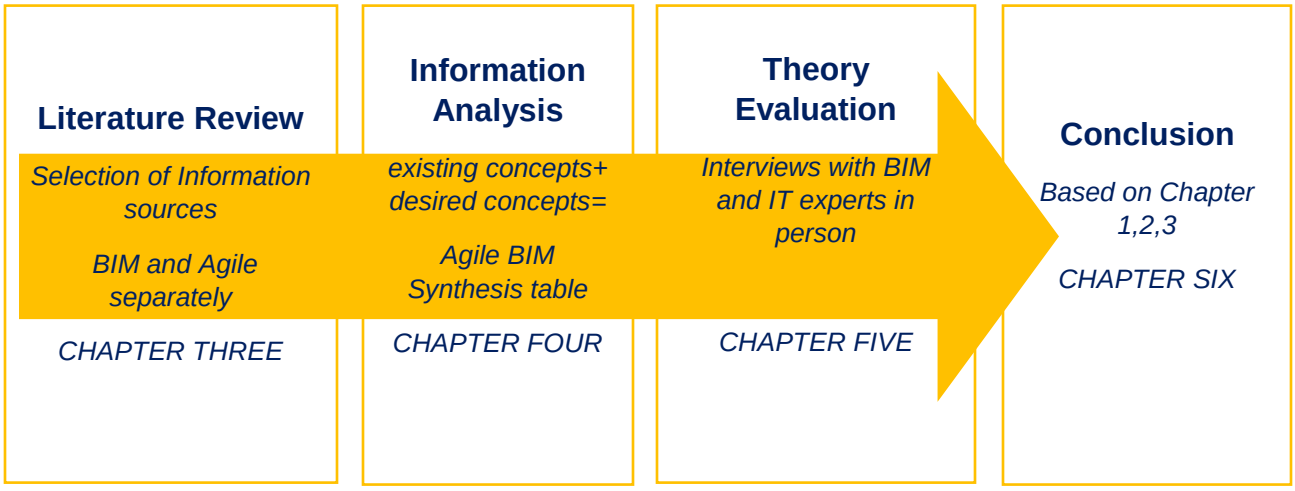



**Figure 1.** Methodology steps of the paper. Drafted by the Author.

[17] Research Questions, (P.3).
[18] Back and forth via feedback loops.
[19] A sequential and phase-defined process in which there is no flexibility to change when the previous step is done. According to HOAI the pre-planning, planning, construction, monitoring and cost management and all follow a sequence in which the further the process progresses, the more detailed it gets, and the less change is possible.

## 2.1 Literature review

Through the literature review the information for the basis of the suggested treatment in this paper have been gathered in chapter 3. The chapter includes 3 sub-chapters. The first sub-chapter focuses on BIM and the collaboration facilitation that it brings about through Common Data Environment (CDE) and Building Collaboration Format (BCF). This part of the research is intended to widen the Author's knowledge about the virtual communication platforms that are used to facilitate the collaboration, organize data and exchange information on BIM projects.

The second sub-chapter explores the Agile Methodology, it's origin and appearance in IT industry and its Scrum framework. This part of the research is intended to familiarize the Author with the Agile methodology's main concepts in order to examine the possibility of translating them into another context such as the construction industry later on.

The third sub-chapter is dedicated to studying the existing efforts to translate Agile Scrum into construction and project management. The theoretical articles and recommendations for adapting Scrum into project management have been studied and considered as the reference for chapter 4 which is the main solution finding part of the research.

As indicated in figure 2 after the thorough literature review in chapter 3 on the Agile and BIM method separately, in chapter 4 the main concepts of both are identified and analyzed. After the analysis the common points of them are extracted to form the basis of the suggested Scrum BIM synthesis in this paper.

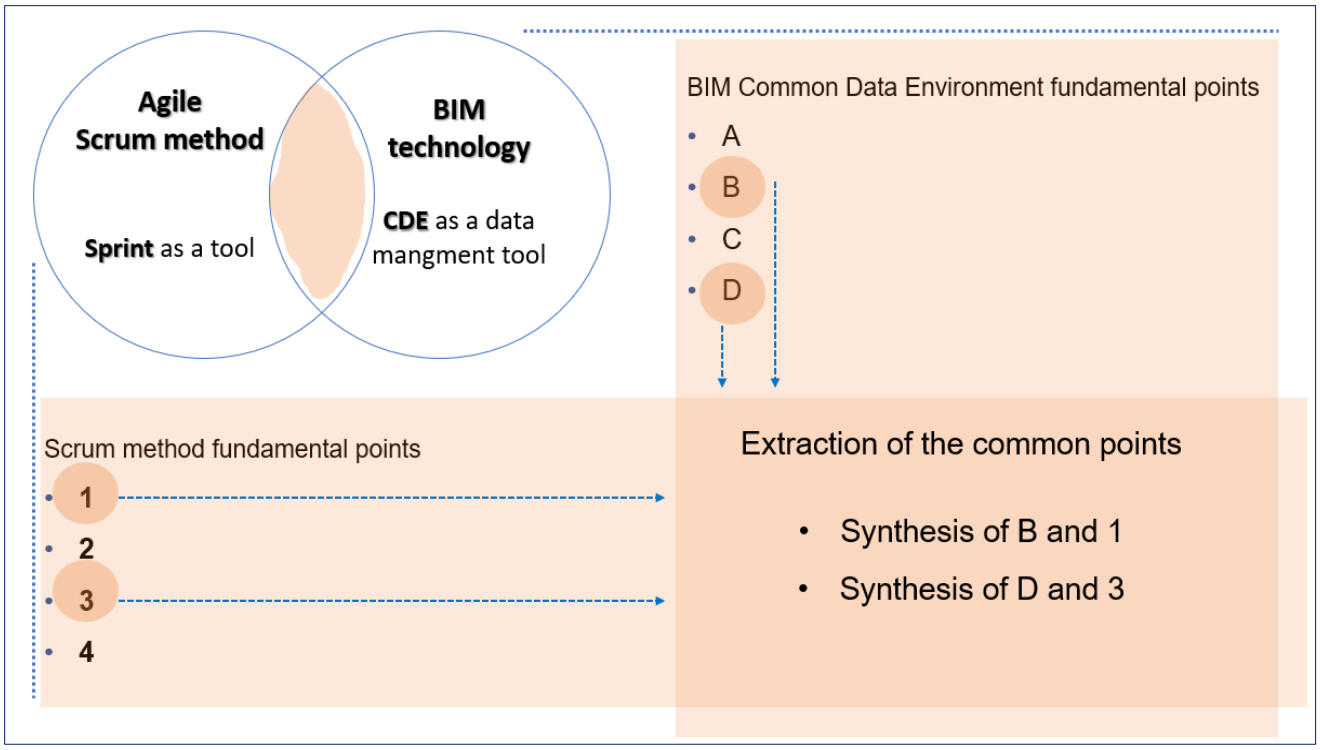



**Figure 2.** Extracting the common points of the two mehtods . Drafted by the Author.

### 2.2 Development of the BIM Agile method

In this paper it is intended to define a structure for the Agile BIM synthesis in project management using a CDE[20]. According to the literature review as indicated in figure 2 the two methodologies share some common goals and theories; even though the tools to achieve those shared interest might be different it can be imagined that the integration of the two is more likely to be a success in the project management context.

For this Synthesis to be possible this table is employed, in which the combination of two different concepts will be visible, phase-specific and convenient. As indicated in figure 3 the table is comprised of two directions presenting the approaches which are intended to be merged[21]. In this research, due to the length of the building life cycle and time shortage, treatments will only be provided for highlighted cross-sections of the table.

[20] Common Data Environment.
[21] See Figure 3, (P.9).

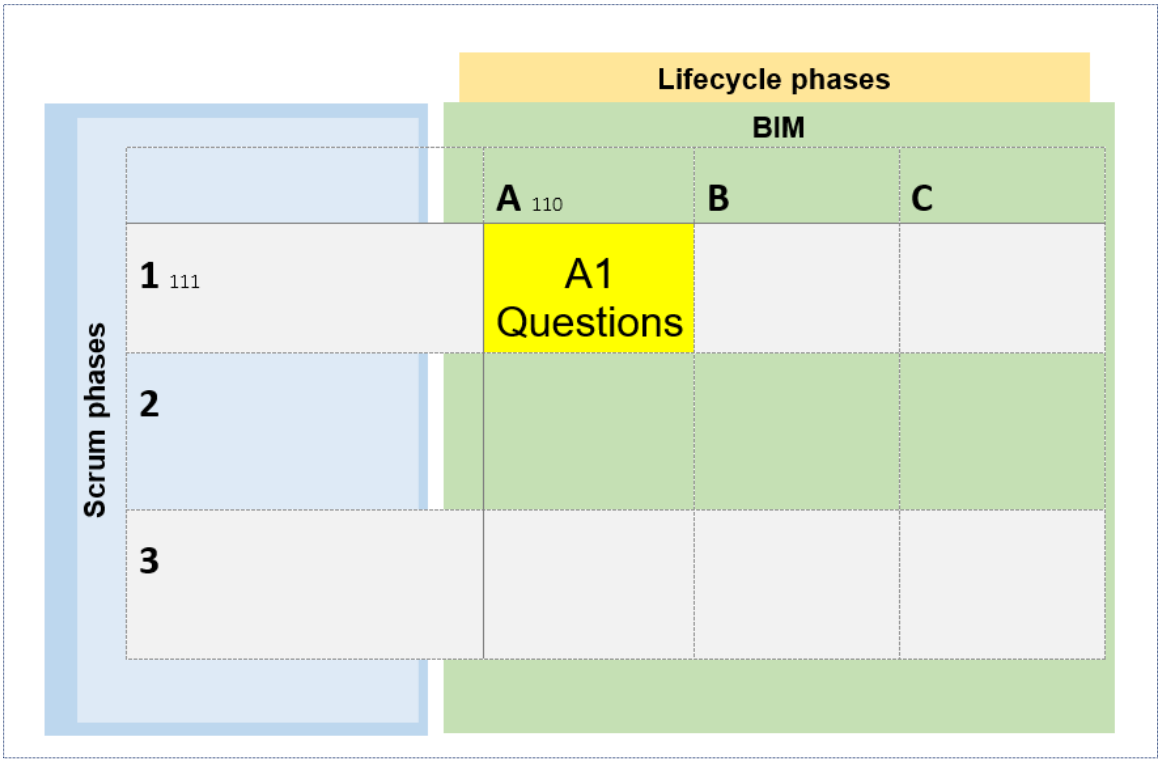



**Figure 3.** Screenshot of the Synthesis table approach drafted by the author.

### 2.3 Evaluation of the results

To prevent this research from being limited to a fully theoretical discussion and to ensure its practicality it is intended to conduct an interview to validate the method, the results or both. In order to make the evaluation process scientific and to reduce the errors, the main reached steps and the reached solution at each step leading to the further ones during the thesis will be summarized and visualized as well for the convenience of the interviewee which ensures a more reliable evaluation.[22]

[22] See Appendix 1. Interview Guide, (P.73).

### 2.3.1 Interview Type

The interviews and questions can be adapted depending on the interviewees' background or workplace. The interviews were conducted in a written form resulting in the interview transcript[23]. The interview questions were formulated such that the researcher could obtain an evaluation on the research method and the obtained metrics[24] from the literature review for monitoring the Scrum BIM process.

| |
|---|
| *1. Sprint backlog Scope-Velocity %* |
| *2. Sprint Backlog consistency -velocity %* |
| *3. Team predicted productivity -Planned to Done Ratio %* |
| *4. Team enthusiasm -happiness factor %* |
| *5. Team's understanding of Scrum 0/1* |
| *6. Team's collaboration metric- Mutual Assessment (MA) %* |
| *7. Scrum master shifting cycle 0/1* |
| *8. Customer satisfaction metric-defect rate 1/defect rate %* |
| *9. Scrum impediments- Daily clean code %* |
| *10. Scrum impediments- removing top impediment 0/1* |
| *11. Interruption precautions – Emergency procedure 0/1* |

**Table 1.** Scrum BIM monitoring and control metrics, gathered from the literature review.

[23] See Appendix 2. Transcripts of Interviews, (P.77).
[24] For the complete definition and the literature review on the metrics see 4.5 Scrum BIM monitoring metrics, (P.54).

### 2.3.2 Interview Study Sample

The sampling is purposive, to provide the researcher with an evaluation of the methodology for the Scrum BIM process and the suggested metrics in order to monitor it. The group of interviewees for this study is limited to professionals with the required theoretical and practical knowledge in the field of Agile, Scrum and BIM project management.

### 2.3.3 Interview Codification for Analysis

The interview transcripts must be analyzed to ensure validation of the results. The data must be treated with care, as the richness and complexity of qualitative data presents a challenge to the researcher to find the analytical paths needed to extract the required information. A coding method is used to offer better analysis of the transcripts of the interviews by directing the interview questions into categorizes of the subjects that require evaluation and gathering the data into categories directly connected to the research objectives and question[25]. In order to codify the interviews, the following phases of coding need to be considered[26].

I. Initial Coding: In this stage, the data is broken down into component parts with certain names or codes to explore the information and trying not to overlook information that could be valuable to the research.
II. Focused Coding: Focused coding will result in the classification of most of the information, and the elimination of many initial codes that do not fit into the predefined coding categories.
III. Theoretical Coding: This is the last step of code refinement, in which the researcher makes sense of the codes selected during Focused Coding. The process consists of structuring the codes according to the research question and aim.[27]

[25] (Bryman, 2015).
[26] (Charmaz, 2006).
[27] (Jimenez, 2017), (Bryman, 2015).

The codes directing the interview towards the objectives of the research and enabling evaluation of the obtained metrics and the suggested Scrum BIM process within CDE[28] are described in Table 1.

| | |
|---|---|
| **Personal and Organizational Background** | BIM performance experience |
| | Common Data Environment utilization experience |
| | Scrum performance experience |
| | Applied Monitoring System |
| **Methodology Evaluation** | Based on the Interview Guide |
| **Monitoring and Control Metrics' Ranking** | Capacity |
| | Consistency and Predictability |
| | Motivation and Happiness |
| | Healthy Team |
| | Customer satisfaction |
| | Scrum Impediments |
| | Emergency Plan |

**Table 2.** Basic coding strcuture. Developed by the Author.

[28] Common Data Environment.

# 3. Literature review

## 3.1 Building Information Modelling

Building Information Modeling (BIM) is a process of creating and managing a three-dimensional (3D) design model containing digital information about a built asset with the purpose of facilitating the coordination, simulation, and visualization, as well as helping owners and service providers achieve a more accurate insight to help them make more informed decisions. On a project that takes advantage of BIM, information is coordinated and consistent, creating efficiencies throughout the project lifecycle. BIM also improves planning, cost estimation, monitoring and control through easier collaboration and communication.[29]

| Architects | Engineers | Contractors |
|---|---|---|
| 1. Marketing Your BIM capability | 1. Marketing Your BIM capability | 1. Developing Collaborative Processes with External Parties |
| 2. Communications Infrastructure to Improve Model Sharing | 2. New or Upgraded Hardware | 2. Marketing Your BIM Capability |
| 3. Developing Collaborative Processes with External Parties | 3. Developing Internal Collaborative BIM Procedures | 3. BIM Training |
| 4. Developing Internal Collaborative BIM Procedures | 4. Developing Collaborative Processes with External Parties | 4. Communications Infrastructure to Improve Model Sharing |
| 5. BIM Software | 5. Software Customization/ Interoperability Solutions | 5. Developing Internal Collaborative BIM Procedures |

**Figure 4.** BIM advantages. **(McGraw Hill Construction, 2012, pp. 18-33)**.

In the United Kingdom (UK) the Government Construction Strategy stated that the Government will require fully collaborative Level 2 BIM[30] on centrally-procured public projects as a minimum by 2016[31]. BIM Level 2 is the creation of a managed 3D environment with data attached, but created in separate, distinct discipline models. These

[29] (Autodesk, 2017).
[30] Building Information Modelling here and later will be referred to as BIM.
[31] (British Standard, 2013).

separate models may originate with the client, architect, structural engineer, building services engineering, contractor, sub-contractors, suppliers and so on. A federated model is an assembly of these distinct models to create a single centralized information source of the asset[32]. Providing a digital simulation of the building enables the stakeholders and the project manager to understand the buildings behavior before it's construction which leads to significant savings in time and money.[33]

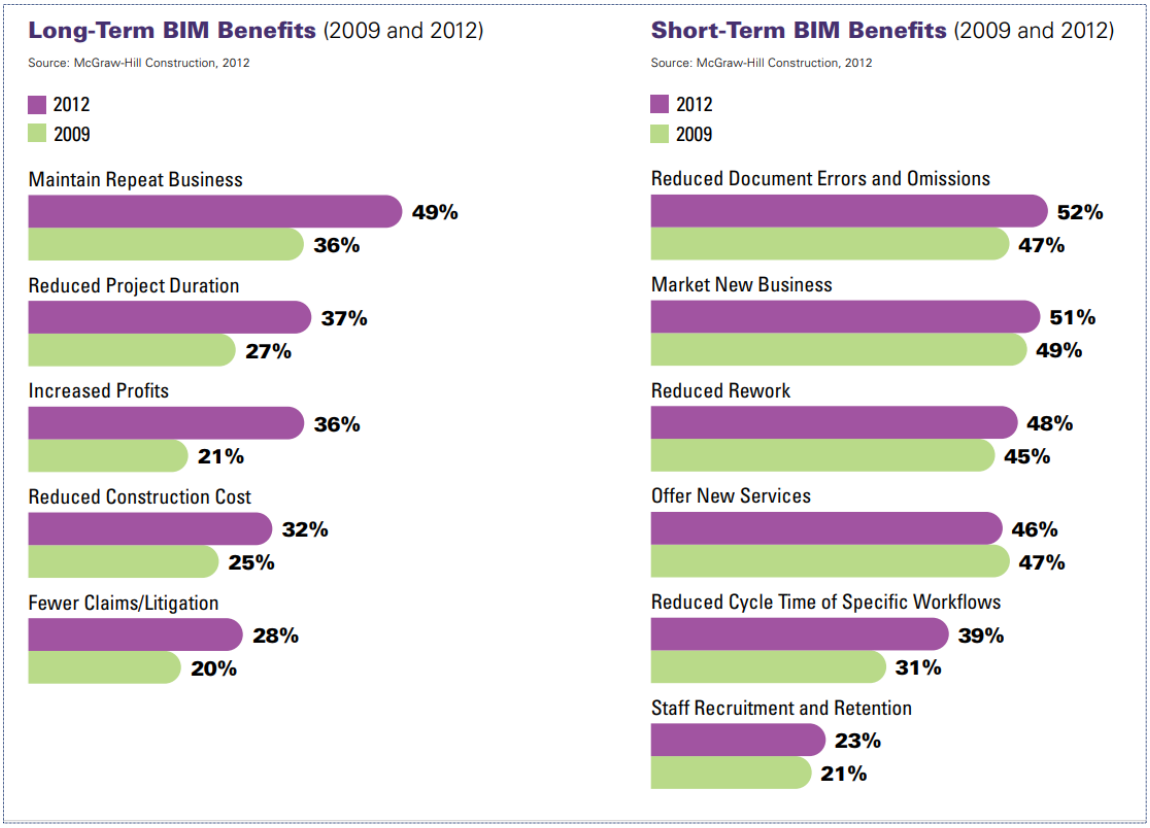



**Figure 5.** Short and Longtime BIM advantages. **(McGraw Hill Construction, 2012, pp. 18-33)**.

[32] (British Standard, 2013).
[33] (PCI, 2009).

