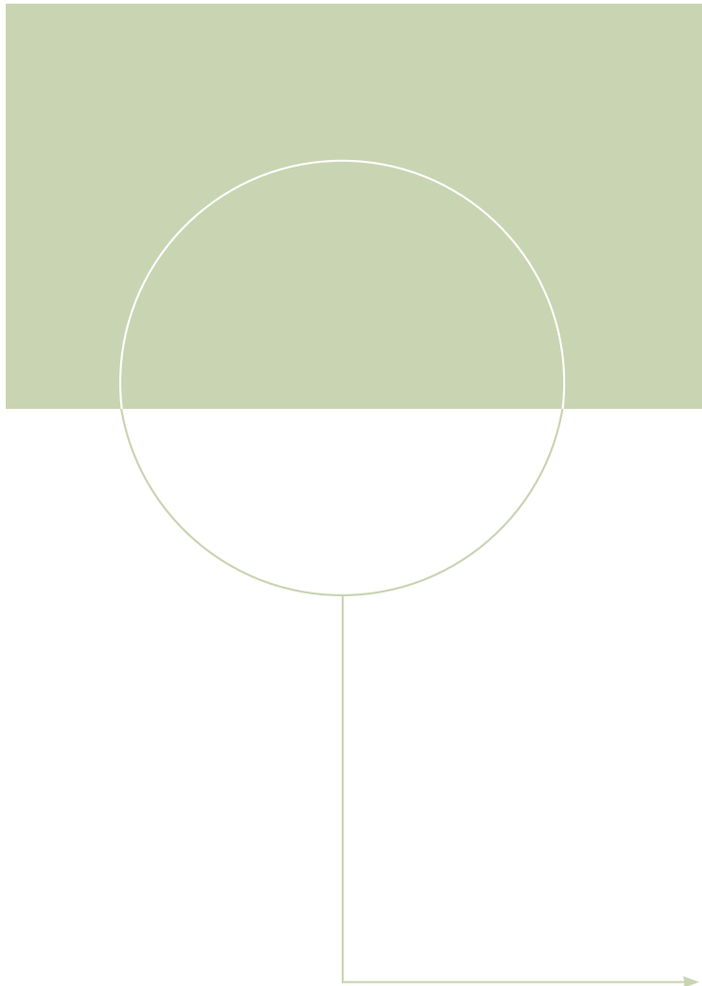

Master's thesis

2020

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Fully integrated BIM at maturity level 3 in the Road Project "E39 Kristiansand West - Mandal East".

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Fully integrated BIM at maturity level 3 in the Road Project "E39 Kristiansand West - Mandal East".

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Master of Science in Project Management
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Abstract:
In the last decade, digitalization and the improvement of internet solutions has transformed a wide range of industrial sectors, resulting in a tremendous increase in collaboration and sometimes in productivity, product quality and product variety. Due to this development and advancement in technology, the BIM revolution has arisen in AEC industry also.
The aim of this paper is to explain what contractor building road project "E39 Kristiansand Vest – Mandal Øst" is trying to deliver in accordance to BIM Implementation Strategy, particularly "F*ully integrated BIM at maturity level 3"* and try to uncover challenges that are related to data quality which will be uploaded in the BIM model and the information flow inside organizations and other directly related stakeholders. Thesis is designed to answer the following research questions

1) *What are the theoretical possibilities of level 3 Fully integrated BIM?*
2) *What are challenges in accordance to data quality and information?*
3) *How to close the gap between theoretical approach and practice?*

Through literature review, formal and informal conversations, in-depth interviews and partly working on a scientific article, the paper tries to investigate the challenges and benefits that the Implementation of BIM at maturity level 3 will provide for the project. The challenges revealed and experience gained from working with the collaboration partner AF Gruppen as Main Contractor, are compared with the theory and both benefits and points of improvement are identified. The study shows that those involved in the usage of BIM are largely positive for development of new technology and they believe that this is the right step toward a fully digital construction environment. The research pinpoints the need to hire more qualified staff, more training among the staff that is actually working in the project, early involvement of the subcontractors, improve the model descriptions, integrate more digital tools in the web-based portal and involve the Road Authorities in the whole design process so can this save time in the approving process. Lean principles as improved reliability and effectivity in a BIM level 3 Project are observed but some obstacles as development of new software`s and early involvement of stakeholders must be addressed. These problems can be addressed by gaining more experience in further projects, early involvement of important stakeholders and by training staff before starting to work in the project.

Keywords:

1. Building Information Modelling
2. Challenges
3. Implementation
4. Infrastructure projects

TABLE OF CONTENTS

Table of Contents

TABLE OF FIGURES

Table of Figures

ACRONYM	
AR	Augmented Reality
API	Application Programming Interface
AIM	Asset Information Model
BIM	Building information Modeling
BCF	BIM Collaboration Format
CAD	Computer-Aided Design
FM	Facility Management
HSE	Health Safety and Environment
ICE	Integrated Concurrent Engineering
IFC	Industry Foundation Classes
ISO	International Organization for Standardization
LPS	Last Planner System
NBS	National Building Standards
PIM	Project Information Model
RPA	Robot Process Automation
VR	Virtual Reality

PREFACE

The Master Thesis is the final project of the Project Management Studies at the Department of Civil and Environmental Engineering at the Norwegian University of Science and Technology. The project consists of 30 study points part of the Project Management study program.

The topic for the thesis is *Fully Integrated BIM at the maturity level 3.* The choice of the topic follows the background from the first master's degree and 5 years of experience in Construction field before I decided that it was necessary to take further studies in Project Management within civil engineering specialization. Digitalization as concept, use of BIM, the necessity to increase efficiency and minimize the risks for mistakes is affecting the AEC industry in many dimensions.

Through studies at NTNU, experience as Civil Engineer in Europe and as Construction Manager in the biggest road project ever in Norway, I have gained knowledge and exchange experiences about the challenges that affects the construction in general and the last project especially. With this research I try to uncover the challenges and benefits of the BIM implementation in the road project *"E39 Kristiansand West – Mandal South"*. The research work has been very demanding, educational and very valuable for my future as Project Manager.

Firstly, I thank my direct supervisor Ola Lædre and the PhD. Student David Fürstenberg for the valuable contribution. I would particularly thank BIM Coordinator Herman Horsle for his extraordinary knowledge in the application of technology and BIM training through the different phases of BIM implementation strategy. In addition, I would thank all the respondents of the interviews for their support and time that they dedicated to this project. Finally, I would like to thank my wife, my daughter Amla and my whole family for the patience and support in this awesome project.

Without them this would not have been possible.

Trondheim, Juni 2020

Gentjan Ramaj

SUMMARY

In the last decade, digitalization and the improvement of internet solutions has transformed a wide range of industrial sectors, resulting in a tremendous increase in collaboration and sometimes in productivity, product quality and product variety. Due to this development and advancement in technology, the BIM revolution has arisen in AEC industry also.

BIM means different things to different people, but the most known and accepted definition of BIM is given by the US National Building Information Model Standard Project Committee as follows:

"Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder".

The reason why I chose this definition to represent the central point of my thesis is the attention that the definition gives the lifecycle of the asset, from concept to demolition.

The Master Thesis has been designed to investigate the implantation of "Fully integrated *BIM at maturity level 3"* in the *Road Project E39 "Kristiansand West – Mandal East"*, a project that was under construction at the time the thesis was written.

Through literature review, formal and informal conversations, in-depth interviews and partly working on a scientific article, the paper tries to investigate the challenges and benefits that the Implementation of BIM at maturity level 3 will provide for the project. The challenges and experienced gained from working with the collaboration partner AF Gruppen as Main Contractor, are compared with the theory and both benefits and points of improvement are identified. Going through previous literature the researcher has identified, benefits and challenges using BIM in all construction phases, from design to operation but is mainly focused in production phase due to the fact the researcher was working full time as Construction Manager in the project. AF Gruppen in collaboration with Norconsult as design company and Nye Veier as the client have set the goal of achieving the implementation of fully integrated BIM at maturity level 3 in the project by delivering the "Paper free" concept for the design and production phase and use the BIM model further during the operation time.

To achieve this the Contractor itself must develop and maintain the software necessary, train staff and find better solutions than those offered in the market.

The aim of this paper is to explain what road project "E39 Kristiansand Vest – Mandal Øst" is trying to deliver in accordance to BIM Implementation Strategy particularly BIM maturity level 3 and try to uncover challenges that are related to data quality which will be uploaded in the BIM model and the information flow inside organizations and other directly related stakeholders.

In line with what I have described above the thesis is designed to answer the following research questions

1) *What are the theoretical possibilities of level 3 Fully integrated BIM?*
2) *What are challenges in accordance to data quality and information?*
3) *How to close the gap between theoretical approach and practice?*

The study shows that those involved in the usage of BIM are largely positive for development of new technology and they believe that this is the right step toward a fully digital construction environment. Overall, BIM in design phase seems to be contributing to the simplification of work among users and has led to a better information flow but the research finds out the the respondents would feel better with a standardized solution that the whole industry can use instead of different solutions that contractors are developing on their own.
When it comes to production phase the research revealed that the goal of the project to deliver fully integrated BIM will be achieved partially but all the respondents agree that there is no doubt that the project that utilizes the potential of fully integrated BIM can save time and money. The research pinpoints the need to hire more qualified staff, more training among the staff that is actually working in the project, early involvement of the subcontractors, improve the model descriptions, integrate more digital tools in the web-based portal and involve the Road Authorities in the whole design process so can this save time in the approving process.
The E39 project is addressing the need to use BIM in operation phase by providing a cloud or web-based solution with integration possibilities of different digital work tools. The research reveals that all the respondents feel positive and support the solutions, but much more effort should be given to make the solution to filter right information.
Finally, the researcher identified Lean principles as improved reliability and effectivity in a BIM level 3 Project. However, there are two main obstacles for using the full potential that lies

within the digitalization of the AEC industry: 1) the existing software tools are not completely adapted to digitalization and 2) external stakeholders that slow down the production.

These problems can be addressed by gaining more experience in further projects, early involvement of important stakeholders and by training staff prior to coming to work in the project.

SAMMENDRAG

I det siste årene har digitalisering og forbedringen av internettløsninger forandret store deler innenfor den industrielle sektoren, noe som har resultert i en enorm økning i samarbeid og noen ganger produktivitet, produktkvalitet og produktsortiment. På grunn av en slik utvikling av avansert teknologi, har BIM revolusjonen oppstått i AEC industrien.

BIM har ulik betydning blant folk, men den mest kjente og aksepterte definisjonen på BIM er gitt av US National Building Information Model Standard Project Committee:

"Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder".

Grunnen til at jeg valgte denne definisjonen til å representere de sentrale tema i min avhandling er oppmerksomheten som definisjonen gir til livssyklusen av ressursen, fra konsept til riving.

Masterens oppgave er laget for å utforske implementeringen av **«***Fult integrert BIM nivå 3***»** på veiprosjektet E39 «Kristiansand vest – Mandal øst», et prosjekt som ble bygget i perioden da avhandlingen ble skrevet.

Gjennom litteratur, formelle og ikke-formelle samtaler, dybdeintervjuer og til dels gjennom arbeidet med en vitenskapelig artikkel, prøver oppgaven å utforske ulemper og fordeler ved implementering av BIM på nivå 3 vil gi på prosjektet. Utfordringene og erfaringene fra å jobbe med samarbeidspartneren AF Gruppen som hoved entreprenør er sammenliknet med teorien og både fordeler og punkter på forbedring er identifisert. En gjennomgang av litteratur har identifisert fordeler og ulemper ved å bruke BIM i alle bygningsfasene, fra design til operasjon med fokus på produksjonsfase ettersom forskeren jobbet fulltid som prosjektleder. AF Gruppen har i samarbeid med Norconsult som designer og Nye veier som klient satt seg som mål å implementere **«***Fult integrert BIM nivå 3***»** i prosjektet ved å levere en papirfri konseptmodell i design og produksjonsfase, i tillegg til å bruke BIM modeller lengre ut i prosjektet.

For å oppnå dette må Entreprenøren utvikle og vedlikeholde den nødvendige programvaren, lære opp personale og finne bedre løsninger enn de som allerede ligger ute på markedet.

Målet med denne artikkelen er å forklare hva veiprosjekt «E39 Kristiansand Vest – Mandal Øst» prøver å levere i samsvar med BIM implementeringsstrategi og særlig BIM nivå 3. Målet er også å prøve å avdekke utfordringer relatert til data kvalitet som vil bli lastet opp i BIM modellen og gi informasjonsflyt til organisasjoner og andre direkte relaterte interesse parter.

På linje med hva jeg har beskrevet ovenfor er avhandlingen laget for å svare på følgende forskningsspørsmål:

1. *Hva er de teoretiske mulighetene til komplett integrert BIM nivå 3?*
2. *Hva er utfordringene i samsvar med data kvalitet og informasjon?*
3. *Hvordan kan gapet mellom teoretisk tilnærming og praktisk tilnærming blir mindre?*

Studien viser at de involverte i bruken av BIM er svært positive til utvikling av ny teknologi og mener at dette er det rette steget mot et komplett digitalt konstruksjonsmiljø. I sin helhet ser det ut til at BIM i sin designfase bidrar til forenkling av arbeidet til brukere og har ført til bedre informasjonsflyt. Studien viser imidlertid at målgruppen ville respondert bedre på en standardisert løsning som kan brukes av hele industrien i stedet for forskjellige løsninger som underentreprenørene utvikler på egenhånd.

Når det kommer til produksjonsfasen viser studien at målet med prosjektet; å levere et komplett integrert BIM system, kan spare penger og tid. Studien viser at det er et behov for å ansette flere kvalifiserte ansatte, mer opplæring blant de allerede eksisterende ansatte som jobber på prosjekter, tidlig involvering av underleverandører, forbedring av modellbeskrivelsen, integrering av flere digitale verktøy i den nettbaserte portalen og å involvere Statens Vegvesen i hele design prosessen da dette kan spare tid i godkjenningsprosessen.

E39 prosjektet tar opp behovet for bruken av BIM i driftsfasen ved å tilby en sky eller nettbasert løsning med integrerte muligheter for forskjellige digitale arbeidsverktøy. Studien viser at alle respondentene er positive til denne løsningen, men det må legges inn mye mer innsats for å få systemet til å filtrere riktig informasjon.

Til slutt viser studien at Lean prinsippene forbedrer påliteligheten for effektiviteten i et BIM nivå 3 prosjekt, men det er to hovedutfordringer når det kommer til utnytting av potensialet til digitalisering av AEC industrien; 1) De eksisterende programvareverktøyene er ikke tilpasset digitaliseringen, 2) Eksterne interesseholdere som bremser produksjonen. Disse problemene kan adresseres ved å få mer erfaring fra fremtidige prosjekter, tidlig involvering av viktige interesseholdere og ved å trene ansatte før de ansettes til å jobbe i prosjektene

1. INTRODUCTION

1.1. Motivation for the research and background

To find the root of the concept we must search on publications by mid 1980s and early 1990s, however, the concept as we know today was used for the first time from an Autodesk white paper publication in 2002. Presented more as an Autodesk business strategy for the application of information technology to the building industry, this would lay the foundation to become a standard for the whole AEC industry.

The terms 'Building Information Model' and 'Building Information Modeling' (including the acronym "BIM") were used for the first time in that paper. Further publications opened the range of definitions and descriptions for the acronym “BIM” and today we can find publications that define “BIM” as Better Information Management or Building Information Management.

BIM means different things to different people, but the most known and accepted definition of BIM is given by the US National Building Information Model Standard Project Committee as follows:

“Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder”.

In the last decade, digitalization and the improvement of internet solutions has transformed a wide range of industrial sectors, resulting in a tremendous increase in collaboration and sometimes in productivity, product quality and product variety. Due to this development and advancement in technology, the BIM revolution has arisen in AEC industry also. In recent years, maybe all large vendors have published software products with powerful BIM functionalities and the concept that originated from 1980s has now become an industry practice.

In Norway the concept was officially introduced in 2008, one year after Finland introduced the BIM Guidelines in 2007. Statsbygg and BuildingSmart introduced BIM manual to be used in construction industry. Since then a lot has happened and the industry is moving from BIM in design and construction phase to a life cycle management model that includes operation and

future development of the asset. In technical terms this can be described as a transition from BIM maturity level 2 to BIM maturity level 3.

BIM maturity level 3 fully integrated BIM is based on implementation of BIG open BIM and ISO standards are used for data exchange and process description. In addition, the digital models are used throughout the entire lifecycle. Health, Safety, Environment, quality deviations, project information and planning will be part of a model and cloud services in collaboration with web-based solutions will be used for managing project data continuously over the asset`s life cycle.

In this paper I approach the topic of Fully integrated BIM level 3 in road projects in Norway and particularly in a project that is under construction, "E39 Road Project Kristiansand Vest-Mandal Øst". The project has started in 2018 and is predicted to finish in early 2022. What is different in this project from other road projects that are being built in Norway are the contractual requirements for digital tools and especially for the BIM requirements that the contractor must deliver.

In this paper I will try to explore the opportunities and challenges that follow this kind of transition in terms of information systems and data quality.

1.2. Collaboration partner

The researcher partnered with AF Gruppen Norge AS for the Master thesis. AF Gruppen is a construction company within infrastructure, buildings, renovations, environmental projects, demolitions and offshore and it is very familiar with BIM usage. The researcher was employer of AF Gruppen Anlegg (AF Grupen Infrastructure Projects) in the position of Construction Manager in the road project "E39 Kristiansand Vest – Mandal Øst". The researcher was involved in the implementation of BIM strategy for the project, by helping and addressing the need for different tools and options in the new system that was being developed particularly for this project. In the early phases of the project the researcher was involved in the quality assurance system where BIM was a huge part of the control systems, planning and implantation of the project and this triggered the idea of a further study in the implementation of BIM in the maturity level 3. From September 2019 – December 2019 the researcher conducted a pilot project which paved the road for the master thesis.

1.3. Purpose

Building Information Modelling BIM represents the consistent and continuous use of digital information across the entire lifecycle of a built facility, including its design, construction and operation. This idea was originally proposed by researchers in the 1980s but has only reached technical maturity in recent years and is now being successively adopted by the industry across the globe. The implementation of BIM technology profoundly changes the way architects and engineers work and drives the digital evolution of the AEC industry. (A. Borrmann et. al 2018)

BIM model is usually misunderstood as a 3D model that visualizes just three dimensions, but BIM model can support dimensions extending the three geometrical dimensions. Time is commonly recognized allowing users to keep track of projects progress and schedule. Additional dimensions are typically cost, life cycle assessment, health and safety, environmental impact, facilities management, operations and management. All these dimensions expand the BIM by adding new data that further builds understanding of the project.

With all these possibilities, the real challenge lies in creating the right models and applying the right tools in the most beneficial way, as well as in developing and establishing the corresponding workflow and processes. (A. Borrmann et. al 2018)

The mid 2000s were the years where the BIM started to be adopted in practice and since then has been consistently intensified. USA, Singapore and South Korea are among the most advanced countries worldwide with a long history in establishing BIM working methods. The Europe forerunners are the Scandinavian countries and they have reached a high degree of BIM adoption also.

Since 2015 has Norway established standards related to BIM and model-based projects by publishing “Håndbok V770 Modellgrunnlag”, the Norwegian standard for design and implementation of BIM in road projects. According to “Statens Vegvesen”, Norwegian Road Authority, the conceptual models can contain all information about objects that have previously been commonly written in documents, such as requirements for sizing, calculations or execution. Similarly, requirements for a system of objects, such as a water network, road network or electrical network can be specified. Based on information models, various technical solutions, floor plans or dimensions can be simulated and analyzed in design software and manual work processes can be automated using algorithms and artificial intelligence.

Model-based road projects are today at a crossroads between 3D models and information models. Some subjects have software and standards that support information modeling to some extent, while other subjects have little support beyond 3D geometry.

The purpose of this study is to uncover the challenges and the opportunities of BIM implementation in Norwegian Road Projects. BIM improves information flow between contractors and subcontractors, sometimes increases efficiency by building better the first time and reduces the risk of collisions but in the other hand it takes a lot of effort and support by the management to develop and implement these strategies in a conservative type business as construction.

The aim of the project "E39 Kristiansand Vest – Mandal Øst", as case study, is to deliver fully integrated BIM maturity level 3 and all the information about the project must be in and taken out from that model. The "Paperless" concept is being used and the project is being implemented with extensive use of digital technology, where it is important to point out that "BIM" in this context involves more than the use of only technology. Therefore, interdisciplinary forms of collaboration, methodology and attitudes will also be the focus.

1.4. Problem statement

According to one study by the Association of German Chambers of Commerce and Industry (DIHK), 93% of companies agree that digitization will influence every one of their processes. Following this statement, also the AEC industry will face significant changes by digitalization and automatization in the near future. According to NBS (National Building Specifications) the awareness and usage of BIM in the UK Construction industry has risen from 10 % in 2011 to 70% in 2019, however a lot of challenges and uncertainties are following this process.