### 3.1.1 Common Data Environment in BIM

Structuring the poorly coordinated information of a typical construction project is estimated to eradicate 20-25% cost waste from it[34]. The key to well-structured data is a Common Data Environment (CDE); an online place for collecting, managing and sharing information amongst a team working on a project. The CDE form depending on the project size and type could vary between a project server, an extranet or a cloud-based system. The graphical model and non-graphical data for the whole project team[35] builds up a foundation from which project information between multi-disciplined team flows in a managed process throughout the project lifecycle and helps avoid duplication and mistakes[36]. The CDE is not just a place to share geometric information. Other information such as registers, schedules, contracts, reports and model information are all shared, building on the concept of a federated model by bringing everyone's information together in a virtual space.[37]

The process begins with the Client's authorized Employer's Information Requirements (EIRs). This document states the required information from the team at key points of the project[38] for the Client to make decisions. Individual project contributors will start developing graphical and non-graphical information on their own "Work In Progress (WIP) areas". When approved this information is moved to the "Shared area" for further access and use in developments done by the other parties. In BIM Level 2, whilst others may re-use information, the ownership and power to change the information remains with its originator. At key project decision points such as at the milestones, the Employer or Employer's Agent approves and signs-off information before moving it to the "Published area" in order to ensure the alignment of the project with the Client's stated requirements in their EIRs. The published information can then be used to engage specialists. They are able to work in similar "Work-In-Progress" areas to the design team before sharing their

[34] (British Standard, 2013).
[35] (i.e. all project information whether created in a BIM environment or in a conventional data format).
[36] (what is Common Data Environment, 2015; designing buildings, 2018).
[37] (Mordue, 2015).
[38] Including during its operation and use.

approved contributions. As each project milestone is met, published information is moved to the 'Archive' area for future reference and use such as the asset management phase.[39,40]

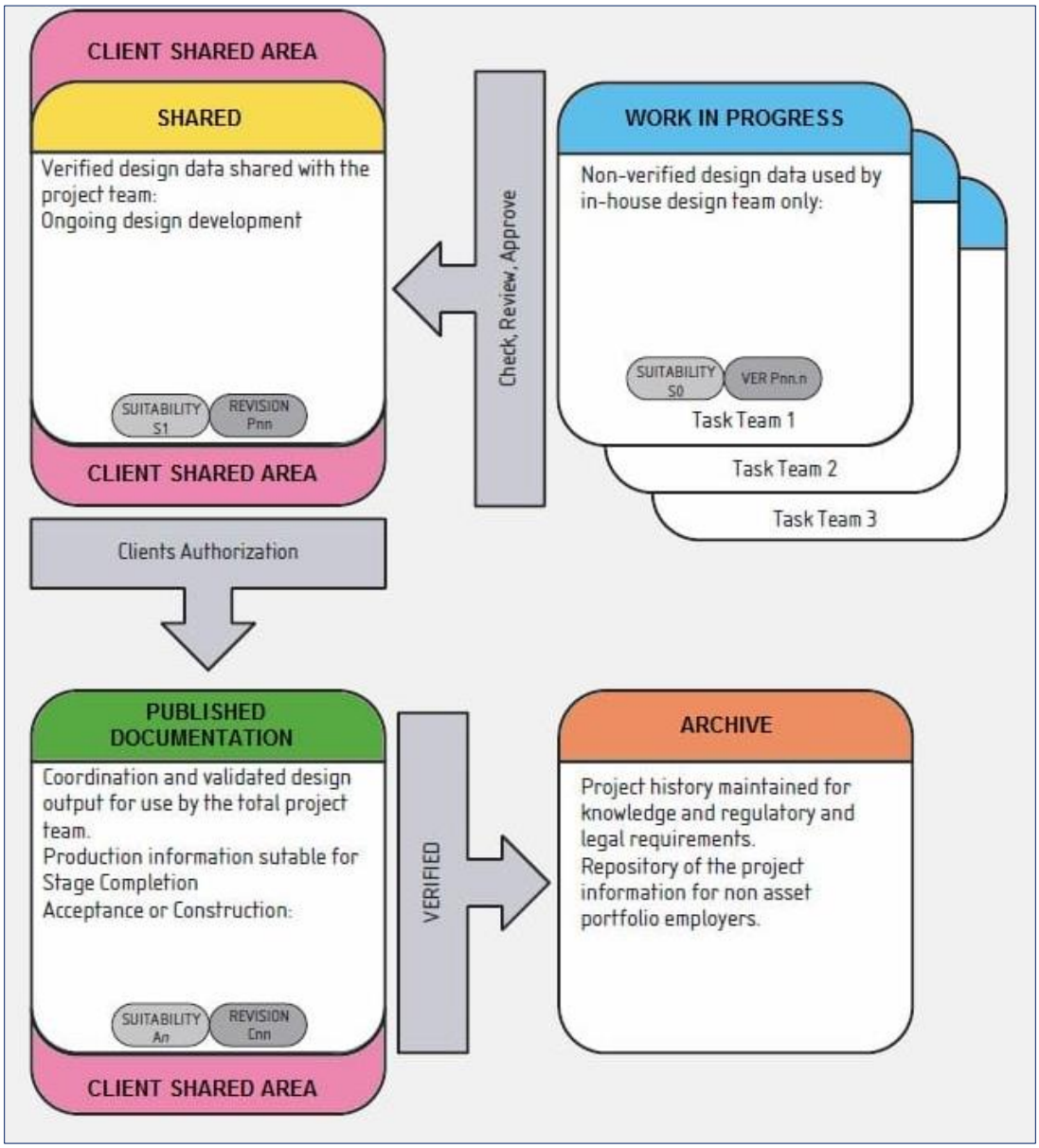



**Figure 6.** The common environment (CDE) strcuture. **(British Standard, 2013)**

[39] Known as an Asset Information Model (AIM).
[40] (British Standard, 2013).

Generally, a license is granted to the client to use the information contained in the separate models for the permitted purpose[41]. A sub-license from the client enables project team members to use models prepared by the others. The UK Construction Industry Council (CIC)[42] BIM protocol proposes that an information manager, appointed by the client, should set up and manage the CDE. The information manager is essentially a procedural gate-keeper, policing the CDE to ensure that it follows the agreed protocols and that the data is secure. They are not a BIM coordinator and have no design responsibility and no responsibility for clash detection or model coordination. The common data environment may include a number of different information environments. It may include a supply-side CDE used by the project delivery team, and an employer's information environment that provides an employer-side document and data management system for the receipt, validation and approval of project information delivered by suppliers. Responsibility for supplying and managing the supply-side CDE should be stated in the Employer's Information Requirements (EIRs).[43]

Whilst this may sound complex, on small projects, the CDE might simply be common folders on server, or may use a free, web-based file sharing application. Even on large projects, where sophisticated software might be used, during the early stages of the project it might simply be matter of creating four folders in which files are stored, with files named in accordance with a standard naming protocol. It should be noted that the CDE itself is not collaboration tool, although it may be used with one or more collaboration tools.[44]

[41] (ie for the purpose for which that level of detail of information was intended).
[42] Construction Industry Council Supporting the UK Government Strategy for BIM implementation defined a standard protocol for BIM use in Projects in UK.
[43] (British Standard, 2013).
[44] (designing buildings, 2018).

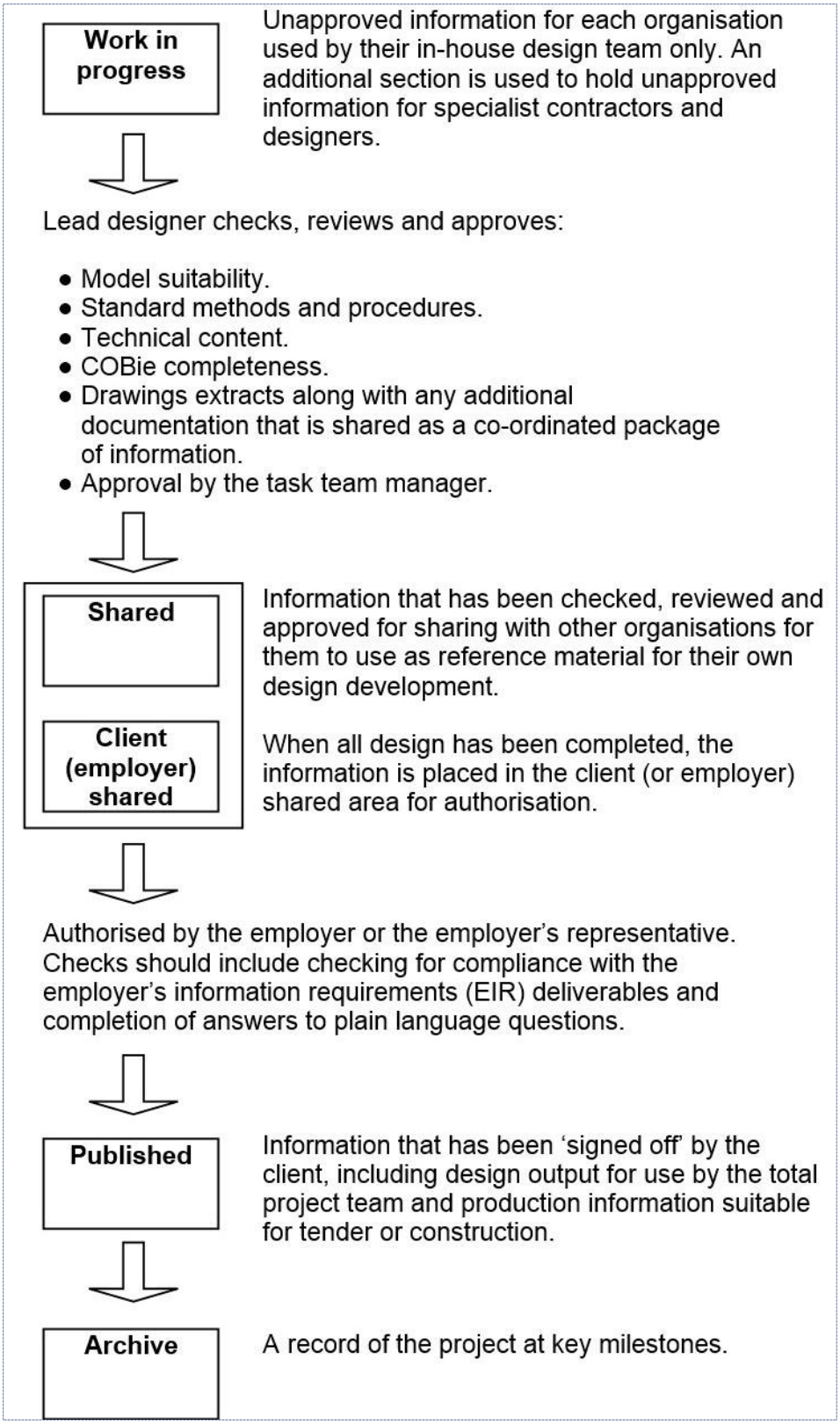



**Figure 7.** Common structure of a Common Data Environment. **(designing buildings, 2018)**

### 3.1.2 BIM Collaboration Format

Construction projects might have team members who are applying different applications, work in different companies, have different specialties and so on. When issues arise during a project and it is required to be addressed by collaboration of such different parties. Industry Foundation Classes (IFC) is the key in such situations. It enables exchanging the actual models via an 'open standard'. IFC contains data linked to the main building model and its objects and is therefore not suitable for documenting issues or workflows; hence there is still the challenge of transmitting the issue.[45]

The Building Collaboration Format (BCF) was first introduced by Solibri.Inc and Tekla Corporation in 2009. They presented the idea of enabling the communication related to the issue with an open file format between the BIM set software. BCF was developed which encodes messages designated to a party in order to be fixed. Using BCF enables the team members to separate the issue tracking communication from the communication that is directly related to the BIM model. Therefore, the file does not include the BIM file which facilitates the messaging process.[46]

BCF allows additional textual comments, screenshots and more, on top of the IFC[47] model layer to be sent as a message for further communications. viewpoints, selected objects, snapshots, and comments that have been saved into a BCF can be used in any modeling software in order to open the file and check out the referred issue and its position in the BIM model.

The use of BCF improves the workflow and eliminates the need to transfer large BIM files over the Internet. BCF has been submitted to BuildingSMART under the new "Affiliation Scheme" to become an official buildingSMART specification. Solibri Model Checker, MagiCAD, Tekla Structures, Tekla BIMsight, DDS, and many other BIM tools support BCF.[48]

---

[45] (BIMcollab, n.d.).
[46] (BIMcollab, n.d.).
[47] Industry Foundation Classes here and later referred to as IFC.
[48] (BIMcollab, n.d.).

BCF Managers are plugins for the BIM tools offered by BIMcollab[49]. BIMcollab is an issue collaboration platform for BIM, built on the widely accepted IFC and BCF open standards. BCF issues contain all relevant information enabling communication about BIM models. They enable the team to create, filter and lookup issues directly in the BIM model, save and load those issues from BCF files or synchronized from BIMcollab, Share issues with team members whether they are working with the same or different BIM tools. All features of BIMcollab are supported in the BCF Managers, like private issues, notify, approval-workflow, filtering, favorites etc. BCF Manager enables. BIMcollab simplifies issue management, and offers a structured way of storing, sharing and solving issue including reliable history tracking in any BIM development process.[50]

[49] BIMcollab is a BIM issue management in the cloud.
[50] (BIMcollab).

## 3.2 Agile Strategy

### 3.2.1 Appearance of Agile Movement in the Software industry

**The Application Development Crisis**

In 1990 Software Development faced a crisis regarding matching the speed of a business need and an actual application production. At the time experts estimated that the time gap between the two is at least three years whereas business was accelerating to upgraded requirements, systems and even the entire nature of it.[51]

1970 to 1990 was the era in which the fundamental theories and practices regarding project development and software engineering such as the waterfall methodology[52] appeared. In waterfall methodology all the requirements and planning phases must be done before moving on to the execution phase; like a waterfall stream moving only downhill, this methodology rarely supports provisions and returns to the earlier steps of the project. But in reality, business needs would have changed overnight which made the speed of the traditional waterfall process inadequate. Furthermore, it seemed impossible to define all the requirements and details in the beginning with no further upgrades from the business changes or user feedbacks. The users were able to describe their desired software based on their workflow but transferring their needs to an actual working code required far more details and provisions. The inability to precisely define the process separated software engineering from most other engineering disciplines which were benefitting from the waterfall approach.[53]

---

[51] (Dove, 1996).

[52] A sequential and phase-defined process in which there is no flexibility to change when the previous step is done. According to HOAI the pre-planning, planning, construction, monitoring and cost management and all follow a sequence in which the further the process progresses, the more detailed it gets, and the less change is possible.

[53] (TechBeacon, n.d.).

**Agile Manifesto** the Snowbird meeting in Utah in 2001

These frustrations led to a gathering of twelve experts[54] in the Snowbird meeting in Utah in early 2001 during which Agile was born. These thought leaders tried to bridge the gap between the business needs and the software development by releasing a Manifesto and introducing a fast and safe delivery approach referred to as Agile. As stated in the Manifesto Agile approach enables users to experience the software faster which informs the team with rapid feedbacks on the software scope and its direction. Rapid feedback and willingness to adapt the needs and feedbacks in to the process are the key features of the agile movement. Since the team is unable to fully determine the user needs, it delivers a first approximation and then listens to feedback. Perhaps various agile and iterative techniques would still be in the minority were it not for the Agile Manifesto, codified at that 2001 meeting in Snowbird. This Manifesto is one of the clearest statements and guidelines to this approach. the software development community has been following the Agile Manifesto and its twelve principles[55] ever since.

**Scrum Software Development Process**

In 1990 Jeff Sutherland and Ken Schwaber conceived the scrum process which is a more specific iterative methodology driven from the Agile movement. The term Scrum was adapted from Rugby huddle act and referred to a team working together to reach a common goal. They codified Scrum in 1995 and published it under the title of SCRUM Software Development Process. It suggested that within complex production projects the best results occur when small and self-organizing teams are given objectives rather than specific assignments because the team had the freedom to determine the best way of meeting those objectives. Scrum also defined time-boxed iterative development cycles whose goal was to deliver working software.[56]

[54] This group included Kern, Extreme Programming pioneers Kent Beck and Ward Cunningham, Arie van Bennekum, Alistair Cockburn, and twelve others, all well known today in the agile community.
[55] (Beck, et al., 2001).
[56] (Sutherland, et al., 2014).

Scrum's goal is to deliver as much quality software as possible within a series (three to eight) of short time boxes (fixed-time intervals) called Sprints that last around a month and release a working piece of software for review at the end. All the stages of a waterfall process are now mapped to short-time sprints while some traditional development stages are retained for convenience tracking the milestones. In other words, Analysis, Design, and Evolution all take place during one sprint. In Software development typically, the Requirements stage may use one Sprint, the Analysis and Design stage may take one Sprint each, while the Evolution stage may take anywhere from three to five Sprints. In recent years, release cycles have shortened to three months or less for most software products.[57]

Each sprint operates on a number of work items called a Backlog. As a rule, nothing is added externally to the allocated Sprint Backlog during the Sprint. External additions are only added to the global Backlog, but blocks (unresolved issues) resulting from the Sprint can be added to the allocated Sprint Backlog. A Sprint end with a demonstration (Demo After Sprint) of new functionality. This gives the developers space to be creative, to learn by exploring the design space and by doing actual work. At the same time, this keeps management and other project stakeholders confident by showing real progress instead of documents and reports produced as proof of progress. The net result is that each sprint produces a visible and usable deliverable that is shown to the users at the demo (Demo After Sprint). An increment can be either intermediate of shippable, but it should stand on its own.[58]

[57] (Beedle, et al., 2014).
[58] (Beedle, et al., 2014).

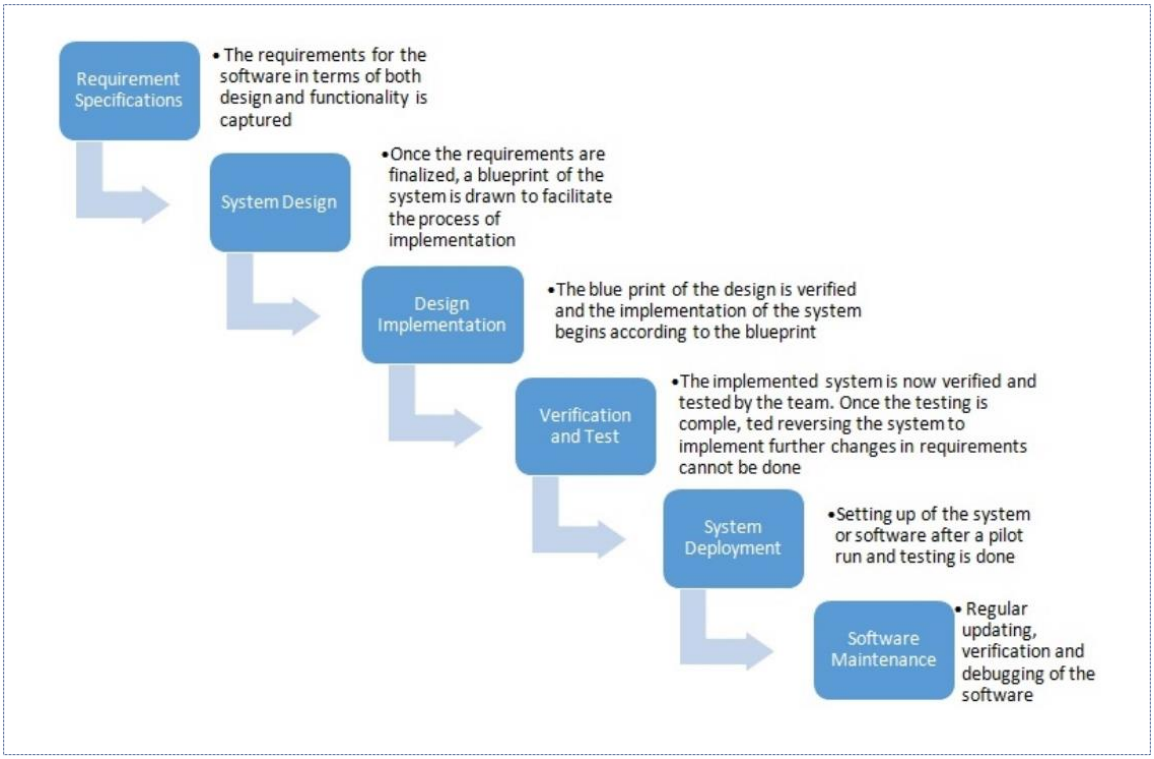



**Figure 8. The** Traditional and phase-oriented, and subsequential „waterfall“ development **(Kukhnavets, 2016).**


**Figure 9.** The fixed intervals of Scrum Sprints by blending all the phases together for each interval. **(James, 2015)**.

The result is a high degree of Effective Ownership by the participants, which in this case means both empowerment and the involvement of all the participants. At the end of a Sprint, during a review session, the supervisors have the opportunity to change the planning for the future. The project is totally flexible at this point. Target, product, delivery date, and cost can be redefined.[59]

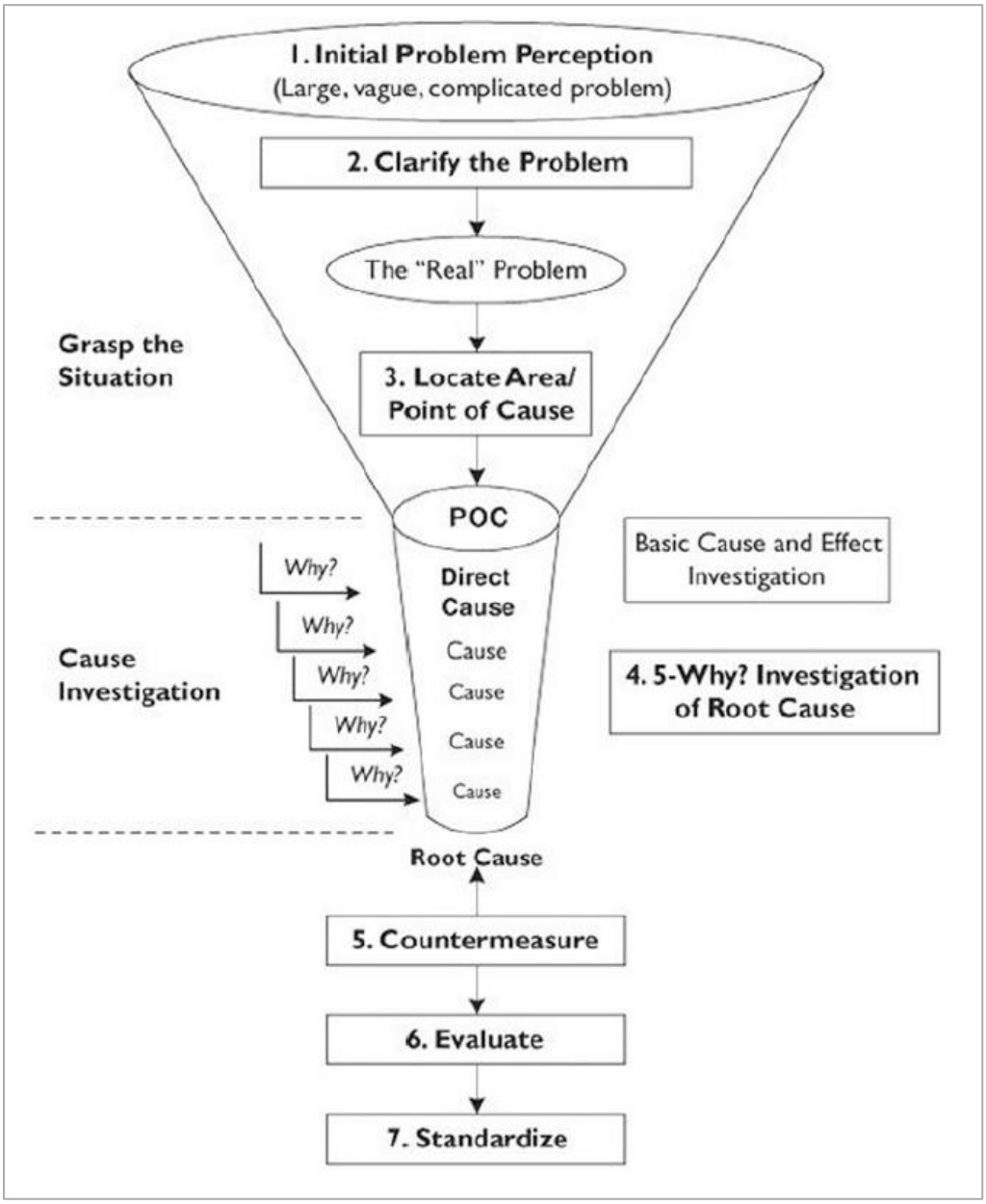



**Figure 10.** Scrum workflow. **(Sutherland, et al., 2014)**

[59] Scrum enables a large amount of post-planning flexibility (for both customer and developer).

## Scrum Metrics

Every year at the Scrum PLoP conference[60] newly discovered Patterns are proposed and examined through an editorial process by some of the most influential minds in the Scrum community. Eventually, when approved they will be added to the Scum Patterns which currently includes 1. Stable teams , 2. Yesterday's Weather , 3. Swarming , 4. Interrupt Pattern , 5. Daily Clean Code , 6. Emergency Procedure, 7. Scrumming the Scrum, 8. Happiness Metric, 9. Teams That Finish Early, Accelerate Faster.[61]

[60] ScrumPLoP is a PLoP® conference. It will be a gathering of experienced Scrum practitioners, assembled with the goal of contributing to the body of pattern literature with proven practices. (Source: www.scrumplop.org).
[61] (Sutherland, et al., 2014).

### 3.2.3 Scrum Rules

Scrum's early advocates were inspired by empirical inspect and adapting feedback loops to cope with complexity and risk. Scrum emphasizes decision making from real-world results rather than speculation. Scrum is a simple set of roles, responsibilities, and meetings that never change.[62]

**Sprint Planning Meeting**

At the beginning of each Sprint, the Product Owner and the team hold a Sprint Planning Meeting to negotiate which Product Backlog Items require to be converted to working product during the next upcoming Sprint. Due to the Product Owner's priorities and the business strategy the most important factors are stated. The scrum team choses the amount of work that can be delivered according to the previous and expected functionality level of the team on the upcoming Sprint. In other words, the team "pulls" work from the Product Backlog to the Sprint Backlog. Toward the end of the Sprint Planning Meeting, the team breaks the selected items into initial list of Sprint Tasks.[63]

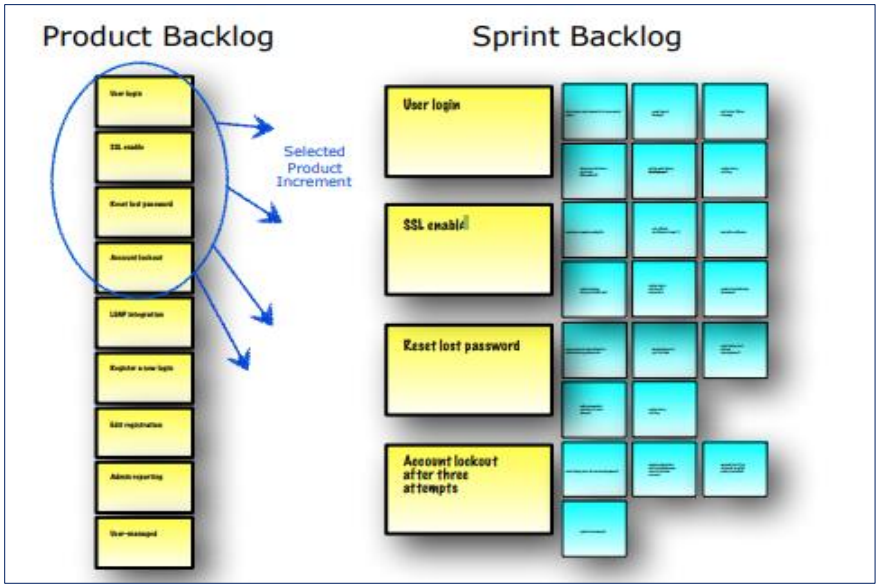



**Figure 11.** Product, Sprint Backlog, and Sprint Tasks. **(James & Walter, 2010)**

[62] (James, 2015).
[63] (James & Walter, 2010).

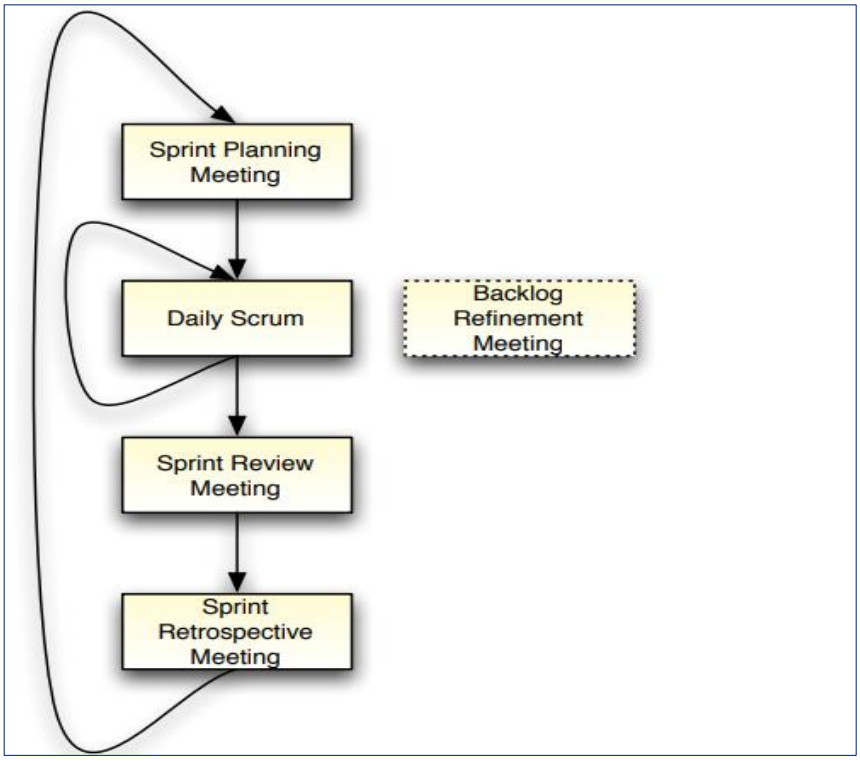



**Figure 12.** Scrum ceremonies. **(James & Walter, 2010)**

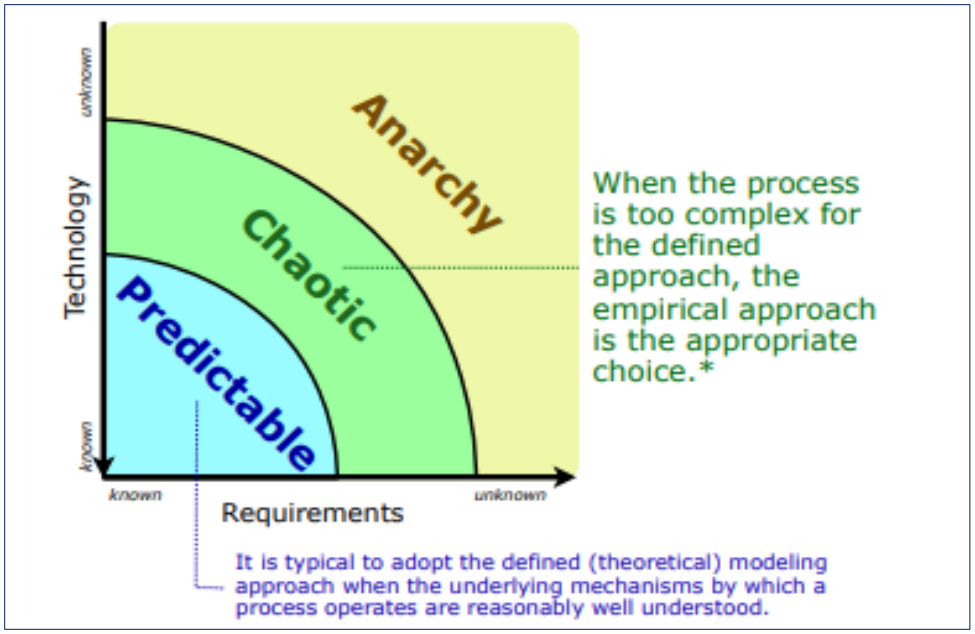



**Figure 13.** Requirements for Scrum. **(James & Walter, 2010)**

| Scrum Development Team | Product Owner | Scrum Master |
|---|---|---|
| • Cross-functional (e.g., includes members with testing skills, and others not traditionally called developers: business analysts, designers, domain experts, etc.) | • Single person responsible for maximizing the return on investment (ROI) of the development effort | • Works with the organization to make Scrum possible |
| • Self-organizing / self-managing, without externally assigned roles | • Responsible for product vision | • Ensures Scrum is understood and enacted |
| • Plans one Sprint at a time with the Product Owner | • Constantly re-prioritizes the Product Backlog, adjusting any longterm expectations such as release plans | • Creates an environment conducive to team self-organization |
| • Has autonomy regarding how to develop the increment | • Final arbiter of requirements questions | • Shields the team from external interference and distractions to keep it in group flow (a.k.a. the zone) |
| • Intensely collaborative | • Decides whether to release | • Promotes improved engineering practices |
| • Most successful when located in one team room, particularly for the first few Sprints | • Decides whether to continue development | • Has no management authority over the team |
| • Most successful with long-term, full-time membership. Scrum moves work to a flexible learning team and avoids moving people or splitting them between teams. | • Considers stakeholder interests | • Helps resolve impediments |
| • 6 ± 3 members | • May contribute as a team member | • Has a leadership role |

**Table 3.** Scrum Roles[64]. Created by the author. **(James & Walter, 2010)**

[64] (James & Walter, 2010).

### Sprint Review Meeting

At the end of the Sprint, the Scrum Team holds a Sprint Review Meeting to demonstrate a working product increment to everyone who is interested. This meeting is the appropriate meeting for external stakeholders (even end users) to attend. It is the opportunity to inspect and adapt the product as it emerges. The meeting should feature a live demonstration, not a report. The Product Owner reviews the sprint backlog scope and presents the related resulting Demo of it. A Demo will give the costumer an opportunity to react to the process by trying a piece of functioning software to discover what they will truly want. This value-driven approach allows the creation of products that couldn't have been specified up front in a plan-driven approach.[65]

### Sprint Retrospective Meeting

The Sprint ends with a retrospective meeting during which the team evaluates itself and the process. They inspect and monitor their behavior and take controlling actions for the next sprints. A truly deep and effective retrospective requires a psychologically safe environment to avoid the uncomfortable issues or deterioration. A main impediment to achieve such an environment can be the presence of people who conduct performance Another impediment to an insightful retrospective is the human tendency to jump to conclusions and propose actions too quickly[66]. Another guide recommended for the Scrum Masters is the Art of Focused Conversations to break the process into similar steps: Objective, reflective, interpretive, and decisional (ORID)[67].

[65] (James & Walter, 2010).
[66] (Larsen & Derby, 2006).
[67] (R. Brian Stanfield, 2000).

### Backlog Refinement Meeting

Most Product Backlog Items (PBIs) initially need refinement because they are too large to handle. In some cases, it is considered just a short time activity out of sprint for this matter. The result is the predefined Product backlog for the next Sprint. During this event large vague and unclear items will be discussed and split and clarified.[68] A skilled Scrum Master can help the team identify thin vertical slices of work that still have business value, while promoting a rigorous definition of "done" that includes proper testing and refactoring. It is common to write Product Backlog Items in User Story form in the IT industry.[69]

### Product Backlog Item (PBI)

- Describes the customer-centric feature.
- Often written in User Story form.
- Has a product-wide definition of done to prevent technical debt.
- May have item-specific acceptance criteria.
- Effort is estimated by the Development Team, ideally in relative units (e.g., story points).[70]

[68] The team should collaborate to produce a jointly-owned estimate for an item. (James & Walter, 2010).
[69] (Cohn, 2004).
[70] (James & Walter, 2010).

**Sprint Task (optional)**

- Describes how to achieve the PBI's what.
- Typically involves one day or less of work.
- During Sprint Execution, a point person may volunteer to be primarily responsible for a task.
- Owned by the entire team; collaboration is expected.[71]

**Sprint Backlog**

- Consists of selected PBIs negotiated between the team and the Product Owner during the Sprint Planning Meeting.
- No changes are made during the Sprint that would endanger the Sprint Goal.
- Initial tasks are identified by the team during Sprint Planning Meeting.
- Team will discover additional tasks needed to meet the Sprint Goal during Sprint execution.
- Visible to the team.
- Referenced during the Daily Scrum Meeting.[72]

[71] (Sutherland, et al., 2014).
[72] (Sutherland, et al., 2014).

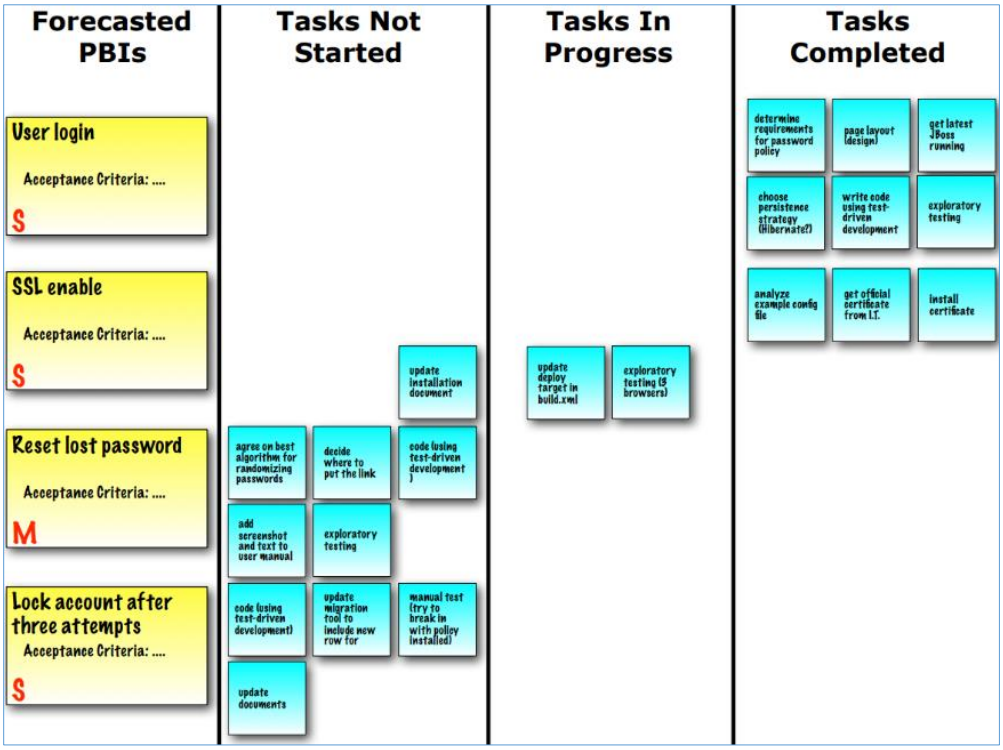



**Figure 14.** Scrum Board presenting the Scrum tasks. **(James & Walter, 2010)**

### Engaged Teams Outperform Manipulated Teams

During the sprint self-organized and self-socialized teams will engage themselves in a far more motivated manner in order to achieve the scrum common goal in a healthy democratic environment by being self-propelled, rather than manipulated through extrinsic punishments and rewards.[73]

[73] Intrinsic motivation is linked to mastery, autonomy, and purpose. “Rewards” harm this. (RSA, n.d.).