Many see BIM adoption as a process that will influence more those who design and plan than those who build but this is not fairly true anymore and this can be justified by the publications of ISO standards and by National BIM Strategies being adopted from all developed countries.

In 2015, "Statens Vegvesen" Norwegian Road Authority published "Håndbok V770 Modellgrunnlag", the Norwegian standard for design and implementation of BIM in road projects. This was the official framework that defined the requirements of BIM models for infrastructure projects.

Based on further publications from Norwegian Road Authority, model-based road projects are today at a crossroads between 3D models and information models. Some subjects have software and standards that support information modeling to some extent, while other subjects have little support beyond 3D geometry.

In 2016, "Nye Veier" a new state-owned company was founded to overtake the road portfolio from Norwegian Road Authority. A new concept, strategy and a new approach to digitization and automatization began in road projects that were now under supervision of the new company.

In 2018, Nye Veier signed a contract with a private owned company AF Gruppen to build a 20 km highway in south of Norway. This contract was very innovative in terms of BIM implementation and the usage of digital tools through the project lifetime. For the first time the BIM Implementation Strategy was completely defined, and development steps of digital tools to be used were described and were part of a contractual agreement.

Since BIM as a concept and particularly as definition is accepted in different ways in different companies around the world, a lot of uncertainty covered the contract and the implementation phase. The challenges were in terms of definitions about BIM maturity level to be delivered, digital tools that had to be developed, the contractual requirements to be fulfilled and the management approach to deliver something that would satisfy both the client and the contractor.

The contractual requirement about BIM was to deliver fully integrated BIM maturity level 3 by developing some new digital solutions, new BIM platforms and make the model accessible from everyone by using web-based platforms to upload, download and filter the necessary information from and in the model. To come to this kind of solution the staff needs to upload and process enough amount of data and the right amount of information inside BIM model. This is not easy when working with different stakeholders which maintain different levels of Quality and Management systems.

In this term it is important to find a solution and to create a framework for the information and data quality that will be part of the BIM solution. This is for the moment the most challenging part and where the industry is struggling in order to achieve optimal flow of information and have full understanding of model from everyone involved in the project.

The aim of this paper is to explain what road project "E39 Kristiansand Vest – Mandal Øst" is trying to deliver in accordance to BIM Implementation Strategy particularly BIM maturity level

3 and try to uncover challenges that are related to data quality which will be uploaded in the BIM model and the information flow inside organizations and other directly related stakeholders.

In line with what I have described above I propose in this paper following research questions

1) *What are the theoretical possibilities of level 3 Fully integrated BIM?*
2) *What are challenges in accordance to data quality and information?*
3) *How to close the gap between theoretical approach and practice?*

In my opinion this is relevant from academic and industrial point of view due to the fact that even the concept is not new, the technological development, the new managerial approach and the introduction of new digitalization standards combined with a real implementation in a Norwegian Road Project make this very useful to understand the level of digitization and uncover the challenges for future projects.

1.5. Reasons for choosing case study.

Since BIM is defined in different ways around the world, a lot of uncertainty covered the contract and the implementation phase. The challenges were in terms of definition of BIM maturity levels to be delivered, digital tools that had to be developed, the contractual requirements to be fulfilled and the management approach to deliver something that would satisfy both parts.

The contractual requirement about BIM was to deliver fully integrated BIM at maturity level 3 like defined by Digital Build Britain (2015) by developing new digital solutions, new BIM platforms and to make the model accessible for everyone by using web-based platforms to upload, download and filter the necessary information in the model. However, there is not always a full alignment between BIM design manuals, contractual requirements in tenders and the final BIM (Fürstenberg and Lædre, 2019). This is not easy when working with different stakeholders which maintain different Quality and Management systems.

Therefore, there is a need for a framework for information and data quality that will be part of the BIM solution. This is for the moment the most challenging part and where the industry is struggling in order to achieve optimal flow of information and have full understanding of model from everyone involved in the project.

Followed by what written above the researcher chose a project that had all the characteristics of a project with high risk and high reward in terms of BIM developments and where he had full access in documentation and was part of daily routines.

1.6. Limitations.

Even that the paper will give an overview of all project phases and BIM integration between them, the researcher was employee just in AF Gruppen and was mostly focused on the implementation and integration of the BIM in construction phase. With "*integration*" the researcher means the collaboration and automated actions between different software's in a developed platform to support different data types and upload these data in a way that everyone in the project can have access from the PC, mobile or BIM stations without the need to use different tools to extract information form the model. The research is mainly focused in the solutions offered from the contractor since the empirical data collected comes mostly from them. Other organizations that are mentioned in the paper and the data collected from them are secondary and do not necessarily have the same challenges and benefits in their organizations from the use of BIM in the maturity level 3.

The paper is also limited in just infrastructure projects, therefore the findings not necessarily can be used in the residential building construction or other industries. It was originally thought to collect data from other projects realized from AF Gruppen but neither of them had the same complexity and the same level of BIM usage so the data could mislead to conclusions which could not be compared and reduce the quality of the research.

These limitations were necessary because of available time, resources and scope of the study which was 30 study points.

1.7. The research structure.

In the first Chapter, I try to formulate the problem statement and the framework of the study by explaining why this topic is relevant from academic and industrial point of view. This chapter includes the limitations and study restrictions due to the wide range of the topic.

In the second chapter I perform the methodology and literature review of BIM as concept and as a technical solution. Further, the third chapter is built through 3 main blocks. First, the block of theoretical possibilities and technological foundations. This block will explain what BIM is,

why should industry use BIM and how BIM changes the way we know AEC industry. The second block explains all the digital tools being used in case project and finally the third block gives a detailed view of contractual requirements and the plan to deliver a fully integrated BIM maturity level 3.

The fourth chapter gives an overview of interview results and the method I used to build the interview guide for the people that are directly part of the BIM infrastructure and for others that are directly related with the benefits of the new infrastructure.

The fifth chapter is a discussion of what literature offers as per today, what the contractor is pushing toward the future of road construction and findings from the interviews about the expectations that the staff has for the new platforms being developed.

The sixth chapter covers conclusions by making a comparison between the BIM level 3 concept theoretical possibilities and what the project is delivering in design, production and operational phase.

The paper is written based on literature review of publications from- public agencies, some well-known books on the field, informal and formal interviews with key staff of the project that is working with BIM implementation. The last part covers a short discussion on further possibilities of research and what could be beneficiary in terms of BIM usage.

The content is organized in 8 parts:

1. Problem Statement
2. Methodology and Literature review
3. Theory
4. Interview results
5. Discussions
6. Conclusions
7. Further Research
8. References

2. METHODOLOGY

2.1. General

The method chapter will describe the method for gathering information for available literature and how to process and analyze data collected from different sources. The most important part is to choose the best suitable method for collecting data and choose what is considered important for the study. Related to the topic or case you want to investigate, you must choose the method that is most effective.

There are several different approaches and strategies that could help with the study. As from different master thesis and from help by supervisor Ola Lædre I have observed that usually in the method chapter firstly u start with a description of different methods and approaches that will be used to achieve the goal of the research. This will be generally more theoretical description than practical, and it will be used to help collect data and after that to analyze. How data is collected and analyzed is also presented in this chapter. In addition, this chapter includes also the structure for the interview guide.

2.2. Inductive and deductive data collection

According to Sander (2017), there are two ways of thinking logically, induction and deduction. The methods include the relationship between theory and empiricism. Deductive method means that one has a theory of a phenomenon that is tested with empirical evidence to confirm or disprove the theory. According to Jacobsen (2005), this approach has weaknesses because researchers believe it leads to expectations that can help highlight some information, while others are left out. Inductive method goes the opposite way. That means doing exploratory investigations and making theories based on the empiricism. Both approaches affect us all, and neither method can be chosen in its entirety. Prerequisites can create certain expectations that support the following the deductive approach. It is also desirable to have an open mind to limit the likelihood of important and relevant information being neglected.

2.3. Quantitative and qualitative methods

The way how to approach the data collection process can be decisive for obtaining enough and proper type data. The choice of a quantitative or qualitative approach is depended if you are

looking for numbers or words, for big standardized data collection or conclusions based on personal experience.

Quantitative data is characterized by being standardized and quantified, and results are obtained typically presented in tables, figures and statistics. Quantitative studies typically investigate a relatively large number of units, and is often used to draw descriptive conclusions, as well describe causal relationships between different variables (Dahlum 2017). An obvious benefit of quantitative research is that relatively little resources are required to investigate many subjects. This means that it is easier to reach a representative sample. The data collected is easier to structure so results and variation can be described exactly by numbers or percentages. There are also disadvantages to quantitative studies. One disadvantage is that the distance between researcher and participants in quantitative research is often large and can be led to a lack of understanding of what is really to be investigated. It is thus difficult to know what the participants are thinking as they give their answers. (Jacobsen 2005). The goal of quantitative surveys is often to reach many respondents, and there is therefore a danger that the investigation can lead to results that are superficial and not so deeply related to the goal of the study. It can be challenging to go into depth, and it is difficult to bring out all the individual variations as the participant mass represents.

Qualitative method, for its part, consists of collecting data that is more difficult to quantify and compare directly. Typical qualitative methods may be in-depth interviews, observations, and interpretation of data. It is pointed out that during qualitative interviews it is important to safeguard the integrity of the respondents and that it is generally more difficult to safeguard anonymity because the answers are often based on personal experiences (Fangen 2015).

A qualitative approach has the advantage that it is easier to obtain nuances and details, and thus achieving a correct understanding of a topic. Such an approach is very flexible, and it is relatively easy to adjust along the way (Jacobsen 2005).

Qualitative methods also cause some disadvantages. Such methods are often very resource intensive and can be challenging to achieve representative selection for large groups. Variety and details can also make the results very complex and difficult to compare. In addition, the relationship between the interviewer and the respondent can be decisive for how questions are asked and what answers the respondents chooses to provide. (Jacobsen 2005)

The difference between quantitative and qualitative methods is given by Fangen (2015) as the quantitative method focuses more on breadth and scope while qualitative method is based on

meaning and content. This mean that qualitative method is often regarded as more resource intensive as surveys often need to be adapted to the individual respondent (Fig. 1). By qualitative approach one categorizes and structures the information after the data has been collected, whereas by quantitative approach this is done in advance of data collection (Jacobsen 2005). Quantitative research requires more work on preparation, while implementation requires, fewer resources. An important factor to mention is that qualitative studies can also be treated quantitatively. The qualitative data then becomes processed and quantified so that the results can be presented quantitatively (Befring 2015).