### 3.3 BIM Scrum

There are countless number of former researchers who have applied BIM and Agile individually in their studies to examine them for the purposes of time and cost savings, process optimization and so on.

However, BIM is a technology to centralize and present the graphics and database of a construction project to improve the collaboration between all the project participants. BIM visualizes the processes of a project through virtual and digital models to simulate the planning, design, construction, and operation process of a project.

Although the software is a part of the BIM process, BIM is not just a piece of software or an application among the architectural, engineering, and construction industry (AEC). The discussion about BIM refers to the methodology and the process that BIM creates. Moreover, one of the BIM features is ease of use related to its tools; hence, the use of BIM can reduce time spent in design as well as decrease cost and duration of construction.[74]

Chelson, 2010 presented eight case studies with the use of BIM that included different types and size of construction companies in different regions in the United States and reported that implementation time had decreased by 9 percent when using BIM. Paravan, 2012[75] reviewed a sample of data that consisting of 30 construction projects, some of which did not use BIM and others used BIM, and the projects that used the BIM showed the following information:

- 30% reduction in design time.
- 10% reduction in construction time.
- 16% reduction of delivery time in the entire project.

[74] (Krygiel & Nies, 2008).
[75] (Chelson, 2010).

Differentiated from lean production, Agile manufacturing focuses on how to respond to constant changes or adapt proficiently in an unpredictable environment[76]. This can only be accomplished through well established and maintained relationships between the customer, manufacturer, and suppliers as well as a win-win system of cooperation within the manufacturing organization as emphasized in Deming's 14 principles[77].

A company which uses Agile methodology is usually very flexible, quickly adapts to changes, iterates less while implementing faster, and is able to seize new opportunities as they appear. It enables a fast decision-making process through flexible organizational structure and simple communication. The application of BIM and Agile together in this research contributes greatly of solving most of the reasons for the delays of the construction process and the reduction of the duration of the project. The strong synergy between BIM and Agile can enhance management practice and can improve planning and control systems, especially design and coordination, and reduction of claims and disputes.[78]

[76] (Dove, 1996).
[77] (Deming, 2000).
[78] (researchgate.net, n.d.).

In a project in which the Agile approach and the BIM approach are simultaneously involved an interval goal is to be reached which is economic gains during an optimized process.[79]

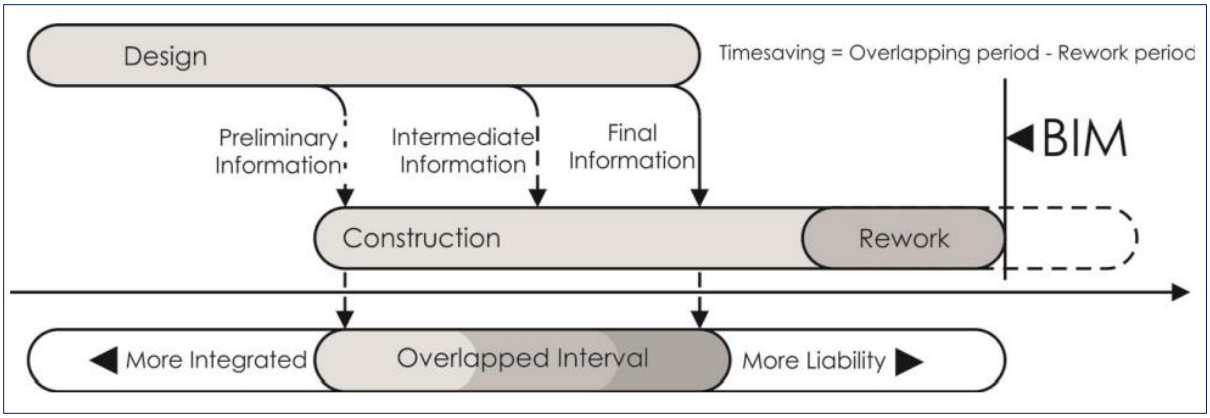



**Figure 15.** BIM and the effect of overlapping activity. **(Tomek & Kalinichuk, 2015)**

In contrast to traditional approaches Agile approach assumes that the detailed design specification can be improved with intensive Investor, Designers and General Contractor collaboration during the process.

Building Information Modeling technology plays a key role in the Agile method not only as technological container for information model of construction project but as new construction approach. Therefore, during project planning phase, these two methods collect the essential information inside Building Information Models for the longtime plan [80]. After project planning is finished, the Building Information Model only collects more detailed information on the design features of the next iteration of the given project realization stage to stage the short-time plan.[81]

[79] (Tomek & Kalinichuk, 2015).
[80] i.e. design features allocation to the stages.
[81] (Tomek & Kalinichuk, 2015).

Table 1: Synthesis of two approaches. Source: Own elaborations.

| Issue | Agile | Building Information Modeling |
|---|---|---|
| Concept | scheduling technique | building information model<br>technology solution<br>project management approach |
| Main principles | overlapping the project design and construction phases | creating information model<br>team collaboration<br>effective communication |
| Aim | reduction of the project time | elimination of omissions and rework |
| Method and practices (example) | product development (concurrent engineering)<br>project execution (fast track, design-build) | |
| Practical contribution | construction starts prior to all information is available | Earlier involvement of all key participants |

**Table 4.** Synthesis of two approaches. **(Tomek & Kalinichuk, 2015)**

Architects have battled the misunderstanding that our drawings and designs are ever 100% complete. Effective designers knew that a project co-developed with the client (and the builder) would always be more successful and fit for purpose than a project developed in a vacuum and handed off at the end[82]. As the Constructech magazine argues[83] the design team is actively engaged in the daily back and forth of questions and answers between designer, owner, and builder. They also are looking to help understand the future use of the buildings, issues that don't typically come up when traditional construction administration activities are performed which has been led to colocation. At most cases a Big Room[84]was used where the team of constructors, the general and trade contractors, the architects and engineers and medical planners and of agency officials and inspectors, co-locate with the owner. However, maintaining a co-located team onsite for a period of up to four to five years is expensive.

[82] (Moser, 2016).
[83] (Contructech,2016).
[84] Based on the Japanese Obeya system.

In order to build an adaptive framework for design solving, the traditional BEP (BIM Execution Plan) has been transformed into an innovative vehicle for driving innovation using agile techniques by considering short bursts of scrums (small development teams) and sprints (short duration deliverables) in order to co-create responsive deliverables. The deliverables are created through rapid iterations, which validate a client's requirements and rapidly tests the product.

BIM Scrum work will enable flexibility in project controls already outlined in the BXP (Project Execution Plan). Recommended modifications would be to align the associated risk with the BIM processes and to create dynamic collaboration structure and decision, making oversight which adjusts within the different phases of the project. As mentioned before[85] some projects are complex adaptive systems, in which the overall collaborative and emergent behavior is hard to predict, small changes in inputs or decisions produce large changes in behavior. Complex systems require different problem-solving techniques at different levels of abstraction.

[85] Chapter 1. Introduction, (P.1).

Agile Scrum is basically a new way of project management that allows faster time to market and quicker feedback from users. The end result is the ability to pivot when needed or confirm direction with real market proof. Six BIM Agile or BIM Scrum Integration Tips are as follows:[86]

1. Stakeholders' full involvement

The commitment to it must start at the top with the CEO and extend down to the rank-and-file and to ensure this commitment there needs to be a comprehensive understanding of Scum within the BIM project. In other words; the stakeholders better know that Scrum is a treatment for the source of most of the project related issues which is miscommunication.[87]

2. Considering Scrum as a path, not the destination

Agile Scrum is a continuous improvement methodology Which keeps updating itself. Therefore, there is no true end to it since there is always more to adjust in order to make the project run smoother. With Agile/Scrum, individuals and their interactions become more important than processes and tools; BIM software that gives real-time information takes priority over comprehensive documentation; customer collaboration carries more weight than contract negotiations; and responding to change is the ultimate virtue rather than allegiance to a rigid plan.[88]

3. Learning curve

In order to achieve the desired velocity and the ability to fully utilize Agile/Scrum methodology for BIM spatial coordination some time needs to be invested before the team masters the Scrum BIM process.[89]

[86] (ENGworks, 2017).
[87] (ENGworks, 2017).
[88] (ENGworks, 2017).
[89] (ENGworks, 2017).

4. BIM Real-time monitoring tool

Real-time monitoring is essential since it empowers the stakeholders as the whole Scrum team to observe and react on their behavior. With an advanced BIM tool at hand, everyone at the Scrum team will be able to access the 3d digital model with all the related data attached to it at any moment of the project from any location, which means that they can observe the progress easily and make comments or decide on the adjustments and the work which is left to do.[90]

5. Implementation and use of Agile Scrum

This methodology won't implement itself. Consequently, someone needs to be in charge of the process. However, it is better to avoid naming a person to function as a maximum boss because this contradicts the desired democracy and self-engagement of Scrum. Furthermore, the Scrum Master should not be permanently assigned the role of Agile Scrum coordinator. It should be assigned on a regular agreed-upon rotating basis.[91]

6. Transparent communication

Communication is highly emphasized in the Agile Scrum's goal of collaboration. The best vehicle for this kind of communication is a 15-minute daily meeting which is called the daily Scrum. The daily meeting is a tool that gives cohesiveness to the team effort. By holding it to 15 minutes or less, it will ultimately save the team a huge amount of time. The daily meeting also keeps the client tight in the loop, such that, if anything is amiss at the worksite it will not be a long time before the client learns that corrective action must be taken.[92]

[90] (ENGworks, 2017).
[91] (ENGworks, 2017).
[92] (ENGworks, 2017).

# 4. Agile Collaboration in Project management within the BIM based Common Data Environment

The existing studies on the subject seem to have distinguished great points. Nevertheless because of the great width of a building lifecycle and variety of focused areas to improve within project management, they seem to be too theoretical to be a safe, structured and adaptable approach. Some of the studies focus on the scrum technique and try to import it into construction industry from software industry in which it was first born. This kind of transplant with no consideration of the context could be beneficial as a tool but will not necessarily bring about the economic gain of the Agile approach to the project. In other words, in order to integrate the scrum technique from software development context into construction industry further processing of the scrum game rules and structure will be required.

## 4.1 Analyzing the Agile BIM literature

The Project Management Body of Knowledge (PMBOK)[93] does not precicely prescribe a development approach, however the Waterfall methodology[94] is the most common and accepted approach Scrum framework could also be adapted into it with a few adjustments and a few definitions are made clear.[95]

The adjustment that the traditional project need to make is to consider each sub-phase or sprint as a complete cycle of design, development and test, such that the deliverable is working code and not an intermediate artifact as common in Waterfall methodology. The main difference is that the whole team is involved in the planning processes at all levels in Scrum and is thereby committed to the delivery as the team owns the plan.[96]

[93] PMBOK is a of set of standard terminology and guidelines for project management written by Project Management Institute.
[94] A sequential and phase-defined process in which there is no flexibility to change when the previous step is done. According to HOAI the pre-planning, planning, construction, monitoring and cost management and all follow a sequence in which the further the process progresses, the more detailed it gets, and the less change is possible.
[95] (Sutherland & Ahmad, 2011).
[96] (Sutherland & Ahmad, 2011).

Therefore, the main assumption to be considered in this research is to consider the agreed-upon sub-phases according to the pre-marked milestones of the project as Scrum Sprints. According to the mentioned nature of Scrum in Agile methodology it's safe to assume that it has to be applied to those points of the project process line in which an external review or input and budget checks is inevitable; hence, the milestones.

Based on the literature review, the applicable concepts of Scrum method to the BIM Common Data Environment are as follows:

- Developers get feedback frequently (at the end of each Sprint).
- The end users are deeply involved throughout the development of the application through the Demos after the Sprints, but they are not allowed to interfere with the day-to-day activities.[97]
- Project status is visible since the Sprint produces working code.
- Teams meet in front of the Board which has multiple columns with Product Backlog (features to be delivered) on prioritized order of business value.
- At the start of the Sprint, the tasks to be accomplished are visible. Each day developers move tasks to an "In Progress" column, then to a "Validation" column, then to a "Done" column.
- The format of the Backlog and the blocks can also vary, ranging from a list of items on a piece of paper, to software representations of it over the Internet/Intranet.
- The Scrum Meeting's frequency can be adjusted and typically ranges between 2 and 48 hours. These meetings are often held standing up. This ensures that the meetings are kept short and to the point.[98]

[97] (construtech, 2016).
[98] (Mordue, 2015).

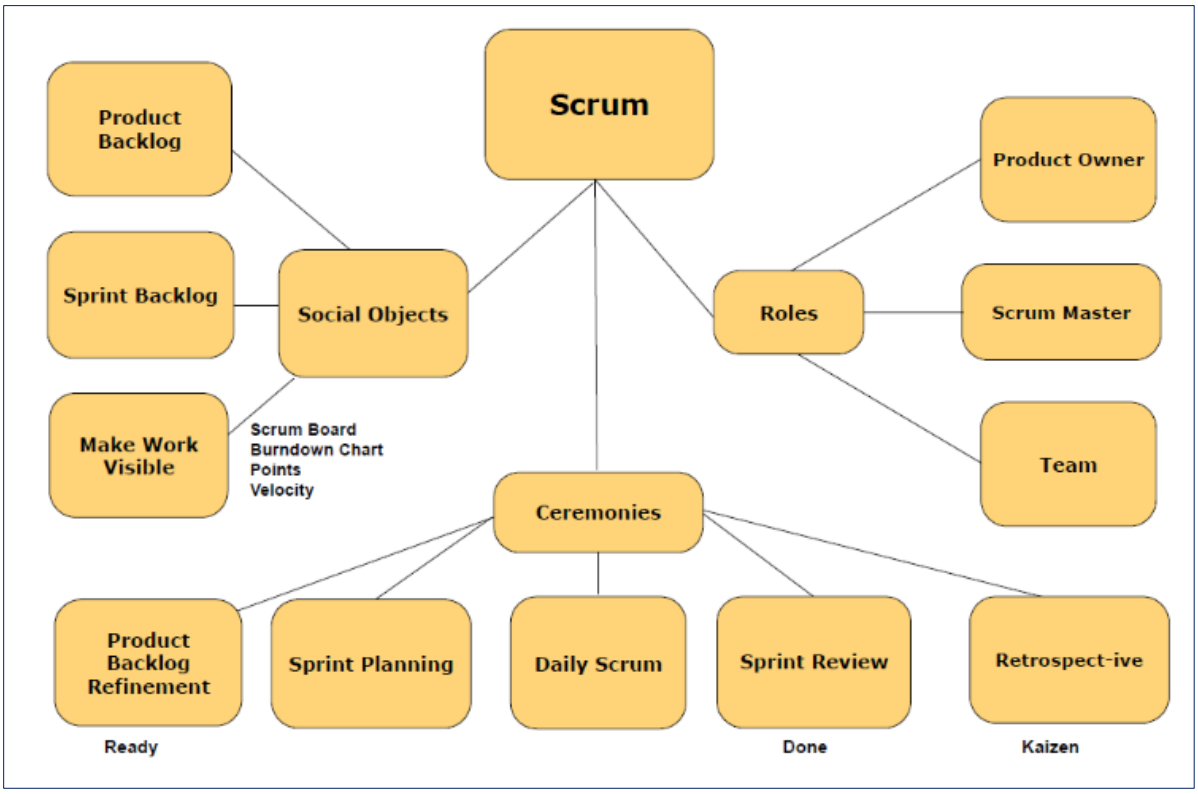



**Figure 16.** Scrum Framework. **(Sutherlans, 2014)**

According to the information gathered during the literature review, the main concepts of Agile Scrum and BIM project management using a CDE have been extracted. As indicated in figure 18 the intersection between the two has been identified. This intersection is the scope of the Scrum BIM method. In other words, the addressed target of the suggested method has been set inside this intersection.

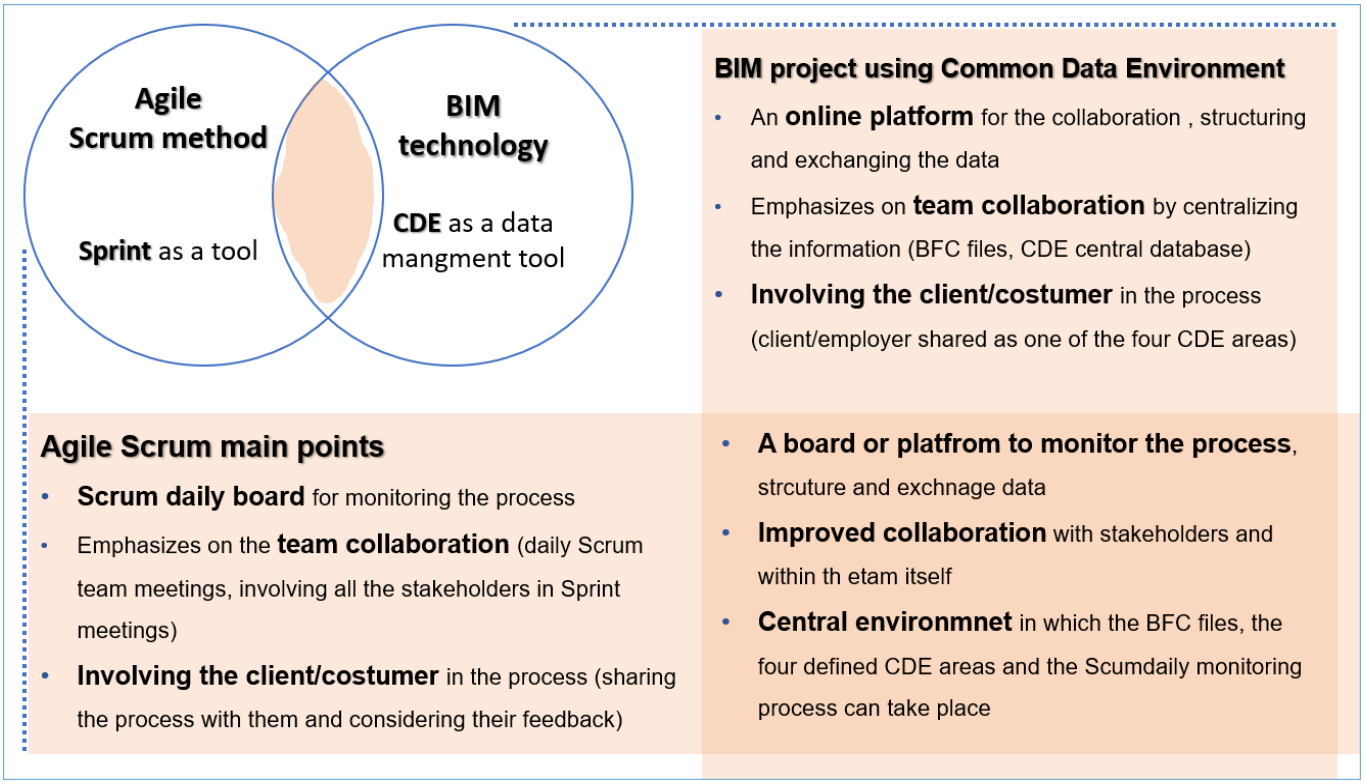



**Figure 17.** Extracting the common concepts of the Agile Scrum method and BIM project using CDE for collaboration. Drafted by the Author.