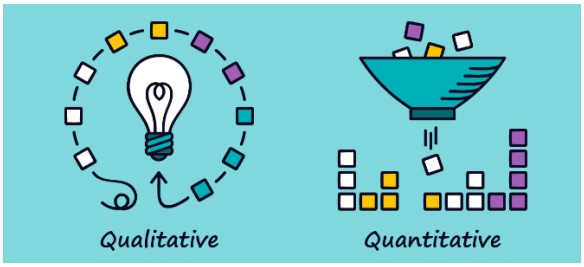


Figure. 1. Quantitative vs Qualitative. (https://blog.optimalworkshop.com)

2.4. Reliability and validity

The data that you collect, and you use to write conclusions have to be reliable and valid and this must be achieved in high grade.

Reliability and validity are concepts used to evaluate the quality of research. They indicate how well a method, technique or test measure something. Reliability it indicates the degree to which the results represent the real situation, and whether it can be verified (Sander 2017b). Validity hast to do more with the relevance of the data it provides. For one to be able to rely on the results you present it is therefore crucial that they both have high reliability and high validity (Fig. 2.)

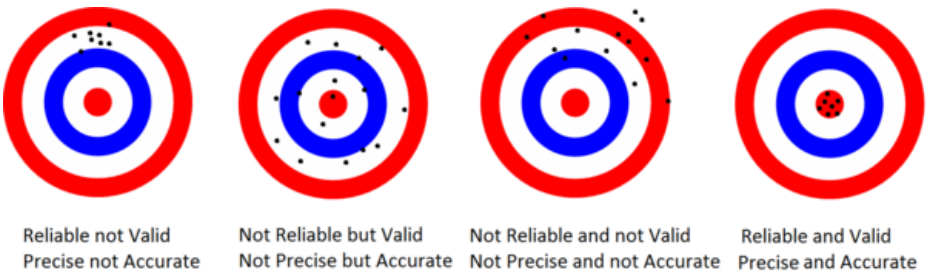


Figure. 2. Reliability and Validity

2.5. Triangulation

To ensure reliable results and conclusions, the researcher can triangulate. According to Yin (2014) triangulation involves using different sources of information, investigators, theories or methods. Triangulation means that one's results are based on multiple sources, and validity and reliability will be strengthened (Jacobsen 2005). There may be uncertainty associated with results from single methods, but the use of several methods such as; interviews, surveys, conversations, literature studies and the like can compensate for this.

2.6. Choice of method

According to the theoretical part of the methodology that is described on the paragraphs above it is very important for the researcher to choose the best suited method.

The problem statement and the main research questions are the starting point that lead to the choice of best approach, interview structure, data collection method, analysis of data and finally to get to conclusions.

The data collection must have an inductive starting point, so the researcher shows that he is open minded, and all the important and relevant information is included in the analysis process.

According to the Statens Vegvesen official webpage, road planning and construction are complex tasks, and the methods used changed as technological innovations become available. Hand-drawn plans for foil were replaced in the 1980s and 1990s with computer aided design (CAD), where the drawings became digital. In the 2000s, scanner technology was used for mapping terrain and surveying buildings and structures. At about the same time, digital 3D geometry was begun to be designed instead of 2D drawings. Accurate geometry models of existing terrain and planned terrain made it possible to control construction equipment.

Now another technological leap is happening: Information Modeling. Objects are modeled in conceptual, digital models, relationships and dependencies between the objects are defined. The conceptual models can contain all information about objects that have previously been commonly written in documents, such as requirements for sizing, calculations or execution. Similarly, requirements for a system of objects, such as a water network or road network, can be specified. Based on information models, various technical solutions, floor

plans or dimensions can be simulated and analyzed in design software. Manual work processes can be automated using algorithms and artificial intelligence.

Due to this complexity model-based road projects are today at a crossroads between 3D models and information models. Related to this statement from Norwegian Road authority the researcher has chosen to limit the range of the questions to an overview of the situation and try to make detail questions with the key personnel that is working directly with BIM. To get the best from the results from data collected the researcher can triangulate but, in this case, the researcher has chosen 9 people to answer the interviews and the methodology is more qualitative than quantitative. The range in organization chart and the position of the interviewers is chosen carefully to get the best results.

Depth interview is chosen as method because it according to Jacobsen (2005) is well suited when few units are examined, the individual's opinions are important. In-depth interviews are very favorable method for collecting empirical data. To be able to evaluate collected data, some references from other examples in the industry or the comparison from the standards that describe theoretical possibilities of the technology are needed.

For this has the researcher done a superficial literature review but not so much theoretical information has been found that is directly related to BIM maturity level 3 that the project is trying to deliver. There are several publications that more or less cover parts of the topic and few projects against which results will be compared. As planned in the specialization project the researcher went further and tried to compare the E39 Kristiansand-Mandal project with the E18 Arendal- Tvedestrand that was the first step to this kind of development in AF Gruppen and for Nye Veier but the results were not as good as planned due to the fact that the E18 project was as a pilot project of the technology and was not fully operational so the results were not good enough to be included in the master theses. The impact of the technology was very weak and the systems and softwares were not integrated at the same level as today.

The combination of all the above methods and literature review will help to increase both the reliability and the validity of the research results. (Eriksen 2018)

In addition, since the researcher is employee in the project several informal conversations will be conducted, but the researcher has to be sure that the results are not bias and to prevent this everything in the results will be noted if that came from informal conversations.

2.7. Literature review

2.7.1. General

The purpose of the literature study is to form a theoretical basis of the literature that is available or related to the research topic. For the specialization project and further for the master thesis it is beneficial to make a literature investigation to find to what extent empirical research questions are supported by theory. The literature study is chosen to provide academic insight about the topic and has been used to form the basis for the collection of empirical data and the comparative basis for evaluating results. (Ericksen 2018)

Since the digitization in construction industry is a field of enormous development and especially fully integrated BIM maturity level 3 is quite new concept in the branch it can be challenging to find enough information and the quality of the information found it is not directly related to the topic, but it can be used to create an overview of the today situation and the road ahead.

2.7.2. Search criteria

To find the literature, Google Scholar is used as the primary search engine. With relevant keywords, Google Scholar searches among a very large selection of publications, research reports, conference articles, dissertations, etc. Google Scholar allows the user to sort results by relevance, date or author etc. In addition to Google Scholar is also used Oria and Google.com itself as search engine to find several publications. The research done in Oria and National Norwegian Library resulted in much less finds than Google scholar and Google.com. Google.com with the right keyword gives a lot of results but the researcher has to be careful to filter the qualitative information related to the main topic.

Since the research topic is quite new and the reports, publications and studies are mostly written in English, the keywords used are also in English. The researcher has used also his experience as Construction Manager in AF Gruppen and the knowledge in Norwegian language to make some research in official websites of Norwegian Road Authority, Buildingsmart.no and several other Norwegian websites to find publications and the standards used for BIM and especially BIM in infrastructure projects. The researcher received a lot of help from the supervisor David Fürstenberg by providing some very useful literature from his personal library and the main

supervisor Ola Lædre provided the guidelines to build the interview structure and some additional information about the research structure.

A lot of effort is given to the assessment and the validity of the literature. Assessment of literature is resource intensive, and it is therefore important to work efficiently, effectively systematically to reject unfavorable literature as quickly as possible (Ericksen 2018). The method used to assess which literature to review has been to step by step examine parts of the publications. During the literature search, each publication has been through the following assessment criteria in the specified order and the researcher has eliminated the irrelevant literature by using following structure provided by the help of Ola Lædre:

- **Authority**
  - Is the author an expert in that field?
  - What work or educational experiences does the author have?
  - With which institution, organization or company is the author affiliated?
  - How many total citations do the author have?
  - Has the author written other publications?
  - Who is the publisher and is he well-known?
  - Does the publisher have any benefits from the research presented in the article?
- **Credibility**
  - Is the article peer-reviewed i.e. from a refereed journal?
  - How many citations does the article/the book have?
- **Relevance**
  - Is the article/the book relevant to the research?
  - What audience is the article directed towards?
  - Is it proper to be used in my research?
  - Does the article answer my research questions?
  - Does the article address a topic from a certain geographic area/region or timeframe?
- **Purpose/Objectivity**
  - What is the purpose writing the article/the book? Is it for research purpose of entertainment/ making money?
  - Is the information presented objectively?
  - Is the researcher biased to his opinion?

- **Accuracy**

  • Does the title demonstrate that the article is too specific or not specific enough? Is there a subtitle with more details?

  • Is all the information supported be evidence(referenced)?

  • Is there any obvious writing errors or typos (for books)?

- **Timeliness**

  • Is the information current and up to date? Does it need to be?

  • What about the sources used by the author? Is it up to date/recent?

This scanning process has helped the researcher to find the relevant information from well know sources. The research has been largely done using the keywords as: Building Information Modeling, Building information Management, BIM standards, BIM in infrastructure, BIM strategy, BIM integration, BIM maturity levels, BIM level 3.

Mainly, information about standards and BIM development strategies has been retrieved from official government websites. The research has assumed that the information which is coming from official authorities and standards are reliable and trusted sources. In addition, some documents were provided also from Nye Veier in accordance to BIM requirements and future development of the concept. The official websites are provided in the reference list so the reader can check and verify. When it comes to the validity of the literature, it is considered to be relatively good. A lot of the theory that has been found about BIM as a concept and this has been tested from several publications and author but for the topic of fully integrated BIM it was hard to find a lot of information and the information founded it is not supported by many sources so the researcher has tried to focus more on the contract documents provided from Nye Veier which is the Norwegian state owned company for the development of new infrastructure. They hold high professionalism and all documents are part of a road building contract that is now under construction.

2.8. Case study

2.8.1. General

To be able to answer the research questions and examine what the theoretical possibilities and challenges are related to fully integrated BIM the researcher took as a case study E39 Road Project Kristiansand – Mandal. The researcher is at the same time an employee of the main contractor with a position as Construction Manager and a NTNU master student. This means that the researcher has an increased possibility to take a lot of necessary information but also increases the risk to be bias in decision making and in conclusions. To prevent this the researcher with the help of supervisor has created a semi structured interview and the researcher has tried to introduce himself in this study as an NTNU student and not as an employer of main contractor AF Gruppen.

The case study is used to cross and compare the literature study recommendations with experiences gained in the project by using different research approaches.

2.8.2. Interviews

As described above the qualitative approach is used to conduct the interviews. All interviews are semi-structured, and the researcher approached open conversations with the respondents. According to Jacobsen (2005), open individual interviews fit well when relatively few units are investigated and when we are interested in what each individual says. This is very good in our case where not more than 10 individuals will answer the questions. It was possible to interview a larger number of individuals, but the researcher is interested to interview people that are directly related to usage of BIM. The research has tried to find the most important individuals that work with BIM and are directly related to the development of new tools for the exact requirements of the particular contract. Therefore, the focus has been on getting each one off the interview subjects to share as much of their experience in the topic as possible.