As indicated in the figure 18, after the literature review and the Analysis the following common points have been extracted:

- The real daily Scrum board used for process monitoring and visualization can be combined with the virtual online platforms (CDE) of BIM used for collaboration and data exchanging and organization.
- The deep daily collaboration of all the participants in Scrum can be combined with the emphasis on the collaboration via a central and online platform with one open file format recommended for all files (IFC and BCF) in BIM.
- The sheer involvement of the client or the product owner in Scrum can be combined with CDE in BIM which allows the client to take the process's control in hand and be able to maneuver in decision points, approve the checked and valid information, and monitor the situation thoroughly.

### 4.2 Scum BIM Synthesis Table

Due to the wide range of the lifecycle of a building and the limited scope of this master thesis it seems only senseful to somehow limit the wide scope of the lifecycle to match the thesis capacities. As mentioned earlier in this paper[99] the BIM context in which Agile is to be applied will be further categorized and further defined. For this purpose, as indicated in table 5 for the Horizontal direction of the table (Top Row) the whole lifecycle of the building will be categorized into its three most common phases which are AEC[100], Utilization and Project Development for further use in the Scrum BIM synthesis table in which some of the cross-sections will be chosen to be further processed according to their own categories, characteristics and their involved stakeholders.

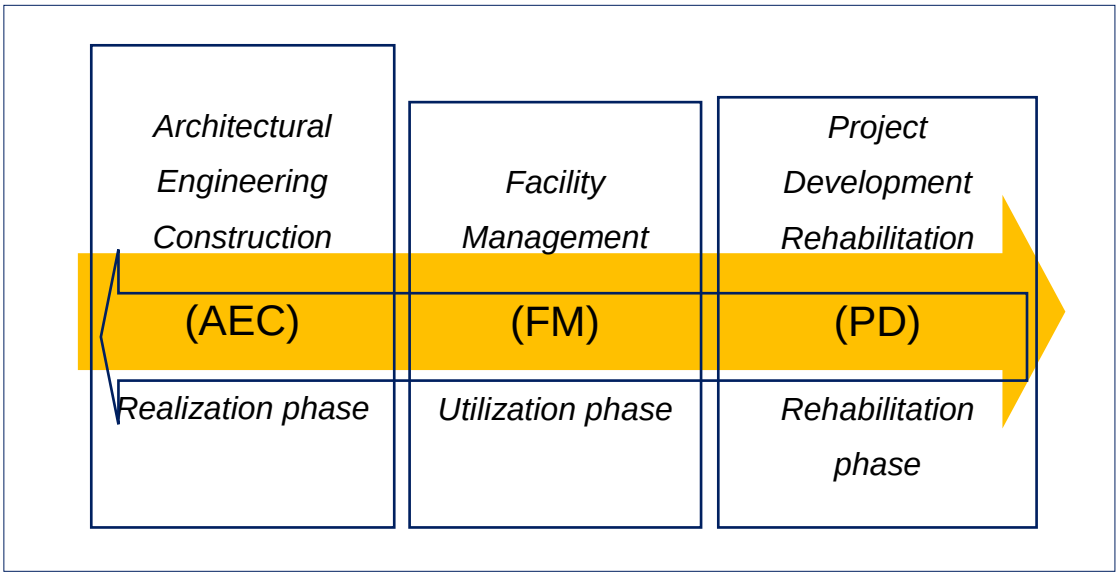



**Figure 18.** The Criteria for applying Scrum to BIM CDE throughout the Building Lifecycle. Drafted by the Author.

[99] Mentioned before at 1.3 Research Assumptions, (P.5).
[100] Architecture, Engineering and Construction.

For the Vertical direction of the table (Left Column) that presents the Scrum methodology a stablished framework of scrum [101] is needed as the reference. Then the fitting items will be marked to be further refined to match the BIM project management during the life cycle[102] of the building. As indicated in table 5 for this Synthesis to be possible the combination of the two different concepts will be visualized in a phase-specific manner and the solution will be provided for the highlighted intersections. For instance, in the case of the A1 cross-section there will be questioned designed to address the integration of column A with row 1.

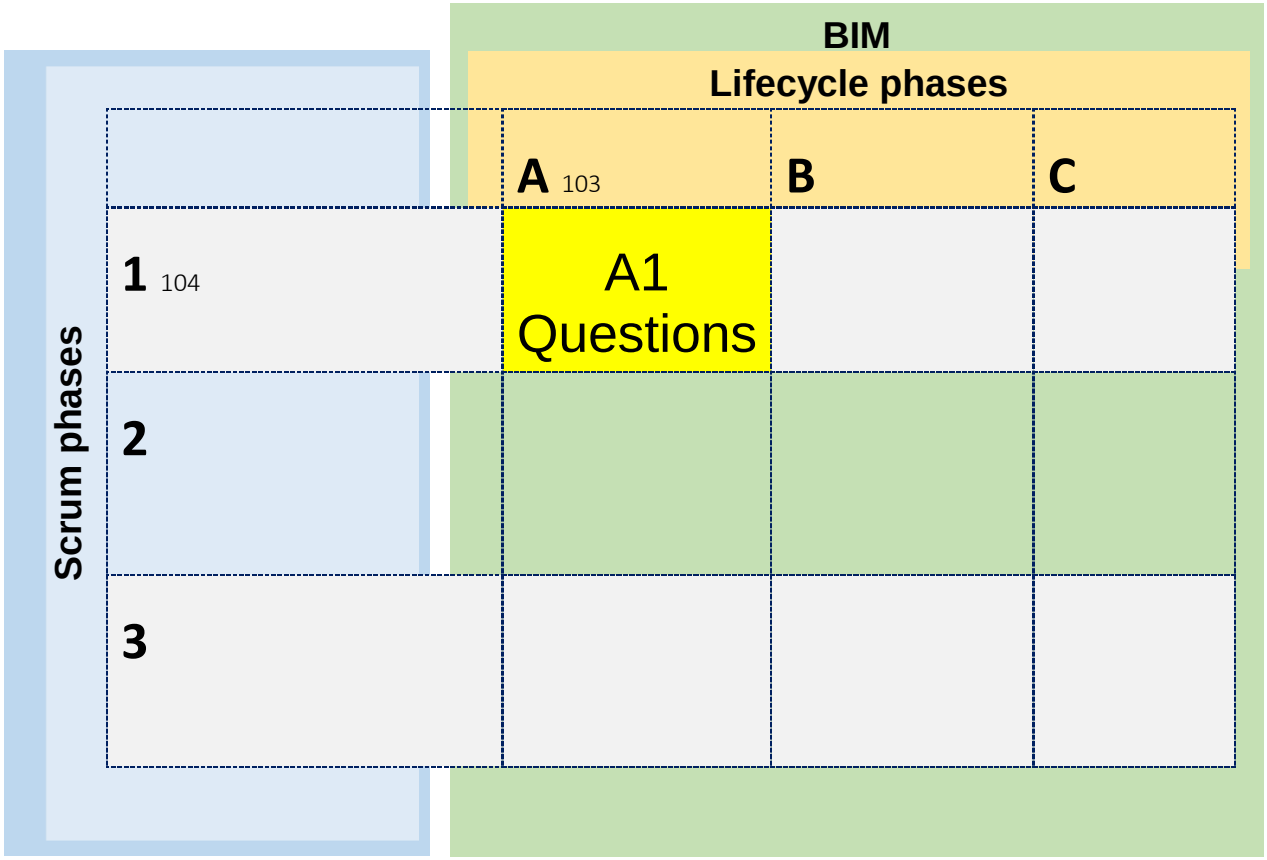



**Table 5.** Synthesis Table Approach . Drafted by the Author. **(Aibeo, 2018)**

[101] See Figure 17. (P.43).
[102] AEC, Utilization and Project Development.
[103] A: lifecycle phase of the building. E.g.: AEC phase**.**
[104] 1: The Scrum Role (1)*, what they do (2),* The resulting Object (3). E.g.: product owner, *business prioritization,* Product Backlog.

| *Agile BIM Synthesis* | | **LIFE CYCLE OF THE BUILDING**[105] | | |
|---|---|---|---|---|
| | | **A.** **AEC** *project management* | **B.** **FM**[106] facility management during utilization | **C.** **REHABILITATION** *project development* |
| **1. Sprint Planning** | **1.1 Owner** *business priorities* **product backlog** [107] | | | |
| | **1.2 PM team** *doable amount of work* **sprint backlog** | | | |
| | **1.3 PM team** *from the sprint backlog* **Sprint tasks** | | | |
| **2. Daily Scrums** | **2.1 PM team** *done yesterday* **updated task list** | **Daily Scrums**<br>**1. where is the Daily Scrum held?**<br>**2. How is the info shared & monitored?**<br>**3. How are the challenges & discovered tasks reported?** | | |
| | **2.2 PM team** *will do today* **updated task list** | | | |
| | **2.3 Scrum Master** *impediment report* **discovered tasks** | | | |

[105] The width of the columns is not proportional to the length of the time they represent.
[106] Facility Management.
[107] 1: The Scrum Role (1)*, what they do (2),* The resulting Object (3). E.g.: product owner, *business prioritization,* Product Backlog.

| | | | | |
|---|---|---|---|---|
| **3. Sprint Review** | **3.1 Owner** *demonstrates done from the* **sprint backlog via Live Demo** | | | |
| | **3.2 External stakeholders, End Users** *evaluation* **Feedback** | | | **C * 3.2** |
| | **3.3 Scrum Master** *translates user visual feedback& client priorities into* **future Sprint Backlog** [108] | | | |
| **4. Sprint Retrospective** | **4.1 Scrum Team** *self-evaluation* **Experience** | | | |
| | **4.2 Scrum Master** *translates user lived feedback& newly discovered scope into* **future Sprint Backlog**[109] | | | |
| | | | | |

**Table 6.** BIM Agile integration Table. Drafted by the Author.

[108] The future Sprint backlog in decided in this step.
[109] The already decide Sprint backlog will be revised in this step.

### 4.3 Scrum BIM Common Data Environment's structure

The CDE in this case can be organized according to the Scrum ceremonies[110] Whereas in general in CDE the areas are divided into WIP, Shared, published and Archived[111].

**Sprint Scope Area:**

With a license granted to the client the process begins in this area including the sprint backlog and its ratio to the product backlog, the primary documents needed for the daily scrums will be there and the power of changing it only remains with the client and the scrum master and except the client related inner files, it will be visible to all scrum team in case of reference at any time during the Scrum.

**Daily Scrum Area:**

When considering Scrum, the WIP and the Shared area can be one single area with a few justification made. This one single area will provide the scrum team with the visual scrum board and the communication and exchange platform at the same time. By considering the ability to designate files including duties and information to individuals while the ownership and power to change the information belongs to the originator and the designated individual only[112]. This basically means that the WIP area is defined within the Shared area and together they form one Daily Scrum area in which all the Scrum team members participate. This virtual daily platform complements the daily 15-minute real meetings of the group.

**Demo Area:**

Instead of the published area with all the proved information in it, there can be a dynamic platform in which the client presents the sprint backlog which is visible and judgable. The power of changing will belong to the client. This area will include the model of the demo to be presented, and the related work that has been done on it. With some specific

[110] Explained in 3.2.3 Scrum Rules. (P.27).
[111] Explained in 3.1.1 Common Data Environment. (P.15).
[112] See Figure 20. Conceptual Scrum Board in a Common Data Environment screenshot. (P.51).

features it might enable the user to experience the model from their own point of view in order to evaluate it better later.

**Sprint Review Area:**

This area will be a platform in which the evaluation process takes place. The sprint backlog will be divided into visible ratable parcels. Every parcel will have an expandable view next to its symbol in the main desktop, and inside the expanded view will be all information and the parcel of the model related to it. After checking all the parcels separately are all together within the central model on the main desktop, the user can rate their satisfaction on that[113]. The satisfaction rate will serve as a coded input message to the team to make further decisions about the Sprint backlog; Hence, enables the team to decide which items will be re-done in the next sprint backlog and which item are considered as done. It enables the team to determine which items is the end-user unhappy about and how unhappy they are about it.

### 4.4 Conceptual Screenshots for the Scrum BIM Common Data Environment

For each highlighted cross-section of the Synthesis table[114] a conceptual screenshot of the main desktop view of CDE will be drafted by the owner. By asking questions regarding the targeted cross-section, the situation will be discovered which facilitates the drafting part by highlighting the stakeholder in charge, the roles and the objectives of the defined frame.

**Daily Scrums, Questions to be answered:**

- where is the Daily Scrum held?
- How is the info shared & monitored?
- How are the challenges & discovered tasks reported?

[113] See figure 21. Conceptual Feasibility Study Scenario Board in a Common Data Desktop screenshot. (p.62).
[114] See table 6, (P.55).

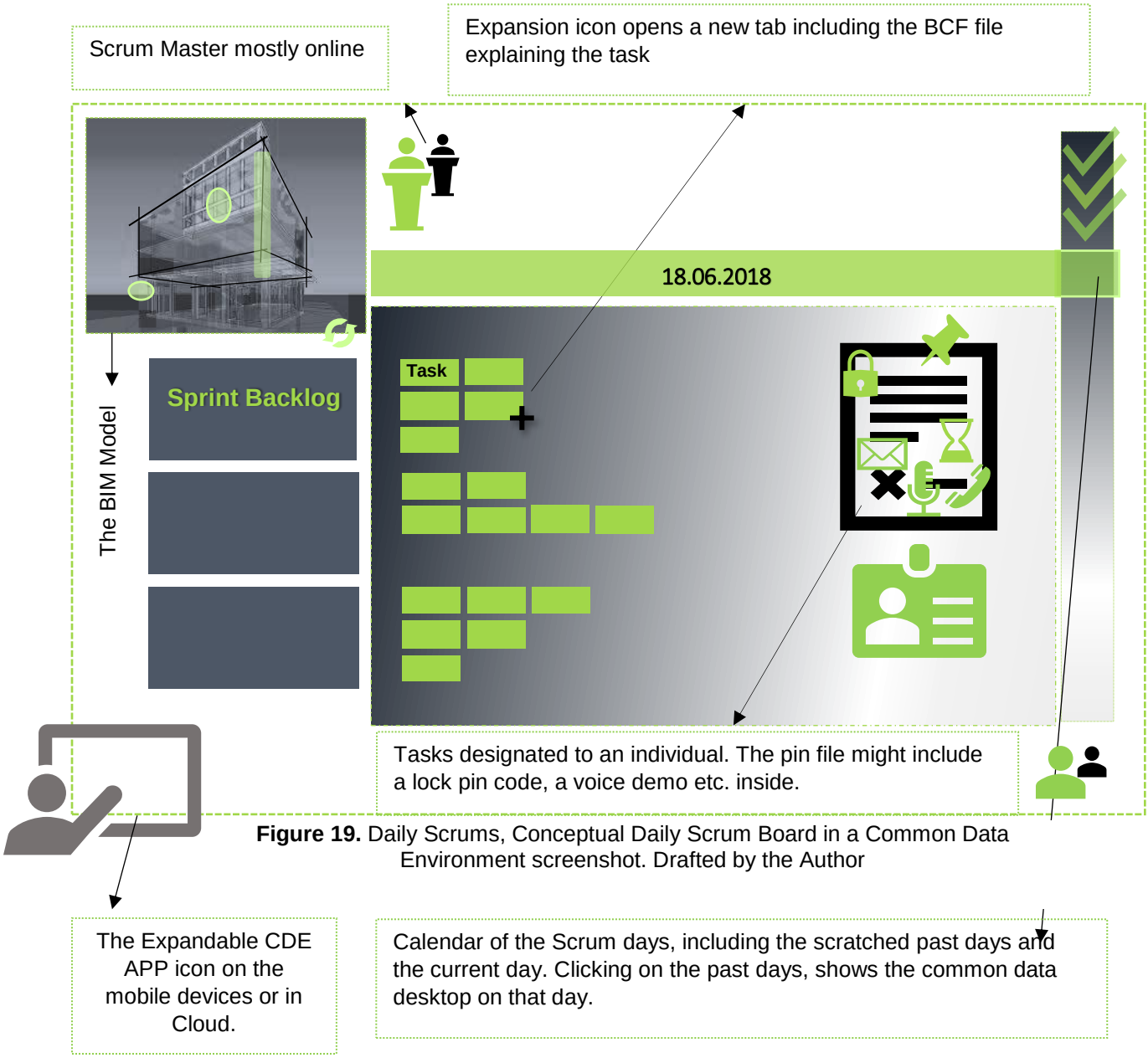



**Figure 19.** Daily Scrums, Conceptual Daily Scrum Board in a Common Data Environment screenshot. Drafted by the Author

- There is the possibility of designating a BCF file to an individual, pin it to the top, set a deadline for it, set a lock on it to keep it private and even use voice or text or calls on it in case they are online.

- The status of the team members will be noticeable. The green Icon represents the online team members on CDE, and the back indicates offline ones.

**External stakeholders and End Users' Feedback * Project Development (C * 3.2)**

In the Project Development Phase there needs to be the feasibility study including at least one realization concept. The feasibility study covers Market and site analysis, Economical, Legal, Technical, Structure and schedule. This specific category can be conducted in one to three sprints. When all the aspects are covered the scope of the development concept will be targeted in the cross-section of all the studied fields.

During the feasibility study the Developer's role is to make the idea come true and sell the concept for which a specific framework is considered. The Feasibility study contains Market and Site Analysis, Technical aspects (architectural, engineering, urban planning, etc.), Legal aspects (pubic, urban and tax law), Economical aspects (costs, earnings, yields), Structure aspects (stakeholders, contracts, communications), Scheduling aspects (concept, preparation, realization, maintenance), Sociological and Ecological aspects.[115]

**External stakeholders, End Users** *evaluation* **Feedback, REHABILITATION** *project development* **- C * 3.2, Questions to be answered:**

- Who are the external stakeholders in the Project Development phase?
- How does the end-user evaluate the demo of the presented scenarios for the building development?

[115] (Riediger & El Gouna campus, 2018).

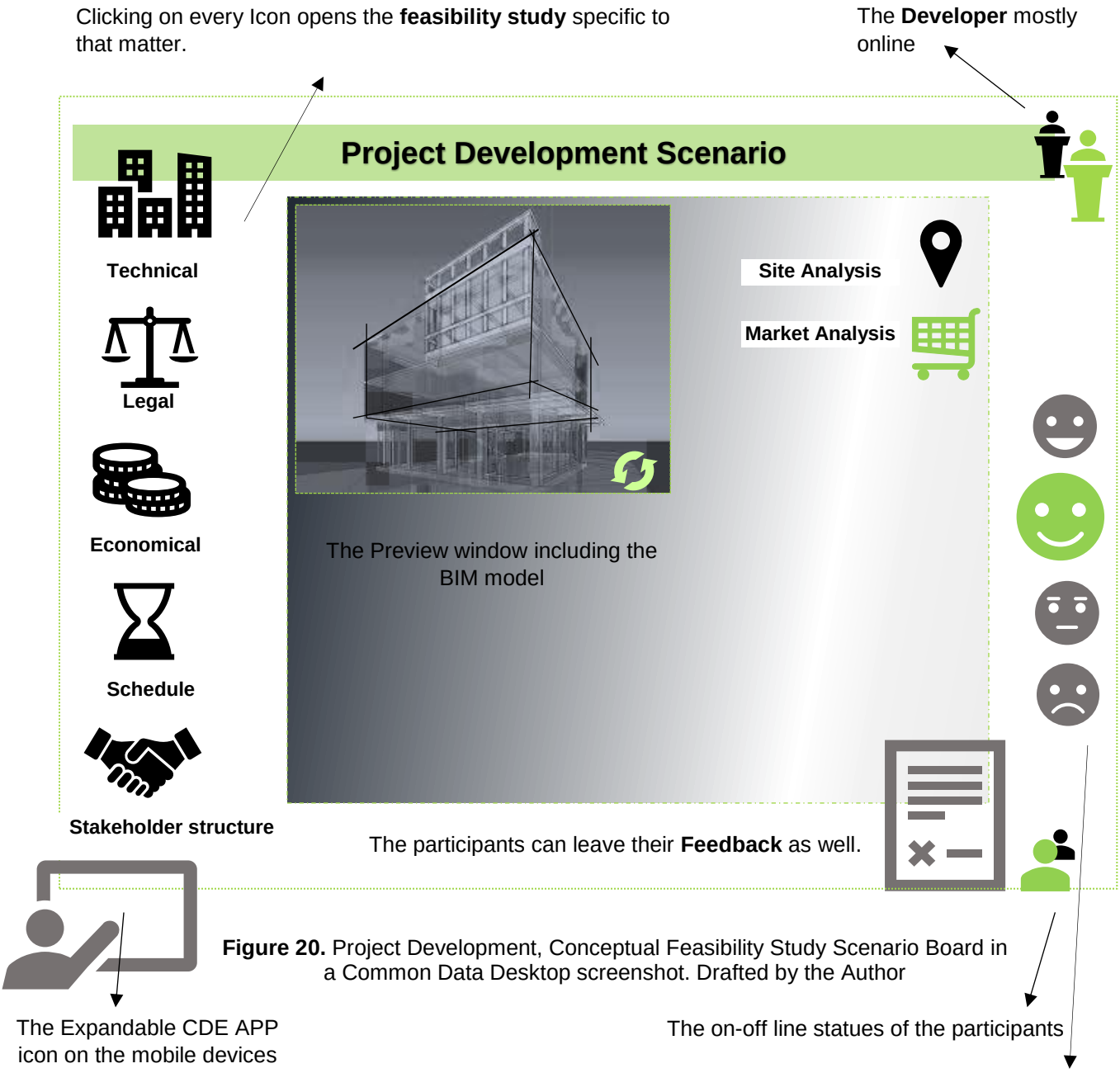



**Figure 20.** Project Development, Conceptual Feasibility Study Scenario Board in a Common Data Desktop screenshot. Drafted by the Author

### 4.5 Scrum BIM monitoring metrics

There is hardly any place for improvement for any process without reliable monitoring metrics. Scrum is not an exception of this fact. In fact, Scrum as a self-improving process including back and forth cycles lies on these measuring factors.

The following metrics are a chosen sample of the great variety of metrics announced and suggested for Scrum. They have been chosen for the purpose of fitting into a BIM project and some justifications have been conducted in their definition details, measuring units, and measuring formulas for them to be adaptable into BIM. Nevertheless, the main concepts still ensure the best Scrum quality for the situation. They will furthermore be evaluated through interviews in order to be rated. Therefore, the top-rated ones will be suggested to be implemented into the Scrum BIM monitoring system.

1. Sprint backlog Scope-Velocity:

Measures the amount of work completed tasks of the sprint backlog[116] during a sprint compared to the whole product backlog points in parentage which helps the team to realize their capacity and provides predictability for future sprints:[117]

2. Sprint Backlog consistency -Velocity:

measured by comparing story points completed in the current sprint with points completed in the previous sprint in percentage and the acceptable range of variance in two sprints in a row is +/- 10 percent.[118]

3. Team's predicted productivity -Done-to-Planned Ratio:

Measures the amount of work actually done at the end of the sprint compared to the work committed to do in the beginning of each sprint which anticipates the sprint's success in percentage.[119]

---

[116] In IT Scrum this item is called Story Point which is a metric for the complexity of the tasks of the product backlog. The least complex task receives 1 point and the last complex one receives 100 points.
[117] (Radigan, 2016).
[118] (Boyd, n.d.).
[119] (Bancroft-Connors, 2017).

4. Team enthusiasm -Happiness factor:

Measures team's willingness and enthusiasm to cooperate and improve. Overlooking this key role player will lead to a probable failure from which no applied process or method can avoid[120]. Can be measured in the retrospective meeting by asking the team members to score their happiness amount on a pre-defined and agreed upon scale like percentage and referring to the average of this percentage, or by simply asking them to answer to the question "are you happy?" with simple yes and no and later calculate the happiness percentage of the team by divining happy members to all in percentage. By keeping track of the trend of this metric the happiness trend is visible to all.[121]

5. Team's understanding of Scrum:

None of the Scrum purposes will be met if the team fails to grasp the whole Scrum concept. Daily in person scrum meetings significantly improves this factor which is a qualitive metric. Therefore, there is no way to monitor it. Nevertheless, having a sprint planning meeting with highlighted focus on addressing this issue and the importance of grasping the Scrum concept to all[122] covers this item.[123]

6. Scrum master shifting cycle:

Scrum Master is a role comparable to a Capitan of a ship. When the current sprint ends the role shifts as well to make sure that the team is self-organized, and no deficient hierarchy is harming the equally fair collaboration within the Scrum Team and encourage the team's engagement enthusiastic sympathy.[124,125]

[120] (Boyd, n.d.).
[121] (Bancroft-Connors, 2017)
[122] Including the owner of the client, external and internal stakeholders, and the daily Scrum team.
[123] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.
[124] (Beedle, et al., 2014).
[125] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

7. Team's collaboration metric-The Mutual Assessment (MA) methodology:

Used at the sprint retrospective meeting in which the team members evaluate the rest of the team on their contribution towards reaching the sprint goals. [126,127]

8. Customer satisfaction metric-defect rate:

Indicates customer satisfaction by counting the number of bugs and defects in the delivered backlog of the sprint after its release. The lower the defect rate, the more satisfied the end-user with the released sprint backlog[128]. It is calculated by dividing one to defect rate in percentage. The defect rate is calculated by dividing the number of defected SPs to the whole released SPs.

9. Scrum impediments- Daily clean code:

Aiming for a clean base of code at the end of every day or trying as hard as possible to fix all the bugs in the same day that they appear saves up to 24 times the time spent to fix it on the originated day compared to postponing it to the future[129]. It is calculated by dividing the clean code days of the Sprint to the whole days of sprint in percentage.

10. Scrum impediments- removing the impediment on top:

Removing the single most destructive impediment at the end of the sprint during the sprint retrospective to start the next one without its trace would result in a better sprint[130]. This factor is using a quantities method to result in eliminating a factor. But choosing which factor to eliminate can be a subject of quantities evaluation. Such as voting online for the single most important impediment and choosing the highest rated one.[131]

---

[126] (Vegard Knottena, 2015).
[127] (Jimenez, 2017).
[128] (Bancroft-Connors, 2017).
[129] (Beedle, et al., 2014).
[130] (Beedle, et al., 2014).
[131] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

11. Interruption precautions – Emergency procedure:

In any project there is a necessity to consider an Emergency plan in the start of the sprint for unpredicted scenarios since thinking for the reaction counts as waste of time and results in horrible harmful consequences. In case of things going off the track the emergency procedure will be executed preferably by mid-sprint with no further delay. in such cases Scrum Mater is in charge of considering the following tasks depending on the accrued emergency. Asking for help from outside of the Scrum team, demanding for redefining a smaller scope of sprint backlog for the rest of the sprint, offloading backlog to someone else, Abort the sprint and re-plan, inform management about the effected changes in the sprint review demo release.[132]

[132] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

# 5. Evaluation of the Scrum BIM synthesis

## 5.1 Interview and Interviewees' Background

The interview questions are designed by the intention of addressing the following queries:

**From the IT point of view:**

1. Interview's familiarity and utilization extent of Scrum and Agile methodology.

2. Evaluation of the recommended conceptual screenshots for Scrum BIM CDE regarding the form and accessibility by the team members, security level and improvement suggestions.

**From the construction point of view** *(Architect and Project Manager)*:

1. BIM utilization level and the CDE form used in it in the interview's experience.

2. The used control mechanism for the project in the interview's experience.

**And from both perspectives**:

1. Evaluating the methodology of this paper.

2. Ranking the 5 most important metrics effecting the Scrum BIM process that need to be implemented into the control mechanism.

The gathered information provides the sufficient knowledge in order to evaluate the results of the paper to come to an overall conclusion. The interview has been processed in written form and the transcript of the interviews are attached in the Appendix of this paper[133].

[133] The data sheet of the interview transcripts will be found in the Appendix, (P.77).

The interviewees for this thesis have been chosen from three different fields of IT, construction project management and Architectural with required theoretical and practical knowledge. The IT background provides a technical evaluation of the recommended Scrum BIM CDE, the Architectural background understands the collaboration and design process challenges of the team and the Project Management interviewee understands the needs and opportunities for proactively monitoring the management process, in order to address the complexity of the team collaboration. Data on the interviewees are shown in Table 6.

| **Interviewee** | **Interviewee 1** | **Interviewee 2** | **Interviewee 3** |
|---|---|---|---|
| **Area of Work** | IT & Web Design | Architecture & Civil Engineer | Construction & Real estate |
| **Company type** | Independent foundation under civil law | Architectural | Construction Company |
| **Company name** | Stiftung Warentest | AIBEO architecture | Zechbau |
| **Professional Experience** | 1.Web, Project and Information Management<br>2.Time planning<br>3.Project Control<br>4.Technical support<br>5.External Service Contractors | 1.Architectural Design<br>2.Architectural Democracy | 1.Site management<br>2.Project control<br>3.Time planning<br>4.BIM<br>5.Lean Construction |
| **Interview type** | Time planning, | Written | Written |

**Table 7.** Interviewee Expert Panel. Developed by the Author.

## 5.2 Interview Results

### 5.2.1. Summary of the First Interview

Interviewee 1 recommended the Scrum BIM Synthesis method to be used to the theoretical scope of the project management. He expressed his concern regarding the practical use of it including a real built project instead of the virtual model, therefore, while emphasizing on the similarities of the Scrum Project Development and the Scum BIM method in the Development phase, recommended that in case of using Scrum for other phases such as the construction and the utilization phase, the virtual BIM model rather be used as the reference instead of the actually built parts of building.

For the improvement of the Conceptual Screenshots of CDE as the suitable environment for the Scrum BIM collaborations to take place, he suggested including a good issue tracking system such as Jira[134] in the process and connecting it through APIs[135] to the BIM platform. And he mentioned that developing issue tracking and task arrangement Add-ins or Plug-ins in to the BIM platform could be another alternative.

Regarding the security, interviewed 1 confirmed the role-oriented model of the suggested CDE and believed that an information manager takes care of the roles and their rights. For the authentication process he recommended just one multi- authentication for logging in to the platform for every role and the security level will be pre-defined for each user account in a role-oriented manner. For instance, the scrum master will have the ability to change and develop the sprint backlog, but the rest can only observe or check and un-check their own done tasks. also, for the client or end-user including parts, the scope of the visible and active features for them would differ greatly compared to the scrum master.

And at the end regarding the form that the Scum BIM CDE can take, comparing the two options of installing it on a cloud (where many companies can make accounts for their needs) or on-premise[136] (On a server in the developing company), he responded that with

[134] Jira is a proprietary issue tracking product, developed by Atlassian. It provides bug tracking, issue tracking, and project management functions. (Atlassian, n.d.).
[135] An application program interface (API) is a software intermediary that allows two applications to talk to each other. (MuleSoft, n.d.).
[136] On-premise or Local or On-site is a Traditional method of installing and customizing software on the customer's own computers that reside inside their own data center.

the cloud option there is less security and less control over customizing it; furthermore, the cloud providing company would have access to the company data, whereas the on-premise option (On a server in the developing company) can still benefit from the cloud's easy accessibility options while maintaining the company data security. In other words, the IT managerial team can make the on-premise accessible for the team by providing Apps for it on their mobile computing devices or using a website for it.

### 5.2.2. Summary of the Second Interview

Interviewee 2 is familiar with BIM approach and within his organization they used the CDE in the from of a shared folder on the cloud including the IFC and COB files. They somehow implement Agile methodology into their CDE by moving the finished work from Work-In-Progress area to the Shared-with-client area to be validated; at this point information required client's feedback and in case of confirmation it will move to the published area.

Regarding the method he confirms the methodology to achieve the solution but in case of the solution itself he recommended less focus on the software aspect and closer to an easily followable construction safety schema for the workers on-site.

Regarding the controlling metrics he believes that the Happiness metric (Team enthusiasm) should be conducted in a different manner to reach the true result; the interviewed team member will be under pressure to talk about this personal and subjective matter in front of all or some.

### 5.2.3. Summary of the Third Interview

Interviewee 3 believes that in case of simplicity and limited resources in today's market the Lean methodology is more accepted and preferred. He also said that Scrum BIM would play an important role in the future of the complex projects in the industry by keeping up with the market demands and keeping track of the project process by everyone within the team.

### 5.2.4. Result of the Metric Ranking

As mentioned before[137] With no measures included in the Scum BIM work frame System it would be relatively impossible to monitor the process to keep Track of it and guide it in the success direction. Therefore, a few critical SuccessFactors are required. Currently there is a great variety of metrics in the industry for monitoring the process. Some of which can even be used differently by different teams or be tailored to each specific project, depending on its methodology, tools, and goals. Furthermore; the metrics applied by the project team better be limited to the project necessities. Rendering too many metrics in the monitoring process can be overwhelming and time consuming.[138]

In order to limit the existing Scrum BIM metrics to the critical success related ones they need to be evaluated through the interview. Interviewees have been asked to rank them according to their importance to the Project Success and the results can be found on table 8. According to table 8[139] the top five ranked Scum BIM control metrics are as follows: [140]

1. Team enthusiasm -happiness factor.
2. Sprint backlog Scope-Velocity.
3. Sprint Backlog consistency -velocity.
4. Interruption precautions – Emergency procedure.
5. Team's understanding of Scrum.

Although some justifications might be needed. For instance, in the case of 1. Team enthusiasm -happiness factor, as interviewee 2 pointed out, it better not be conducted via questionnaires or direct contact because the topic of happiness is too subjective and personal to be asked directly; the interviewed will feel pressured and the truth will remain undiscovered.

---

[137] In the 4.5 Scrum BIM monitoring metrics, (P.54).
[138] (Jimenez, 2017).
[139] See Figure 8. (P.63).
[140] For further explanation of the metrics see 4.5 Scrum BIM monitoring metrics, (P.54).

| | *Interviewee 1* | *Interviewee 2* | *Interviewee 3* |
|---|---|---|---|
| *1. Sprint backlog Scope- Velocity %* | 1 | 2 | 10 |
| *2. Sprint Backlog consistency - velocity %* | 4 | 3 | 11 |
| *3. Team predicted productivity - Planned to Done Ratio %* | 3 | | 8 |
| *4. Team enthusiasm - happiness factor %* | 6 | 1 | 1 |
| *5. Team's understanding of Scrum 0/1* | 5 | | 3 |
| *6. Scrum master shifting cycle 0/1* | 11 | | 7 |
| *7. Team's collaboration metric- Mutual Assessment (MA) %* | 10 | | 2 |
| *8. Customer satisfaction metric- defect rate 1/defect rate %* | 7 | | 6 |
| *9. Scrum impediments- Daily clean code %* | 8 | | 4 |
| *10. Scrum impediments- removing top impediment 0/1* | 9 | | 9 |
| *11. Interruption precautions – Emergency procedure 0/1* | 2 | | 5 |

**Table 8.** The Ranking of the ScrumBIM monitoring metrics by the interviewees; the five most efficient ones are highlighted in the table. Darfted by the Author.

# 6. Conclusion

This research is the first to emphasize on the common interests of Agile methodology and the BIM Technology and set the targeted Synthesis of the two within these shared interests. The resultant framework to which is referred as the Scum BIM Common Data Environment in this paper, aims to support the project team at the decision-making points of the process according to the project Milestones. This brings about more flexibility towards the business realities or demands and the ability to adapt constant feedbacks from the stakeholders in the critical points of the process that require the client's review or the end-user's comments, which might require a continuous design in a back and forth manner.

The literature part of the research has reviewed Agile and BIM separately in order to obtain a thorough understanding of both, after which the main common interests of them were extracted and further refined to fit into the same framework. During this chapter the existing similar efforts to bring Agile software development methodology into the Construction industry were studied as well.

Due to the conducted analysis on the literature review, improved team collaboration, client's sheer involvement in the process, and centralizing the efforts in and around one single source such as the Scrum daily board (in Agile case) and the Common Data Environment (in BIM case) are the characteristics that Scrum and BIM share in common.[141] According to these shared interests, Common Data Environment would be a suitable context for their synthesis to take place.

With Some specific adjustments to the Common Data Environment structure and some refinements to the Scrum rules, the Agile methodology would be adaptable into the BIM project. To avoid complexity, it is recommended that the process follows the same phase-defined methodology as any BIM project except the decision-making points of the process for which Agile methodology is required. Therefore, Scrums will be held during those sub-phases of the project which helps accomplishing the project milestones.

[141] See Figure 17, (P.44).

To clarify and visualize the Scrum BIM requiring points of the process, a phase-specific table has been developed with the main column presenting Scrum and the main row indicating a BIM based Common Data Environment throughout the lifecycle of the building[142]. For the specified and highlighted cross-sections of this table solutions have been presented in the form of conceptual screenshots for the developed Scrum BIM Common Data Environment. As another part of the solution a structural re-consideration have been made to the Common Data Environment component areas to tailor them according to the Scrum needs. Furthermore, the obtained metrics to control the Scrum process from the literature have been tailored for monitoring and controlling the Scrum BIM process and ranked by the interviewees to bring out the five most effective metrics to be adapted into the Scrum BIM Common Data Environment.

The practical examination of the developed method has been conducted through interviews with interdisciplinary experts of the related fields which are Information Technology (IT), Construction and Project Management. Regarding the adaption of the Scrum methodology framework into the BIM project, it has been recommended that the developed Conceptual Screenshots in this paper can be complemented by Issue Tracking and Task Arrangement Systems such as Jira[143] with connecting them to the BIM CDE platform using APIs[144]. Another alternative is to simply develop task arrangement Add-in or Plug-ins into the existing BIM Collaboration platform which in this case is CDE.

Regarding the security a multi authentication method was suggested and about the accessibility, it was recommended that the role-oriented model of Scrum be retained. Therefor the roles and desired rights for every role will be implemented into the common data platform. The accounts of the users accessing the platform will be assigned to these roles. For instance, the features and actions of the Scrum Mater role would be different than those of the client or the team member.

[142] See table 6, (P.47).
[143] Jira is a an issue tracking product, developed by Atlassian. It is used for bug tracking, issue tracking, and project management functions. (Atlassian, n.d.).
[144] An application program interface (API) is a software intermediary that allows two applications to talk to each other. (MuleSoft, n.d.).