The respondents from the opinion of the researcher have been very collaborative and have helped to uncover the possibilities and challenges of this new concept in infrastructure projects. The respondents have been chosen from different positions, subcontractors and from the client itself. In this way the researcher has covered the widest possible area to make the results as representative as possible. The interviews have all been conducted in person and the voice has been recorded with permission of respondent. As instructed from the supervisor the interview guide had been provided via email before the interview meeting, so the respondent had time to

be informed about the topic and purpose of the study. In this way you can lose the effect of a surprise answer but in the other hand the interview is more formal. The interviews have been completed in about 40 to 50 minutes, depending on the amount of information the respondent has about the topic or the level of interest has he about the topic.

The choice of interview-subjects has been in accordance with the purpose of the study to cover as much as possible in accordance to the project delivery requirements about BIM. The effects that BIM has in this project influences everyone working there but for some individuals the influence is greater. The researcher has chosen the subjects from managerial positions to developers and to the end-user. In addition, the researcher has chosen people from 4 different companies directly related to this project and the usage of BIM, the main contractor AF Gruppen, main sub-contractor Kruse Smith, the design contractor Norconsult and the client Nye Veier. In the following table are the names of the subjects that are interviewed. In the Appendix chapter the reader can find The Interview Guide.

Name Surname	Position	Company
Herman Horsle	BIM Coordinator, Developer	AF Gruppen
Magnus Holmsen	Assistant Quality Manager	AF Gruppen
Svein Erik Tomren	Quality Manager	AF Gruppen
Nicolay Aarum	Quality Engineer	AF Gruppen
Jon-Andre Leirflaten	Construction Manager	AF Gruppen
Hubert Scoztak	Quality Manager	Kruse Smith
Mads Ljøstad	BIM Coordinator	Kruse Smith
Terje Fjellby	BIM Coordinator	Kruse Smith
H.R	Quality Check	Nye Veier

The interviews are focused on the theoretical possibilities and challenges of BIM and the BIM maturity level 3 particularly. The interview guide itself was revised by the supervisor, but the researcher does not see it necessary to publish the first version due to the fact that it has no value for the research. The researcher will publish just the final interview in Appendix A.

The interview guide used in the specialization project is just one part of the final interview guide as agreed with the supervisor. The first two questions of the research were planned to be answered partially in the specialization project and the third question and additional info about the first to questions to be filled in the master thesis. The interview questions were as follows:

1) *What are the theoretical possibilities of level 3 Fully integrated BIM?*
2) *What are challenges in accordance to data quality and information?*
3) *How to close the gap between theoretical approach and practice?*

The voice in these interviews has been recorded with permission from all subjects and after that the voice recorded has been used to transcript the interviews. An Excel file has been created with the answer from every subject in such a form to make it easier to compare the answer for each question. The transcripts of the interviews will not be attached to the paper but if needed for further research, the researcher can provide these for study purposes again with the permission of all subjects. The interviews are transcribed that day or one day after the interview so no information is missed or misunderstanding of answers can occur during transcription process. This process was very time and resource consuming and a lot of effort is given to make the best possible from data collected.

After the interviews have been transcribed, each interview has been reviewed and questions and answers are been "coded" for relevance and interest. (Ericksen 2018). The material is then assessed by content analysis (Jacobsen 2005). This means that the data material is systematized and categorized according to research questions. Then the attempt is made to find the relation between categories. One advantage of categorizing the data is that it can thus limit the amount information that one should relate to at one time when interpreting the data. To limit the amount of information in only a few categories at a time can make it easier to have overview than whether you should handle everything at a time. The data material is then interpreted both as individual experiences and as a whole.

2.8.3. Informal conversations

Since the researcher is an employee in AF Gruppen as Construction Manager a lot of informal conversation have been conducted with other key personnel, leadership, field engineers, foreman and workers. These informal conversations cannot be considered part of the study, but these are important to create an overview of situation in field and in the management. By these conversations the researcher can provide additional information according to BIM implementation, the touchable results in field and what the end-users think about the new technology and the “paperless” concept. These informal open conversations have concluded in some very useful recommendations for future development or have uncovered some problems

with the technology. In addition, by these informal conversations the researcher widens the study group by including in the study people that are not directly related to BIM, but BIM influences their daily work in some degree. The challenges or the possibilities connected to this are part of the researcher interest in this investigation. A wider research can be conducted in the future by using quantitative research methods but at the moment that this paper was written, the BIM platforms were under development, so for the researcher it was impossible to get the results for a quantitative data collection.

2.9. Discarded research methods.

2.9.1. Scientific article

The researcher and the supervisor originally agreed to write a scientific article that was planned to be published in The International Group for Lean Construction. IGLC is an international network of researchers from practice and academia in architecture, engineering, and construction (AEC) who feel that the practice, education, and research of the AEC industry have to be radically renewed in order to respond to the global challenges ahead. Their goal is to improve both AEC processes and products by diminishing the current lack of explicit theory of construction. IGLC organizes annual conferences where scientific papers addressing specific themes related to AEC processes and products are presented.

The researcher agreed to write the paper with the help and contributions from the supervisor. The proposal and the paper itself were discarded in the late Mai after some challenges both from the researcher and from the conference. Due to the last events with the pandemic Covid-19 the conference itself was postponed and moved online. For some reasons of formatting requirements and some challenges in the upload of paper after reviewed from the supervisor.

Following the late cancelling the researcher had to continue with the traditional master thesis and not an article-based thesis. Anyways the researcher was able to finish the article and has agreed with the professor to continue with the publications in a later stage and later conferences. The article itself will be published in the master thesis because the findings and conclusions are the same as in the master thesis. The whole work was done to be part of the master thesis and the paper will be published in the near future, so the researcher sees it reasonable to be included in the Appendix B.

2.9.2. Survey

A survey was initially considered a possible research method, and this has also been described in the specialization project. The purpose of the survey as quantitative method was to asses as many possible respondents to check the influence of BIM at maturity level 3 in the project and to see what the differences in BIM implementation are compared with other projects that the respondents have worked before. Formens, subcontractors, environmental engineer, machine operators, and top management of the project were intended to participate.

However, as described above, the idea was discarded because the BIM platforms and new system was not fully operational at the time the researcher was writing the master thesis. It would have been nearly impossible to get 100-200 respondents as recommended to fill the survey and mostly the survey would be filled from people who had interests in BIM implementation. Due to complexity of BIM implementation strategy most probably mostly of the respondents would not understand the level of importance and would not understand the technical terms used in the survey.

3. THEORY

3.1. What is BIM?

Building Information Modelling is use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions. (ISO 19650-1). BIM typically includes the 3-D geometry of the building components at a defined level of detail. In addition, it also comprises non-physical objects, such as spaces and zones, a hierarchical project structure, or schedules. Objects are typically associated with a well-defined set of semantic information, such as the component type, materials, technical properties, or costs, as well as the relationships between the components and other physical or logical entities. (A. Borrmann et al.)

BIM forms by himself a living object that should be used through the lifecycle of the project (Fig. 3). The level of achievement of this objective is the distinction between a game-changing technology and just another digital tool.

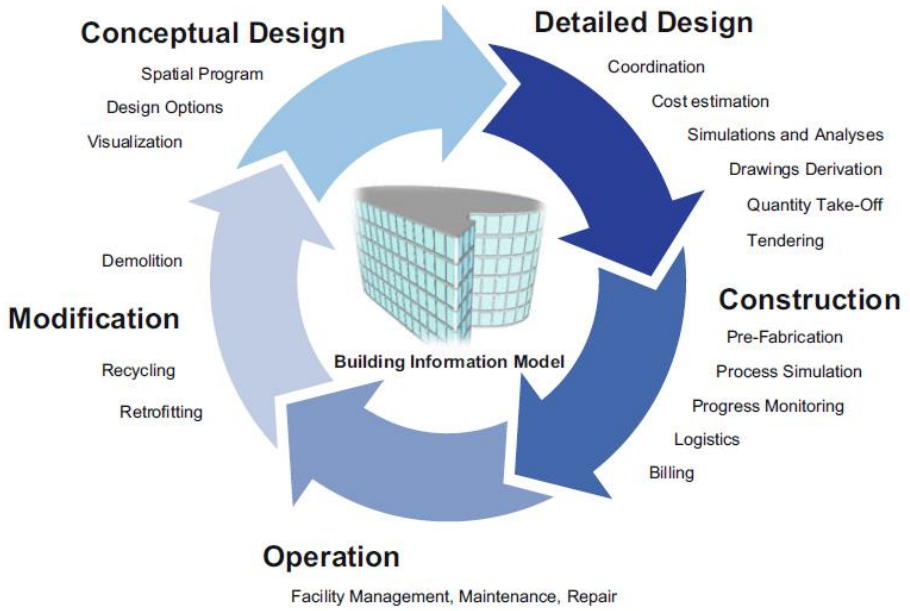


Figure. 3. The concept of Building Information Modelling (A. Borrmann)

BIM as a concept is not new and the genesis of the concept dates to 1970s (Eastman et al. 1974) by introducing concepts of virtual building models but the usage of the concept and acronym as we know today was firstly introduced by Autodesk in a White Paper published in 2003.

BIM is construction industry trend in both infrastructure and building, from concept design to construction process, but the concept can be used in retrofitting, recycling and demolition also. The opportunities that BIM offers today are endless. The use of other technologies as geolocation, laser scanning technology, the usage of API (Application Programming Interface) that makes possible to transfer data from one software to another and RPA (Robot Process Automation) makes BIM a game-changing concept if the right combination of investment and effort is given to develop the right tools for the right purpose.

It is hard to extinguish a definition about what BIM model should deliver, so it is important to divide and give an overview of what BIM represents in different phases of a project.

3.2. Open BIM, BIG BIM

The shift from conventional drawing-based methods to model-based ones requires significant changes in both internal company workflows as well as cross-company processes. To avoid unduly unsettling the basic functioning of established work-flows, a stepwise transition is recommended. Accordingly, different technological levels of BIM implementation are distinguished. (A. Borrmann et. al 2018)

Some concepts, as BIG BIM and LITTLE BIM are expressed from Jernigan 2008. Correspondingly Little BIM has to do more with the application of a BIM software by one stakeholder involved in the project. The data cannot be transferred, and the building model is more for internal use. In the other hand BIG BIM involves consistently model-based communications between all stakeholders and across the entire lifecycle of an asset. (Fig 4)

The concept of Open BIM has to do with the possibility of data transfer from different software and the possibility to access these data from a large number of platforms. Since 2013 the industry has implemented the Industry Foundation Classes (IFC) which provides a very rich data structure covering almost all aspects of built facilities.