For the forms that the Scum BIM CDE can take, it was clarified that the cloud option provides less security and less control over customizing the environment; furthermore, the cloud providing company would have access to the company data, whereas the on-premise or the On-site option which is developed by the company itself would have its own inhouse Information Managerial Team with IT expertise controlling the environment; hence there is more flexibility, security and power over the process structure. Therefore, depending on the decided On-site system It can exist on the team's mobile computing devices[145] as Apps or as a cloud-like online platform.

Regarding the Scrum BIM control metrics, according to the interviewS[146] *1. Team enthusiasm -happiness factor, 2. Sprint backlog Scope-Velocity, 3. Sprint Backlog consistency -velocity, 4. Interruption precautions – Emergency procedure, and 5. Team's understanding of Scrum* are suggested to be adapted into the suggested method in order to track, monitor, and control the process.

Granted the assumption of this paper on applying the suggested Scrum BIM method only in the critical point of the process according to the project milestones, still the complexity of this method is a challenge that needs to be considered; in other words, the simplicity of a manual and easy-to-follow and on-site workflow schema or the existing and acceptable methods such as the Lean methodology might be preferred to the complex, yet effective potentials of the Scrum BIM method within CDE. Therefore, the target of future development on the potentials of the suggested method better be set within the more complex and advanced projects.

[145] This option enables the team members working on the site to be virtually present in the collaboration platform and have updated information and direct access to it at any moment.
[146] Explained in detail in 4.5 Scrum BIM monitoring metrics, (P.54).

## List of literature


1) Aibeo, P., 2018. Architectural Democracy. *Design Studies.*

2) Autodesk, 2017. *getting started with BIM for building design.* s.l.:s.n.

3) Ballard, H. G., 2000. The Last Planner System Of Production Control. In: s.l.: Faculty of Engineering university of Birmingham.

4) Bancroft-Connors, J., 2017. *AgileConnection a TechWell Community.* [Online]
Available at: https://www.agileconnection.com/article/4-balanced-metrics-tracking-agile-teams
[Accessed June 2018].

5) Beck, K. et al., 2001. *Manifesto for Agile Software Development.* Utah, s.n.

6) Beedle, M. et al., 2014. Scrum: A Pattern Language for Hyperproductive Software Development. In: s.l.:s.n.

7) BIMcollab, n.d. *BIMcollab.com/BCF manager.* [Online]
Available at: https://www.bimcollab.com/en/BCF-Manager/BCF-Manager
[Accessed 13 June 2018].

8) BIMcollab, n.d. *BIMvollab.com/openBIM.* [Online]
Available at: https://www.bimcollab.com/en/BIM/OpenBIM/BCF
[Accessed 14 June 2018].

9) Boyd, R., n.d. *pragmaticmarketing.com/9 Scrum Metrics to Keep Your Team on Track.* [Online]
Available at: https://www.pragmaticmarketing.com/resources/articles/9-scrum-metrics-to-keep-your-team-on-track
[Accessed 05 July 2018].

10) British Standard, i., 2013. *PAS 1192-2 (specification for infromation management for the capital-delivery phase of construction projects using building information modelling).* s.l.:British Standards Institution.

11) Bryman, A., 2015. *Social research methods.* New York: Oxford university press.

12) Chelson, D. E., 2010. *drum.lib.umd.edu.* [Online]
Available at: http://hdl.handle.net/1903/10787
[Accessed 25 May 2018].

13) Cohn, M., 2004. *User Stories Applied: For Agile Software Development.* s.l.:Addison Wesley .

14) Cohn, M., 2005. *Agile Estimating and Planning.* s.l.:Pearson Eduction ,Inc..

15) Collier, K., 2011. *Agile Analytics: A Value-Driven Approach to Business Intelligence and Data Warehousing.* Boston: Pearson Education.

16) construtech, 2016. *BIM scrum,* s.l.: s.n.

17) Deming, W., 2000. *The New Economics for Industry, Government, Education.* Massachusetts: MIT Press.

18) designing buildings, w., 2018. *designing buildings wiki.co.uk.* [Online] Available at: https://www.designingbuildings.co.uk/wiki/Common_data_environment_CDE [Accessed 10 June 2018].

19) Dove, R., 1996. *BEST AGILE PRACTICE REFERENCE BASE - 1994:,* Bethlehem, PA, USA: Agility Forum.

20) ENGworks, 2017. *tips for successfully applying the agile scrum mehtodology for BIM spatial coordinations,* s.l.: ENGworks (empowering BIM technology).

21) Excellence, C., 2004. *Lean Construction.* s.l., Constructing Excellence .

22) François Labelle, C. L., 2013. “STAKEPARTNER MANAGEMENT" IN PROJECTS. A turn-of-the-century TURNAROUND AT ALCAN. *The Journal of Modern Project Management.*

23) Haponava, T. a. A.-J., 2016. International Journal of productivity and perfodrmance management benchmarking. *Identifying key performance indicators in construction.*

24) Hundermark, P., 2014. *Do Better Scrum. An unofficial set of tips and insights into how.* s.l.:s.n.

25) James, M., 2015. *training series/scrummethodology.com.* [Online] Available at: http://scrummethodology.com/ [Accessed 20 May 2018].

26) James, M. & Walter, L., 2010. Scrum Reference Card. *CollabNet.*

27) Jimenez, D., 2017. Development of Key Performance Indicators (KPI) for. *master thesis.*

28) Krygiel, E. & Nies, B., 2008. *Green BIM: Successful Sustainable Design with Building Information Modeling.* s.l.:John Wiley & Sons.

29) Kukhnavets, P., 2016. *GANTTPRO.* [Online] Available at: https://blog.ganttpro.com/en/waterfall-project-management-methodology-pros-and-cons/ [Accessed 20 May 2018].

30) Larsen, D. & Derby, E., 2006. *Agile Retrospectives.* s.l.:s.n.

31) McGraw Hill Construction, 2012. *The Business Value of BIM in North America,* s.l.: Smart Market.

32) Monika Agarwal, R. M., 2012. Tracking Scrum projects Tools, Metrics and Myths about Agile. *International Journal of Emerging Technology and Advanced Engineering.*

33) Moran, A., 2014. *Agile Risk Management.* s.l.:SpringerBriefs in Computer Science.

34) Mordue, S., 2015. *bimplus.co.uk.* [Online] Available at: http://www.bimplus.co.uk/management/com8mon-data-environm5ent-dig6ital-space-where-bim/ [Accessed 10 June 2018].

35) Moser, C., 2016. *constructech.com.* [Online]
Available at: https://constructech.com/bim-scrum-part-1/
[Accessed 28 may 2018].

36) PCI, d., 2009. *Building Information Modeling (BIM),* s.l.: s.n.

37) R. Brian Stanfield, T. I. f. C. a., 2000. *The Art of Focused Conversation.* s.l.:New Society Publishers.

38) Radigan, D., 2016. *Five Agile Metrics You Won't Hate,* s.l.: s.n.

39) Richard Torbett, A. J. S. D. M. G. M., n.d. Design Performance Measurement in the ConstructionSector: A Pilot Study. In: s.l.:IEEE Transactions of Engineering Management .

40) RSA, t., n.d. [Online]
Available at: https://www.youtube.com/watch?v=u6XAPnuFjJc
[Accessed 30 June 2018].

41) scrummethodology, 2016. *Scrum Training Series,* s.l.: CollabNet.

42) Sidwell, A. C., 1990. Project management: Dynamics and performance. *Construction Management and Economics .*

43) Smith, P., 2014. BIM implementation.

44) Sutherland, J. & Ahmad, N., 2011. *How a Traditional Project Manager Transforms,* s.l.: s.n.

45) Sutherland, J., Harrison, N. & Riddle, J., 2014. *A Pattern Language for Hyperproductive Software development.* Hawaii, System Science.

46) Sutherlans, J., 2014. *Scrum the art of doing twice the work in half the time,* s.l.: Scrum Inc..

47) TechBeacon, n.d. The history—and legacy—of agile development. *TechBeacon.*

48) Tomek, R. & Kalinichuk, S., 2015. Agile PM and BIM: A hybrid scheduling approach for a. *Procedia Engineering.*

49) Vasiliauskas, V., 2014. *Developing agile project task and team management practices.* s.l.:Eylean.

50) Vegard Knottena, F. S. G. K. H. a. O. L., 2015. *Design management in the building process - A review of currentliterature.* Oslo, Norway, 8th Nordic Conference on Construction Economics and Organization.

51) W.Ambler, S., 2002. *Agile Modeling: Effective Practices for eXtreme Programming and the Unified Process.* s.l.:s.n.

52) *what is Common Data Environment.* 2015. [Film] Directed by B1M. s.l.: s.n.

## Declaration of Authorship

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

| | | |
|---|---|---|
| Location, Date | | Signature of the student |

# Appendix

## Appendix 1. Interview Guide

Helsinki Metropolia University of Applied Sciences

htw.

**Agile Project Management within the BIM based Common Data Environment**

Master Thesis

International Master of Science in Construction and Real Estate Management
Joint Study Programme of Metropolia UAS and HTW Berlin

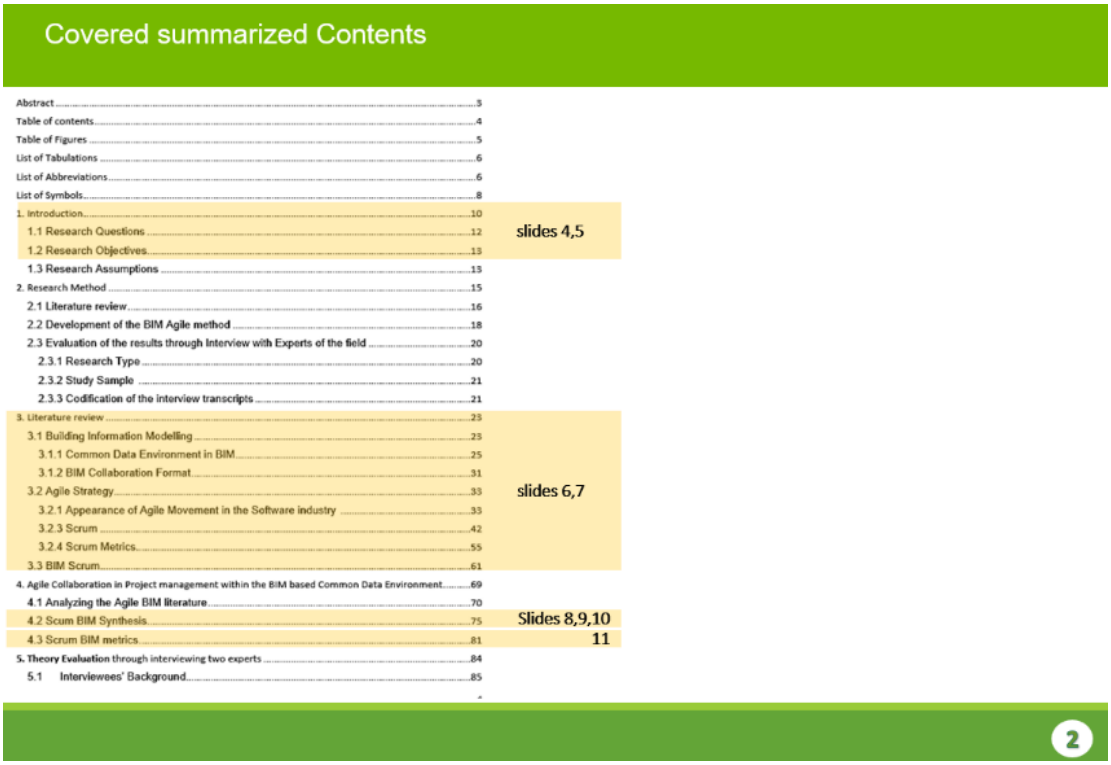
To be Submitted on 20.07.2018

**Razie Qaravi**
557535

First Supervisor: Prof. Dr.-Ing. Markus Krämer

Second Supervisor: Sunil Suwal

1



Covered summarized Contents



2

## Aim of Interview

The interviews will be used to evaluate the research method and results (explained in the following slides) considering the theoretical and practical knowledge of the experts

- Interviewees will be asked questions regarding the methodology for the Scrum BIM synthesis (see table 1 and 2)
- Interviewees will be asked to rank the defined Scrum BIM monitoring metrics in order to their importance in order to the project success (see table 3)



## Research Introduction

- Nowadays for construction projects **one single central control or management unit** is preferred. too many inter-related control points with opportunities for small decisions will result in exponential failures.
- Building Information Modelling **BIM** links the team members' individual efforts to **a central database** referred to as Common Data Environment **CDE**. This cloud or sever enables virtual collaboration and common data space for graphical (such as the 3D digital simulation model of the building and IFC and BCF files related to it) and nongraphical data (such as contracts, calculation's, etc.)

## **Research Introduction** Question and Aim

- What if the project wants to benefit from the **stakeholders constant feedback** to be flexible to business realities and enable a continuous updating (back and forth via feedback loops) design instead of the traditional waterfall approach (pre-defined closed linear phases) **?**

- The research aims to apply **Scrum** method from Agile strategy **into a BIM project** which is using Common Data Environment as tool to coordinate and structure data.



## **Research** Literature - Agile

### **Scrum** an Agile method

- Scrum is made of Iterations called **sprints**
- **Scrum team** spends around 30 days for each Sprint
- **Scrum team, scrum master, and product owner** are the 3 main roles
- **Scrum team** includes expert of all fields (AEC, Monitoring, Planning, Analysis, Acquisition, etc.)
- **Sprint Planning, Daily Scrums, Sprint Review, Sprint retrospective** are the 4 main events (phases) of each 30dayer Sprint
- **Sprint starts with a sprint backlog** (things to do this sprint) and **ends with a live demo** (a visible and testable piece of the sprint backlog) ready to present or release for feedback

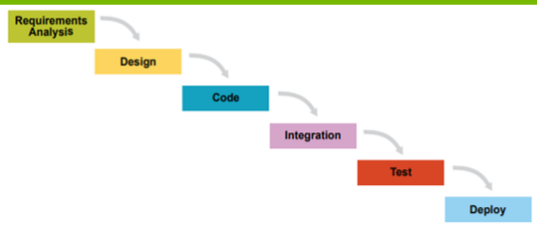



Figure 1. **Traditional „waterfall" development** dividing the work into specific phases with specific ingredients, doing all the design upfront.

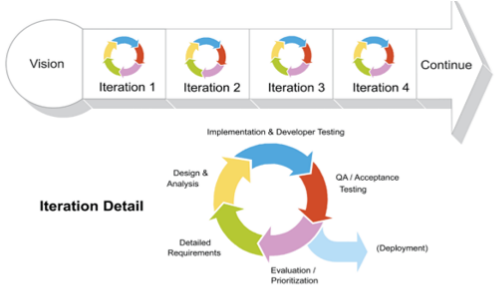



Figure 2. **Scrum** emphasizes on the flexibility to adapt to emerging business realities by introducing **feedback loops.** divided in to **fixed length integration mixture of all ingredients** called sprints. It's a continuous design.

## **Research** Literature - BIM

Building Information Modelling **BIM**

- bridges gaps in communications between stakeholders and project management team disciplines
- provides structured and focused database including the 3D model and project information by providing **a digital simulation of the building** it enables the stakeholders and the project manager to understand the buildings behavior **before it has been built** which leads to significant savings in time and money

BIM Collaboration Format **BCF**

- an **open file format** that allows addition **textual comments, screenshots** and more on top of the model file for better communication between parties. It **separates the communication from the actual model**
- **Encodes messages** that inform one BIM tool **of issues** found by another



## **Research Methodology** Scrum BIM synthesis

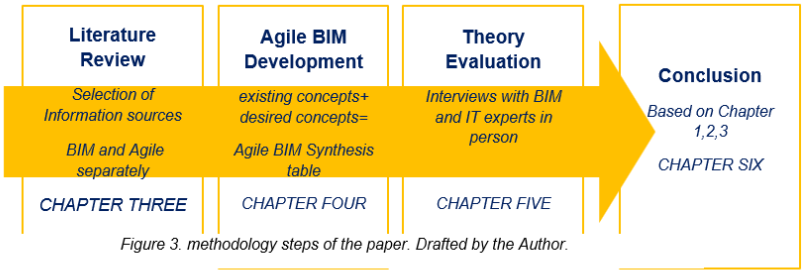
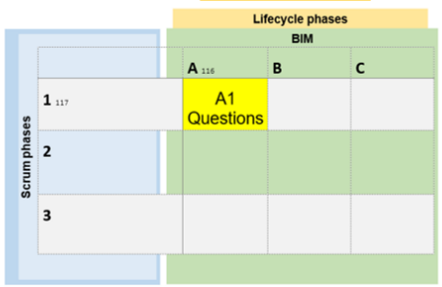



*Figure 3. methodology steps of the paper. Drafted by the Author.*



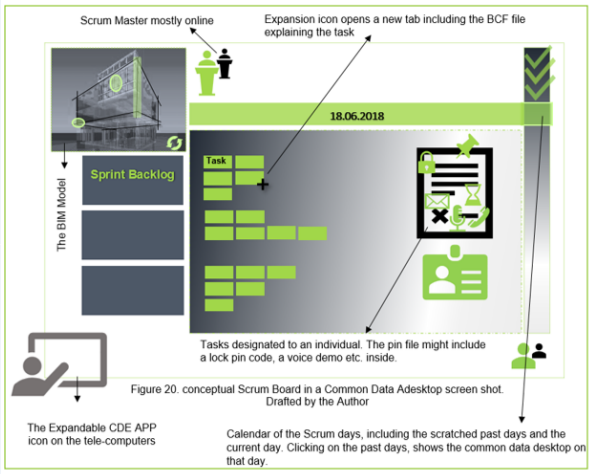

- **A1:** cross-section questions designed to address the integration of column A with row 1.
- **A:** lifecycle phase of the building. e.g.: AEC phase
- **1:** The Scrum Role, what they do, The resulting Object. e.g.: product owner, business prioritization, Product Backlog

*Table 1. Synthesis table approach Chapter 4. drfated by the Author. Source: Pedro Aibeo, 2018*

| Agile BIM Synthesis | | LIFE CYCLE OF THE BUILDING[118] | | |
|---|---|---|---|---|
| | | A. AEC *project management* | B. FM [119] facility management during utilization | C. REHABILITATION *project development* |
| 1. Sprint Planning | 1.1 Owner *business priorities* product backlog | | | |
| | 1.2 PM team *doable amount of work* sprint backlog | | | |
| | 1.3 PM team *from the sprint backlog* Sprint tasks | | | |
| 2. Daily Scrums | 2.1 PM team *done yesterday* updated task list | 2. Daily Scrums<br>1. where is the Daily Scrum held?<br>2. How is the info shared & monitored?<br>3. How are the challenges & discovered tasks reported? | | |
| | 2.2 PM team *will do today* updated task list | | | |
| | 2.3 Scrum Master *impediment report* discovered tasks | | | |

*Table 2. BIM Agile integration (Scrum BIM) Table. Drafted by the Author. Source: Pedro Aibeo, 2018*

## Research Methodology
### Scrum BIM synthesis




- possibility to send a **BCF file to an individual or all** (pin it to the top, set a deadline for it, set a lock on it to keep it private and even use voice or text or calls on it in case they are online)
- **Noticeable status of team members** (offline or online)



## Research Methodology Scrum BIM monitoring metrics

| | Interviewee 1 | Interviewee 2 | Interviewee 3 |
|---|---|---|---|
| 1. Sprint backlog Scope-Velocity % | 3 | Interviewee 1 believes that this is the third most important one, therefore ranks it 3 from 10 | |
| 2. Sprint Backlog consistency -velocity % | | | |
| 3. Team predicted productivity -Planned to Done Ratio % | | | |
| 4. Team enthusiasm -happiness factor % | 1 | Interviewee 3 believes that this is the most important factor , therefore ranks it 1 from 10 | |
| 5. Team's understanding of Scrum 0/1 | | | |
| 6. Scrum master shifting cycle 0/1 | | | |
| 7. Team's collaboration metric- Mutual Assessment (MA) % | | | |
| 8. Customer satisfaction metric-defect rate 1/defect rate % | | | |
| 9. Scrum impediments- Daily clean code % | | | |
| 10. Scrum impediments- removing top impediment 0/1 | | | |
| 11. Interruption precautions – Emergency procedure 0/1 | | | |

*Table 3. **Guide to the Scrum BIM metrics' ranking** gathered from the interviewees **after the interviews**. Drafted by the Author.*

**Thank you for sharing your time and knowledge for this research**

- All the information obtained from the interview will be treated with total confidentiality and anonymity

- The results of this research will be sent to you in A Digital version.

**Appendix 2. Transcript of Interview 1** *IT background*

1. Could you please provide an overview of yourself and the organization in which you are currently occupied? Such as:

(a. your role in the company. b. To what extend is BIM applied in the Organization. c. What form of Common Data Environment (online platform for data exchange and collaboration) is being used (server, cloud-based system, etc.).

I am a computer Scientist with a German University-Diploma. I work as Webmaster in a consumer protection foundation. We are not using BIM, but we do imply Agile strategy for monthly releases for our web-platform. Therefor we are using on-premise Share-Point servers and a ticketing system, as well as MS Teams to cooperate within our foundation and also with our service contractors for web development.

2. Which controlling mechanisms is used in your organization to control and monitor the process?

We are using a ticket system with a well-defined workflow and several complex testing methods, e.g. with Selenium- and Screenshot tests. In another project in which I was involved before, I was using scrum method with Jira Agile to work with the typical sprints.

3. Would you please provide an evaluation of the conceptual screenshots that have been suggested in this research? What are the strengths and weaknesses?

From the software developing or software project managing point of view I suggest that the scrum-BIM synthesis is used for the theoretical developing parts only. In Software development we have feedback loops where we are able to change code or requirements. In real world this might not be possible, because it's hard to roll back already built/constructed decisions. For the theoretical parts of construction and managing I assume this approach to be assertive. Software and construction development in their theoretical scenario-phases are underlying the same methods. You

plan the product, the tools, the developing steps. The development itself in software can always roll back because it is STILL theoretical (like writing this digital text). Architectural development is placed in real world with physical material. But this difference you can pass by with modelling. So, where a software developer starts producing the product is where the architect could start to model before hard developing. Then you can get use of all the feedback loops that SCRUM offers and therefor the in this thesis described milestone-approach can be used.

4. How can it be improved? Would you have done it differently?

I would consider putting more resources in modelling when using scrum-BIM for architectural development to be closer to the software cycle. When we assume, that our model can be constructed one-to-one in real world developing phase, then we should be fine. In general, I would use state of the art software combined with each other, like a BIM software and a good ticket system like Jira together with a documentation platform like Confluence and connecting it through APIs to BIM platform. It is also possible to develop add-ons or plug-ins into one of them.

5. How can non-public spaces be more secure while existing on the same common virtual desktop? pin codes, finger touches on the mobile computing devices or apps?

For a user-related environment you can use a role-system and assigned specials roles, for example the scrum master. As seen in your model, you are already assuming users with some roles, so you need an application manager for the software who also takes care of user roles and role-rights. It’s a good approach to not give users specific read and write rights, but to the roles that are applied to the users. As told e.g. a “Scrum Master” role, a “Customer X” role, a “Developer” role and maybe also “Customer Y” for another company. For authentication of the user you of course can also use multi-factor authentication.

6. How would you imagine the future of such software for a Complex Scrum BIM projects? Would you set some criteria for implying them? Should this entire virtual environment exist only online on the company related platform and only be accessible through the company network? Or is it preferred as applications installed on mobile computing devices accompanying the team members everywhere on the site and all the time. (during work time)

You can use a cloud (where many companies can make accounts for their needs) software or on premise (On a server in the developing company). Then you apply APPs to access the software on several devices. On premise solutions are better for data privacy.

7. Which metrics are more important for a project success within the Scrum framework? Why? Please rank them by importance.

a) **Sprint backlog Scope-Velocity**:

Measures the amount of work completed tasks of the sprint backlog[147] compared to the tasks of the whole product backlog in parentage which helps the team to realize their capacity and provides predictability for future sprints;[148]

Rank 1, because one of the main goals in scrum is transparency of current process / achieved milestones.

b) **Sprint Backlog consistency -velocity**:

measured by comparing story points completed in the current sprint with points completed in the previous sprint in percentage and the acceptable range of variance in two sprints in a row is +/- 10 percent.[149]

Rank 4, because it's an important measurement but team's predicted productivity is more important / expressive for measurement (sprints have different tasks, so sometimes a sprint cannot be planned to have same points as the one before).

c) **Team's predicted productivity -Done-to-Planned Ratio**:

[147] In IT Scrum this item is called Story Point which is a metric for the complexity of the tasks of the product backlog. The least complex task receives 1 point and the last complex one receives 100 points.
[148] (Radigan, 2016)
[149] (Boyd, n.d.)

Measures the amount of work actually done at the end of the sprint compared to the work committed to do in the beginning of each sprint which anticipates the sprint's success in percentage.[150]

Rank 3, because in scrum is all about planning / assuming load. And to plan the next sprints you also have to see if you planned the previous sprints in a right way for the project to succeed on the planned time.

d) **Team enthusiasm -happiness factor**:

Measures team's willingness and enthusiasm to cooperate and improve. Overlooking this key role player will lead to a probable failure from which no applied process or method can avoid.[151] Can be measured in the retrospective meeting by asking the team members to score their happiness amount on a pre-defined and agreed upon scale like percentage and referring to the average of this percentage, or by simply asking them to answer to the question "are you happy?" with simple yes and no and later calculate the happiness percentage of the team by divining happy members to all in percentage. By keeping track of the trend of this metric the happiness trend is visible to all.[152]

Rank 6, because it is important that the workers and everyone in the process is motivated and satisfied, but It could also bring an unwanted emotional factor (try to cheer people instead of work hard to success).

e) **Team's understanding of Scrum**:

None of the Scrum purposes will be met if the team fails to grasp the whole Scrum concept. Daily in person scrum meetings significantly improves this factor which is a qualitive metric. Therefore, there is no way to monitor it. Nevertheless, having a sprint planning meeting with highlighted focus on addressing this issue and the importance of grasping the Scrum concept to all [153] covers this item. [154]

Rank 5, because it's one of the most important besides the tasks ranked 1-4.

f) **Scrum master shifting cycle**:

Scrum Master is a role comparable to a Capitan of a ship. When the current sprint ends the role shifts as well to make sure that the team is self-organized, and no deficient hierarchy is harming

[150] (Bancroft-Connors, 2017)
[151] (Boyd, n.d.)
[152] (Bancroft-Connors, 2017)
[153] Including the owner or the client, external and internal stakeholders, and the daily Scrum team.
[154] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

the equally fair collaboration within the Scrum Team and encourage the team's engagement enthusiastic sympathy. [155] [156]

Rank 11, because I assume that this is not practical in BIM and their processes. I also never used this method during my scrum experiences.

g) **Team's collaboration metric-The Mutual Assessment (MA) methodology**:

Used at the sprint retrospective meeting in which the team members evaluate the rest of the team on their contribution towards reaching the sprint goals. [157] [158]

Rank 10. I would consider this option every two sprints or once a month, but not every sprint.

h) **Customer satisfaction metric-defect rate**:

Indicates customer satisfaction by counting the number of bugs and defects in the delivered backlog of the sprint after its release. The lower the defect rate, the more satisfied the end-user with the released sprint backlog. [159] it is calculated by dividing one to defect rate in percentage. The defect rate is calculated by dividing the number of defected SPs to the whole released SPs.

Rank 7. Customers satisfaction is important, but an only be achieved by considering tasks 1-6.

i) **Scrum impediments- Daily clean code**:

Aiming for a clean base of code at the end of every day or trying as hard as possible to fix all the bugs in the same day that they appear saves up to 24times the time spent to fix it on the originated day compared to postponing it to the future.[160] It is calculated by dividing the clean code days of the Sprint to the whole days of sprint in percentage.

Rank 8, because in my point of view this should be part of emergency / failover. Ut it is for example wise to sleep one night over a bug instead of trying to fix it after a long day of work. So, if, maybe put it to the beginning of a next day.

j) **Scrum impediments- removing the impediment on top**:

Removing the single most destructive impediment at the end of the sprint during the sprint retrospective to start the next one without its trace would result in a better sprint. [161] This factor is

[155] (Beedle, et al., 2014)
[156] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.
[157] (Vegard Knottena, 2015)
[158] (Jimenez, 2017)
[159] (Bancroft-Connors, 2017)
[160] (Beedle, et al., 2014)
[161] (Beedle, et al., 2014)

using a quantities method to result in eliminating a factor. But choosing which factor to eliminate can be a subject of quantities evaluation. Such as voting online for the single most important impediment and choosing the highest rated one. [162]

Rank 9, because this is also part of an emergency plan for me., but of course useful

k) **Interruption precautions – Emergency procedure**:

In any project there is a necessity to consider an Emergency plan in the start of the sprint for unpredicted scenarios since thinking for the reaction counts as waste of time and results in horrible harmful consequences. In case of things going off the track the emergency procedure will be executed preferably by mid-sprint with no further delay. in such cases Scrum Mater is in charge of considering the following tasks depending on the accrued emergency. Asking for help from outside of the Scrum team, demanding for redefining a smaller scope of sprint backlog for the rest of the sprint, offloading backlog to someone else, Abort the sprint and re-plan, inform management about the effected changes in the sprint review demo release.[163]

Rank 2. Nothing is more constant than change. There is a well-known saying that describes exactly the necessity of this task. But it needs the task which is ranked 1 for success.

## **Appendix 3. Transcript of Interview 2** *Architectural background*

1. Could you please provide an overview of yourself and the organization in which you are currently occupied? Such as:

a. your role in the company: I am a MSc Architect and MSc Civil Engineer, I am the CEO of “Gamified Cohousing”, a Vis. Associate Professor at UNAM and researching on the topic of “Architectural Democracy” at the Aalto BIM lab, Aalto University. In my company BIM has been useful to combine the different models from the old buildings we are renovating. Data from laser scans are combined with classical measurements for example or sometimes Photogrammetry modelling.

[162] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

[163] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

b. To what extend is BIM applied in the Organization: We are integrating it more and more as we go. Main goal is to be having the right structure to allow up-scaling.

c. What form of Common Data Environment (online platform for data exchange and collaboration) is being used (server, cloud-based system, etc.): Through a shared folder in the cloud, IFC documents and COBie.

2. Which controlling mechanisms is used in your organization to control and monitor the process?

As we are still a small company with small projects, the data is compiled and validated mostly manually by allocating it into the right folders on the cloud: work in progress folders, shared with the client (validated but requiring feedback) and then published. We try to do these in a lean agile way, in small steps of each stage.

3. How do you find the methodology of this research? (the Scrum BIM synthesis see Interview Guide)

I like the approach, the scrum synthesis could be broader in scope though, less focused on software industry, especially point I (Daily clean code) and for all, it should be shorter. Also, more visual: like a construction safety schema that workers must follow while working on site! The point on happiness measurement (d), should not be done via questionnaires, the topic of happiness is too subjective and personal to be asked directly. The interviewed will feel pressured. Other methods are available.

4. Which metrics are more important for a project success within the Scrum framework? Why? Please rank them by importance.

Point **d. (Team enthusiasm -happiness factor)** is of course fundamental followed by **a. (Sprint backlog Scope-Velocity)** and **b. (Sprint Backlog consistency -velocity)**. The satisfaction of the parts of the whole (of the workers) bring stronger results than the sum of it**.**

**Appendix 4. Transcript of Interview 3** *Project Management background*

1. Could you please provide an overview of yourself and the organization in which you are currently occupied? Such as:

a. Your role in the company. b. To what extend is BIM applied in the Organization. c. What form of Common Data Environment (online platform for data exchange and collaboration) is being used (server, cloud-based system, etc.).

I am a 30-year-old Civil engineer. I graduated my bachelor in University of Mazandaran - Iran in Civil engineering and finished my Master in HTW Berlin in Construction and Real Estate Management in 2015. During my bachelor, I had the chance to work in an architecture company for almost 3 years as Designer and In 2015, I started to work for Zechbau, which is one of the 10 biggest construction companies in Germany with over 1100 employees. The company started as a classical building company almost 100 years ago and has become today a full-service provider across the various fields of modern construction.

Since 2015 more than 80 percent of the projects within Zechbau have been implemented using Lean Construction Method. As a Construction manager by Zechbau I was responsible for implementing and controlling the Lean technique during the construction Phase for a residential project in Berlin Karlshorst. Since 2017 along with changing the company policies towards digitalization of the construction process, I was responsible for development of digital techniques such as Lean and BIM in the future projects of Zechbau East Germany region.

2. Which controlling mechanisms is used in your organization to control and monitor the process?

The controlling process can be broken down into monitoring the activities with respect to the hierarchical structure of management team, which would be realized using classical methods as before, and controlling the project development in which implementing BIM and Lean techniques will play a significant role to increase the efficiency and reduce the amount of errors and omissions.

3. how do you find the methodology of this research? (the Scrum BIM synthesis, see Interview Guide)

For the projects with limited resources is lean concept in today's market situation a more preferred solution. However, there are some complex projects with higher customization and flexibility requirement for which implementing Scrum and BIM simultaneously will in fact increase the efficiency and the adjustability level of the process to the potential changes. Combining model-based solutions with Scrum Agile techniques will play an important role in the future of construction industry by increasing the productivity and keeping efficient tracking of project progress and change management.

The methodology provides firstly a detailed description of both concepts separately as well as deep understanding of benefits of using both methods in one process. The suggested digital solution in the end, introduces a wide range of scrum iteration metrics in form of a software - based data platform focusing on BIM common data format communication that enormously eases collaboration and coordination between shareholders, which is a key factor for agile project management methodic. This idea seems to be aiming for the complex project in future of construction industry. As a person who has more than 4 years of experiences in different digital techniques with varieties of project complexities in German construction market I find the methodology to be interesting to provides an insight into the project scope for all the involved ones.

4. Which metrics are more important for a project success within the Scrum framework? Why? Please rank them by importance.

a) Sprint backlog Scope-Velocity:

Measures the amount of work completed tasks of the sprint backlog[164] compared to the tasks of the whole product backlog in parentage which helps the team to realize their capacity and provides predictability for future sprints;[165]

Rank 10.

[164] In IT Scrum this item is called Story Point which is a metric for the complexity of the tasks of the product backlog. The least complex task receives 1 point and the last complex one receives 100 points.
[165] (Radigan, 2016)

b) Sprint Backlog consistency -velocity:
measured by comparing story points completed in the current sprint with points completed in the previous sprint in percentage and the acceptable range of variance in two sprints in a row is +/- 10 percent.[166]
Rank 11.

c) Team's predicted productivity -Done-to-Planned Ratio:
Measures the amount of work actually done at the end of the sprint compared to the work committed to do in the beginning of each sprint which anticipates the sprint's success in percentage.[167]
Rank 8.

d) Team enthusiasm -happiness factor:
Measures team's willingness and enthusiasm to cooperate and improve. Overlooking this key role player will lead to a probable failure from which no applied process or method can avoid.[168] Can be measured in the retrospective meeting by asking the team members to score their happiness amount on a pre-defined and agreed upon scale like percentage and referring to the average of this percentage, or by simply asking them to answer to the question "are you happy?" with simple yes and no and later calculate the happiness percentage of the team by divining happy members to all in percentage. By keeping track of the trend of this metric the happiness trend is visible to all.[169]
Rank 1. The Success factor of this method has a direct relation with team's motivation.

e) Team's understanding of Scrum:
None of the Scrum purposes will be met if the team fails to grasp the whole Scrum concept. Daily in person scrum meetings significantly improves this factor which is a qualitive metric. Therefore, there is no way to monitor it. Nevertheless, having a sprint planning meeting with highlighted focus on addressing this issue and the importance of grasping the Scrum concept to all [170] covers this item. [171]

---

[166] (Boyd, n.d.)
[167] (Bancroft-Connors, 2017)
[168] (Boyd, n.d.)
[169] (Bancroft-Connors, 2017)
[170] Including the owner or the client, external and internal stakeholders, and the daily Scrum team.
[171] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.

Rank 3.

f) Scrum master shifting cycle:
Scrum Master is a role comparable to a Capitan of a ship. When the current sprint ends the role shifts as well to make sure that the team is self-organized, and no deficient hierarchy is harming the equally fair collaboration within the Scrum Team and encourage the team's engagement enthusiastic sympathy. [172] [173]
Rank 7.

g) Team's collaboration metric-The Mutual Assessment (MA) methodology:
Used at the sprint retrospective meeting in which the team members evaluate the rest of the team on their contribution towards reaching the sprint goals. [174] [175]
Rank 2.

h) Customer satisfaction metric-defect rate:
Indicates customer satisfaction by counting the number of bugs and defects in the delivered backlog of the sprint after its release. The lower the defect rate, the more satisfied the end-user with the released sprint backlog. [176] it is calculated by dividing one to defect rate in percentage. The defect rate is calculated by dividing the number of defected SPs to the whole released SPs.
Rank 6.

i) Scrum impediments- Daily clean code:
Aiming for a clean base of code at the end of every day or trying as hard as possible to fix all the bugs in the same day that they appear saves up to 24times the time spent to fix it on the originated day compared to postponing it to the future.[177] It is calculated by dividing the clean code days of the Sprint to the whole days of sprint in percentage.
Rank 4.

j) Scrum impediments- removing the impediment on top:

---

[172] (Beedle, et al., 2014)
[173] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.
[174] (Vegard Knottena, 2015)
[175] (Jimenez, 2017)
[176] (Bancroft-Connors, 2017)
[177] (Beedle, et al., 2014)

Removing the single most destructive impediment at the end of the sprint during the sprint retrospective to start the next one without its trace would result in a better sprint. [178] This factor is using a quantities method to result in eliminating a factor. But choosing which factor to eliminate can be a subject of quantities evaluation. Such as voting online for the single most important impediment and choosing the highest rated one. [179]

Rank 9.

k) Interruption precautions – Emergency procedure:

In any project there is a necessity to consider an Emergency plan in the start of the sprint for unpredicted scenarios since thinking for the reaction counts as waste of time and results in horrible harmful consequences. In case of things going off the track the emergency procedure will be executed preferably by mid-sprint with no further delay. in such cases Scrum Mater is in charge of considering the following tasks depending on the accrued emergency. Asking for help from outside of the Scrum team, demanding for redefining a smaller scope of sprint backlog for the rest of the sprint, offloading backlog to someone else, Abort the sprint and re-plan, inform management about the effected changes in the sprint review demo release.[180]

Rank 5.

[178] (Beedle, et al., 2014)
[179] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.
[180] It is a qualitive factor for which there is only two possibilities. It is either considered which is one or not considered which is zero.