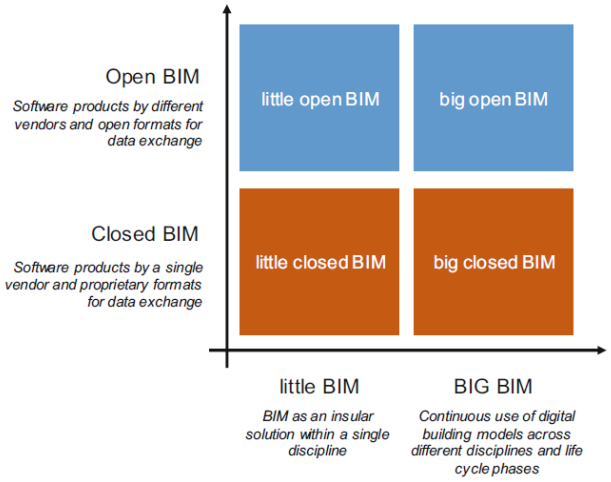


Figure. 4. Open BIM and BIG BIM (A. Borrmann et. al 2018)

3.3. BIM maturity levels

3.3.1. Level 0 and 1

Level 0 is based on 2D CAD drawings and on paper-based drawings. The information is transferred via conventional methods as email, fax and handed over in person.

Level 1 BIM consists on 2D CAD drawings and 3D models for complex designs. The coordination between different software for structure calculations and for further in construction phase is not possible.

3.3.2. Level 2

Level 2 BIM is described as collaborative BIM. Federated model information is shared within a Common Data Environment. Level 2 is based on use of organized 3D tools where every discipline uses specific BIM tools with specific associated property data. 4D (time) and 5D or cost controlled engineering is performed using calculation systems that utilize model data and are integrated with BIM via proprietary interface.

3.3.3. Level 3 and beyond

The jump from level 2 to level 3 is a big step to take (Digital Built Britain), which is acknowledged in the digital built strategy by defining four distinct delivery phase scales:

- Level 3A Enabling improvements in the Level 2 model
- Level 3B Enabling new technologies and systems
- Level 3C Enabling the development of new business models

– Level 3D Capitalizing on world leadership

These stages are illustrated in figure (Fig 5) below:

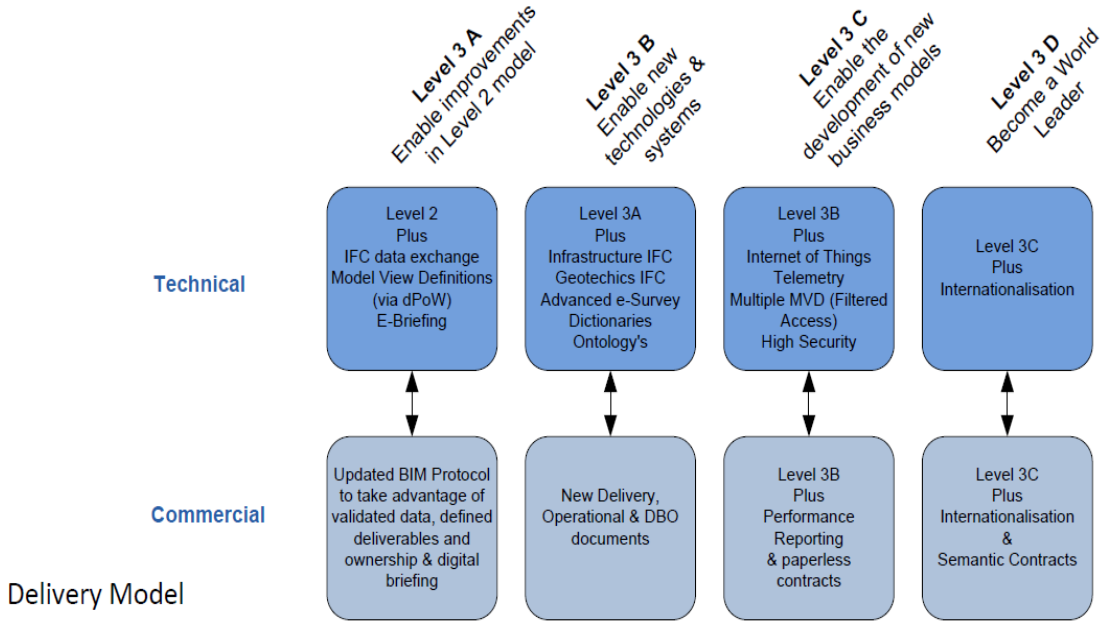


Figure. 5. Level 3 BIM stages (Digital Built Britain)

Level 3 BIM is based on the concept of fully integrated BIM. It is based on the implementation of BIG BIM and OPEN BIM and ISO standards for information flow, data exchange and process descriptions. These models are used throughout the entire lifecycle. (Fig 6) Cloud Services and web-based solutions are used to access the information and project data so that data is continuously and consistently maintained over asset life cycle. (A. Borrman et. al 2018)

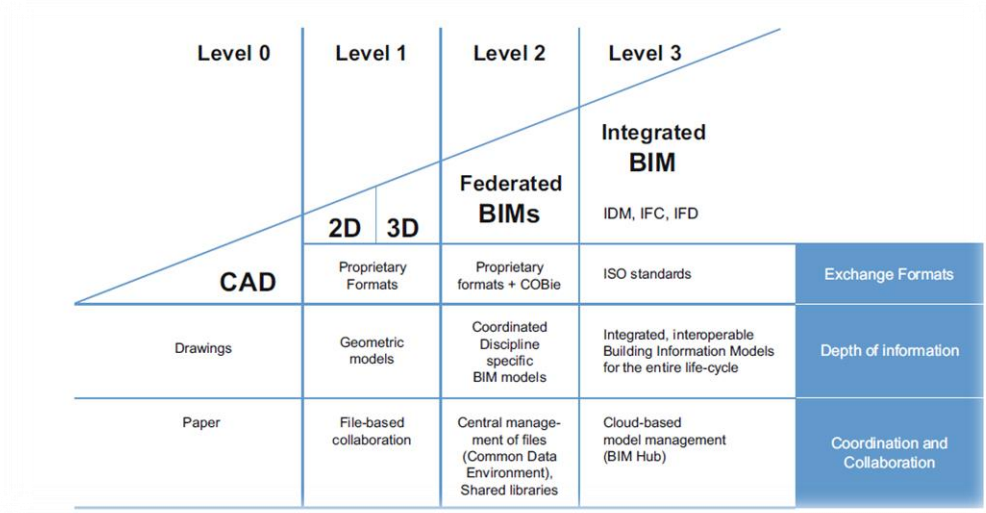


Figure. 6. BIM maturity ramp. (UK BIM task Group)

3.4. BIM benefits.

BIM facilitates efficient project design, construction planning, building, and operation and maintenance based on the standardized representation and sharing of digital information among authorized project stakeholders ((A. Borrmann et. al 2018). At STRABAG, one of the biggest companies in the world in the field of construction, they define different model phases as follows:

- **3D Model**: Coordination of trades and visualization of construction design, planning, execution and production phases.
- **4D Model**: Linking the geometry (3D model) with a project timeline based on the dependencies of processes on resources (people, equipment, and material).
- **5D Model**: Integration of all relevant process information in a model-centric repository (i.e., from automated quantity and cost estimation to digital fabrication).

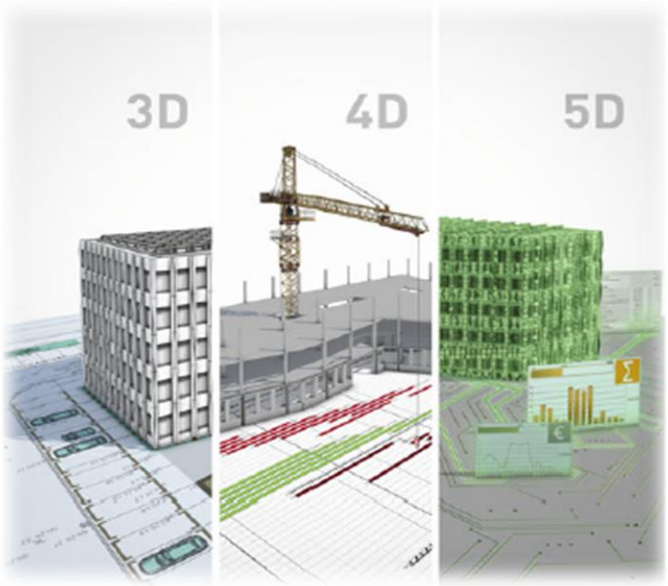


Figure. 7. From 3D modeling, quantity estimation, project scheduling, detailed construction planning, work task simulation, to process control.

- **6D Environmental Management**: Analyses such as energy, lighting, solar impact, photovoltaic potential, rainwater reclamation, computational fluid dynamics simulations, and LEED documentation are different building performance analyses that can be performed on BIM models (Vandezande et al., 2011). The interoperability of the model's geometry and metadata between applications allows for such analyses.

- **7D Facility Management, Operation and Maintenance**: A final project inspection is carried out before the handover of the completed project product to the owner (Hardin, 2009). Building Information Models can be used as punch lists for such work. A 7D Building Information Model is a facility resource with information on warranties, specifications, and maintenance schedules that can simplify the project closeout and make it a briefer process (Bryde et al., 2013).

  Updating data over the building's lifetime can offer, and this is of central concern in the development and use of BIM tools for facility management and building operation. To determine the benefit of BIM for stakeholders in the operation phase – for example, property owners, users, property managers, facility managers or technical services – one must first identify their respective processes, roles and business models. BIM systems for operators link together these roles in a digitally integrated process. (Shepherd 2015) Using BIM for operating buildings extends current document-based exchanges of information by offering a well defined structured way, keeping all information of building elements and its linkages among each other intact, based on the building data model. Structured data about a building can then be linked seamlessly to process-based information.

  Standards and IT systems for implementing BIM methods are now available for all phases of the life cycle of a building (design, construction and operation). If a BIM model has been created during the construction phase, relevant data from the model can be extracted and integrated into the Asset Information Model (AIM) for use in the operation phase. The data can then be maintained on an ongoing basis and passed over to future users or owners of the building at a later stage of the building. BIM can also be used for operation in those cases where no BIM model was developed during construction

  The BIM method divides the operation phase of a building into six work stages. The following diagram shows the succession of work stages in the context of the design, construction and operation phases of a new building. The figure below explains these 6 phases

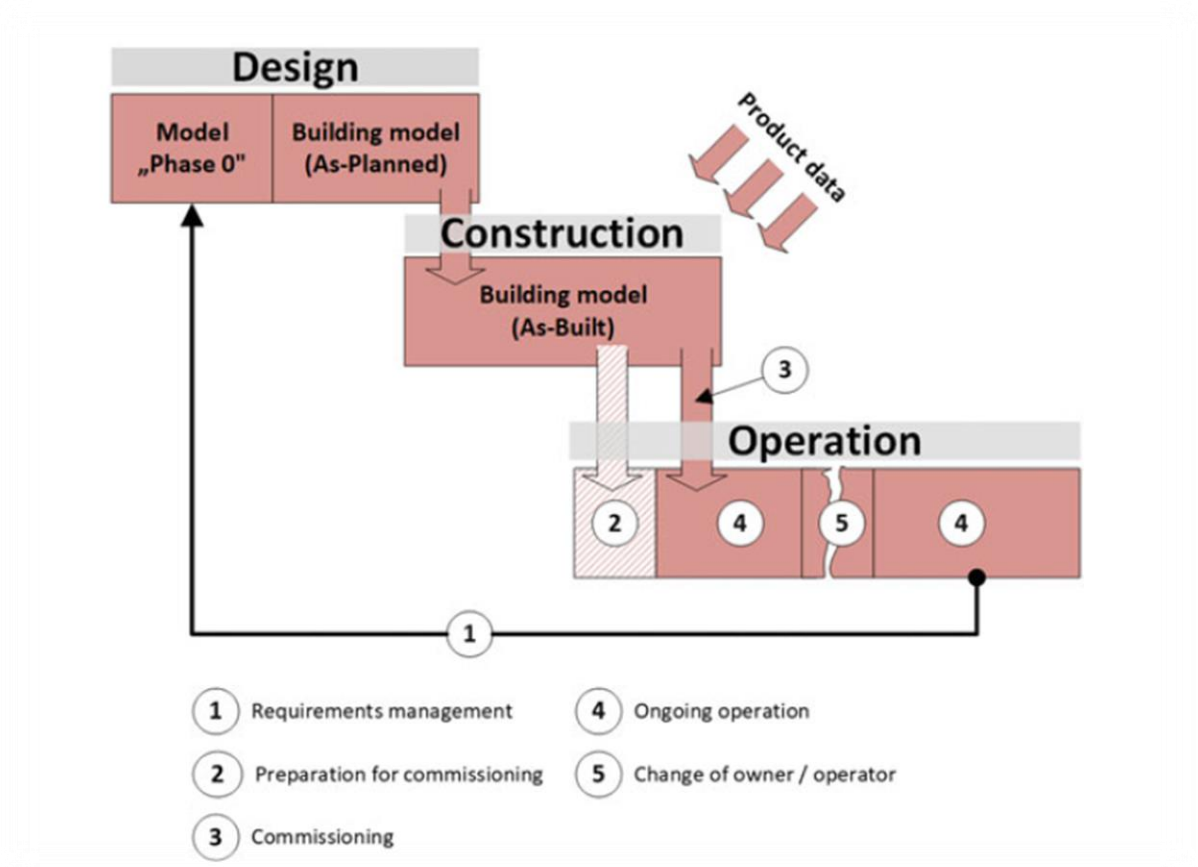


Figure. 8. Typical cycle of work stages for BIM in the design, construction and operation phases of new buildings. Figure taken from page 481 in BIM handbook 2018.

3.5. BIM Products used in the study case

3.5.1. Solibri Model Checker

Solibri Model Checker is a computer program that is suitable for automatic checking of a model of a building or construction. On the one hand it serves to check the quality and integrity of the building model, and on the other hand to check the content of the design against, for example, a program of requirements or regulations. The functionality also includes visualization, clash detection, the comparison of model versions across disciplines and the extraction of quantities. Solibri Model Checker is an application developed based on the Industry Foundation Classes (IFC) file format and is used worldwide by clients, end users, construction companies, architectural firms and engineering firms. (www.solibri.com)

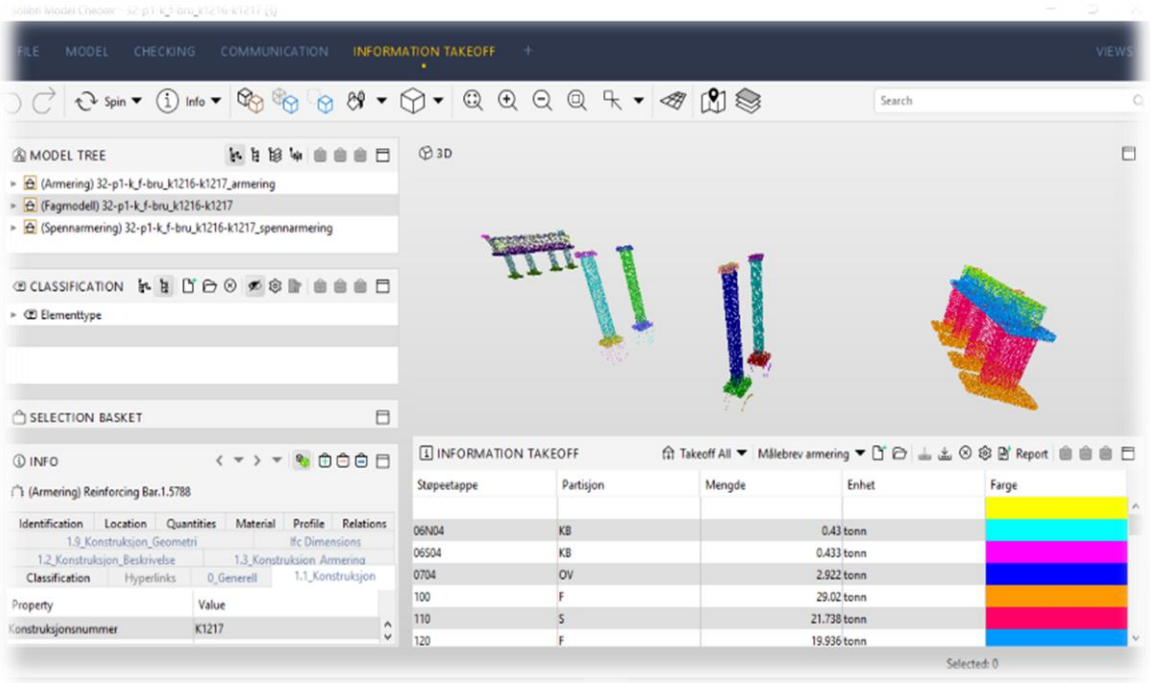


Figure. 9. Solibri Model checker

3.5.2. Infrakit

Infrakit is a collaborative cloud solution available on all PC and mobile devices that helps project owners, design engineers and construction companies to realize road, track and heavy civil earthwork projects using Building Information Models (BIM). (www.Infrakit.com)

- Design engineers can store, visualize, manage and share digital design information (open data format BIM models)

- Contractors are able to report and manage information through different apps (web, android) and connect their machines and devices on site
- Project owners and project consultants can follow work site progress and quality online.

With the help of Infrakit, the project owner can follow the pre-design, the design processes and the execution on worksite in real time. Model-based design process allows effective use of the latest construction technologies such as machine control systems. The quality of designs can be monitored, and the construction site becomes transparent when using Infrakit in the worksite. (www.Infrakit.com)

3.5.3. Dalux

Dalux is a cloud solution available on all PC and mobile devices used to access the BIM model and upload in site information as Concrete checklists, steel reinforcement checklists and product data sheets in real time and connect all these information with the exact part of construction without using conventional paper-based checklists and making the information available for everyone on their mobile devices and PC. All these checklists are then transferred to final documentation and the program is integrated with the web-based solution by providing metadata to the checklists.

3.5.4. Synergi Life

As the complexity and quantity of risk information grows, the need for efficient ways of structuring the risk picture becomes critical. The Risk Management module provides a web-based tool that enables linkage between risks, actions and incidents, automated e-mail notifications, simultaneous data entry, customizable statistical outputs and reports, secure role-based access rights and tracking of audit history. Synergi Life's Risk Management module is a web-based tool used by organizations worldwide, including multi-national companies and public sector organizations. The app is used to register deviations in HSE and quality and is automatically connected and integrated to web-based solution so the engineer and the key staff can monitor the hotspot areas where the deviations happen ant implement measures in real time and prevent risky events. The flexibility and scalability of the tool has been proved through use both in enterprise-wide risk management as well as small to very large projects. Client industries include oil and gas, utilities, hydropower, finance, telecom and transportation. (https://www.dnvgl.com/)

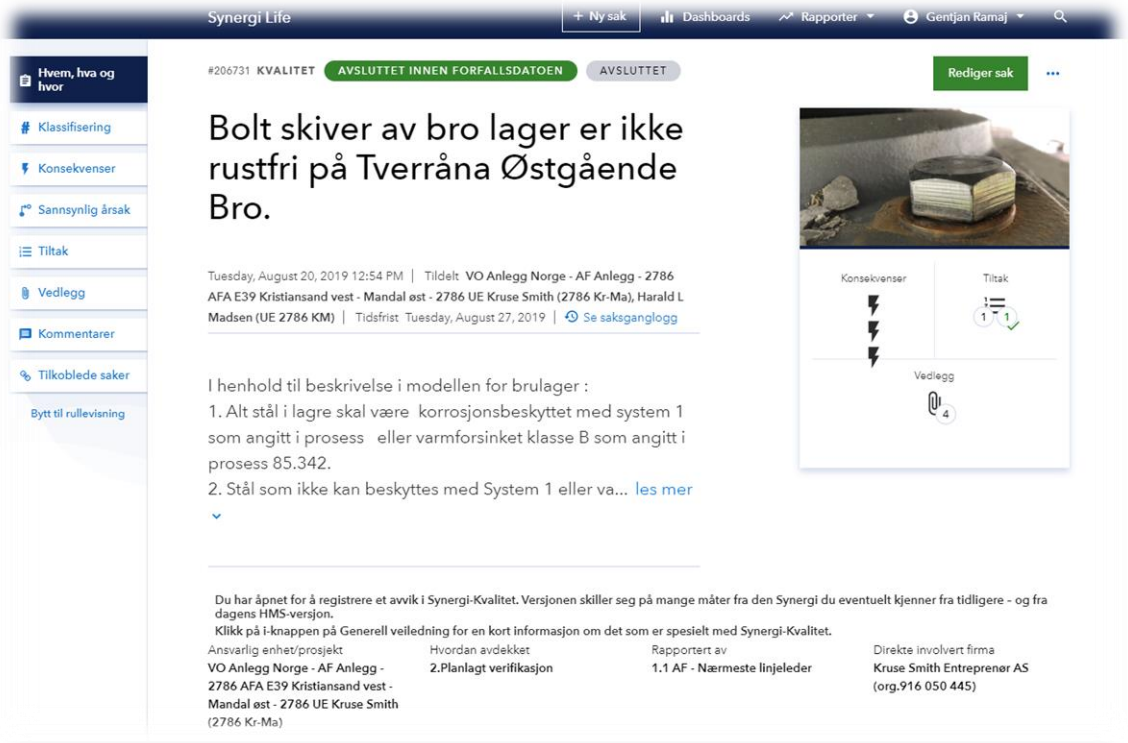


Figure. 10. Synergi life, example of a deviation reporting.

3.5.5. VR Dimension 10

Through exploiting the full potential of your 3D-models using the D10 platform, companies will find a significant increase in creative problem-solving, resulting in faster, better and more accurate discussions and design process, locally and globally, with the potential to significantly increasing both revenue and profits.

AF Gruppen was working on the E39 project, a road between Kristiansand and Mandal. The first time they have tried Dimension10´s software was to be able to experience a roundabout on the road project. Being in the software, the project managers identified design issues that they were not able to see on 2D screens. Both a sign and a lamp post were moved after the meeting in VR, in order to get better visibility for road users.

3.5.6. AR Trimble sSiteVision

Trimble SiteVision is a simple, outdoor augmented reality system that uses your mobile device to visualize complex construction, road, rail and site designs with superior accuracy. From bulk earthworks to finished final grade surfaces, you can communicate and problem-solve in real time. Whether you're communicating new designs, changes to field crews, doing inspections, determining construction productivity or calculating quick measurements on site including points, lines and cut/fill values, SiteVision makes understanding the project simple at every step of the process. You can view and share the design at any phase of construction in a real-world context at 1:1 scale.

SiteVision plays a key role in all stages of the construction life cycle: planning and initial visualization, checking progress and identifying issues to reduce cost and increase efficiency. From concept to completion, integrated, high-accuracy GNSS and remote distance measurement capabilities enable you to quickly and confidently direct operations right from your mobile device.

With real-time reporting from the field to the office, you can eliminate delays with instant change order requests to more efficiently manage costs and minimize safety hazards. Just capture a geolocated augmented reality photo of a problem area showing the design in the context of the actual site conditions and send as a traced, actionable request for change. https://sitevision.trimble.com/

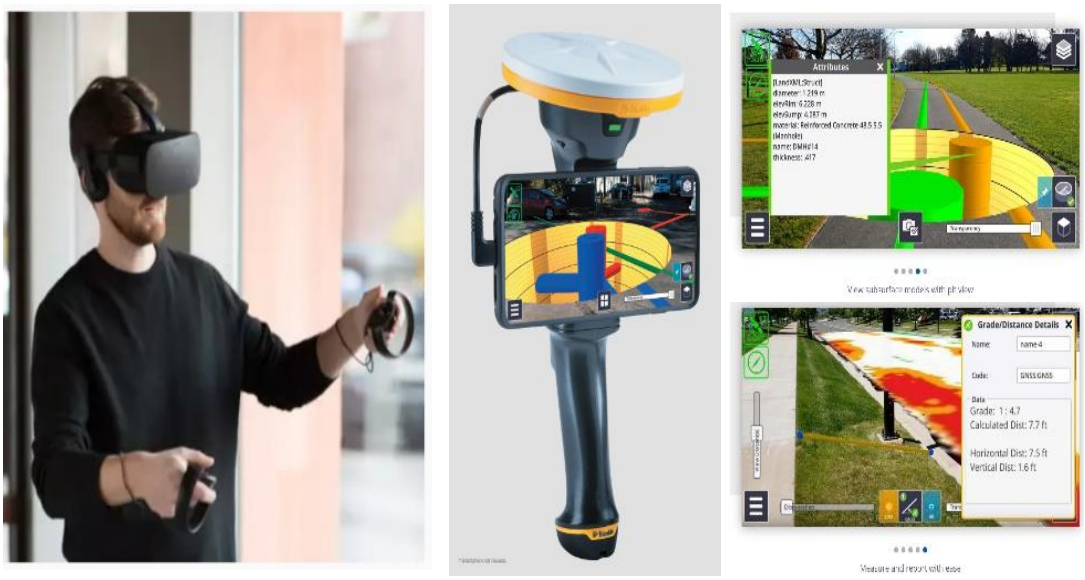


Figure. 11. VR and AR technologies

3.5.7. Trimble Connect Mobile

Trimble Connect is a collaboration tool that connects the right people to the right constructible data, at the right time. It provides up-to-the-minute, construction-ready project information.

Trimble Connect can be used in different phases of workflows, such as design coordination and review, on-site and off-site communication, and when managing activities and tasks during the entire project.

Trimble Connect links data throughout each phase of the building lifecycle to keep the project on schedule and on budget. You can upload and share documents from over 60 industry tools, or add your own source using the powerful API (Application Programming Interface) and by this can be integrated with other software. (https://web.connect.trimble.com/)

3.5.8. Gemini

Gemini is manufactured by Powel AS which was founded in Norway in 1996. The program has since developed modules such as Gemini Terrain and Gemini VA as design tools for municipal technology, transport and for contractors. Gemini 3D field is a mobile solution for the construction industry where you can import BIM and 3D models outside the construction site. This program lets you work directly with original project data and models from Gemini, as well as models with other formats. Users who are in the same project can access the models and work on them at the same time.

With internet access will always information in the project updated. Gemini 3D terrain provides the opportunity of interaction with those involved, both from the office and other field users. It gives the ability to enter data into fields and data that can be used for documentation or checklists. In addition, information such as pictures etc. can be taken directly out in the field. Notes can be linked directly to contract items. The software solution has been on the market for over 30 years and has contributed to the development of the industry standard for mass calculation and documentation. Gemini is also used for designing models for roads, intersections, tunnels, construction pits and water and drainage networks.

3.6. Integration structure

3.6.1. General

As described above, the range and the possibilities offered from software are endless, but these features must be integrated, and all these programs must communicate with each other. The software used in E39 project come from different companies and have different programming structure, but a way must be found to make these programs exchange data with each other and make these data accessible from everyone and if possible, from one source through the life cycle of the asset. This is the concept behind fully integrated BIM, and this is what E39 Kristiansand – Mandal wants to achieve. To achieve this and to make the programs communicate Application Programming Interface or API is used.

3.6.2. API and data transfer between software

An application programming interface (API) is an interface or communication protocol between different parts of a computer program intended to simplify the implementation and maintenance of software.

An API may be for a web-based system, operating system, database system, computer hardware, or software library and in this project is used to make possible that different platforms communicate with each other by transferring data and make this data readable in the BIM web-based solution. The following information flow structure is used to achieve the goal of delivering fully integrated BIM and make the model fully accessible throughout the asset life-cycle. (Fig 12)

The data that come from ground works by the Infrakit solution are transferred in Gemini and are compared with survey data. Gemini generates rapports about volumes, accuracy and the advancement in the project and these data and checklists generated from Gemini are transferred automatically using robotized solution into document server SharePoint.

SharePoint is the centralized information system and all the documents, checklists, survey rapports, product data sheets, 3D models, contractual documents are uploaded there by using automatic solutions and where not possible manual upload of files.

To make the process easier and not fragmentate the information a web-based solution will be provided so everyone can access the data and relate that data to the BIM model in general and in detail for structures and electro-mechanical installations.

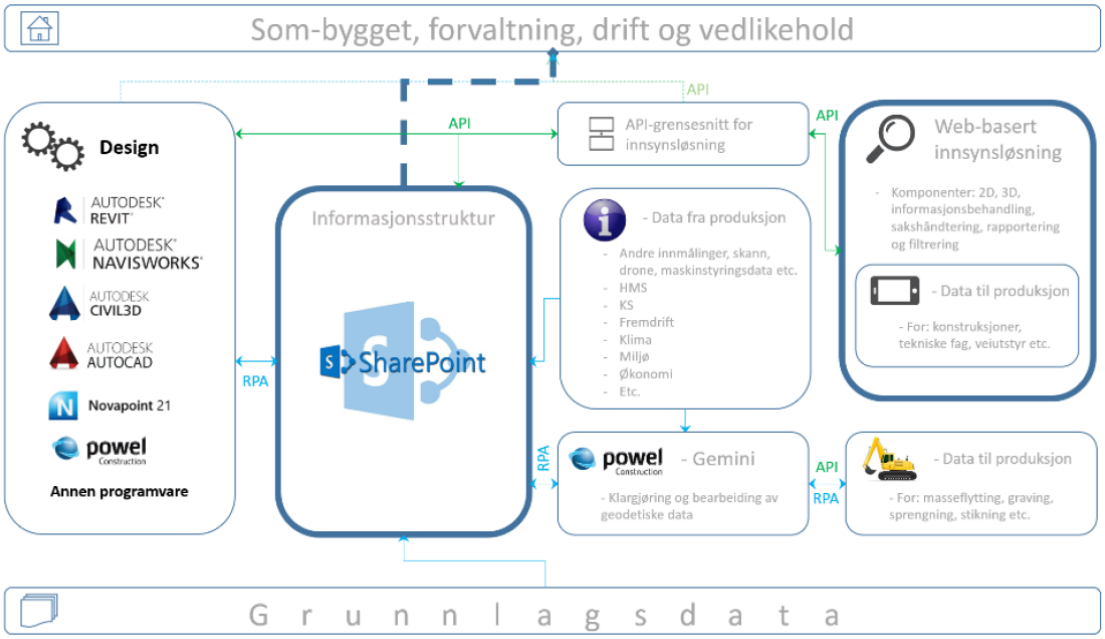


Figure. 12. Integration structure to provide fully integrated BIM

3.6.3. Web-based solution. The next step towards fully integrated BIM.

As part of the BIM model, a web-based access solution is established in the project. This will be used to make available the project's designed BIM model as well as relevant project information related to it. To meet the needs of the project, software development is needed to realize this. The web-based solution is based on established information and metadata structure in the project, in order to make project information visible in an appropriate manner. As shown in the information flow structure above, the solution will consist of several components, packed in the same solution. In order to meet the project's requirements, components within: 2D, 3D, information management, filtering of information and rapport generating.

Information structure is of major importance here, as the purpose is to be able to filter that information on the various parts of model and from different platforms that are connected to the solution like deviation platform Synergi, checklists platform Dalux, and document library SharePoint. For the visualization of projected data, as well as project information, two interfaces one in 2D and one in 3D are established. (Fig 13.)

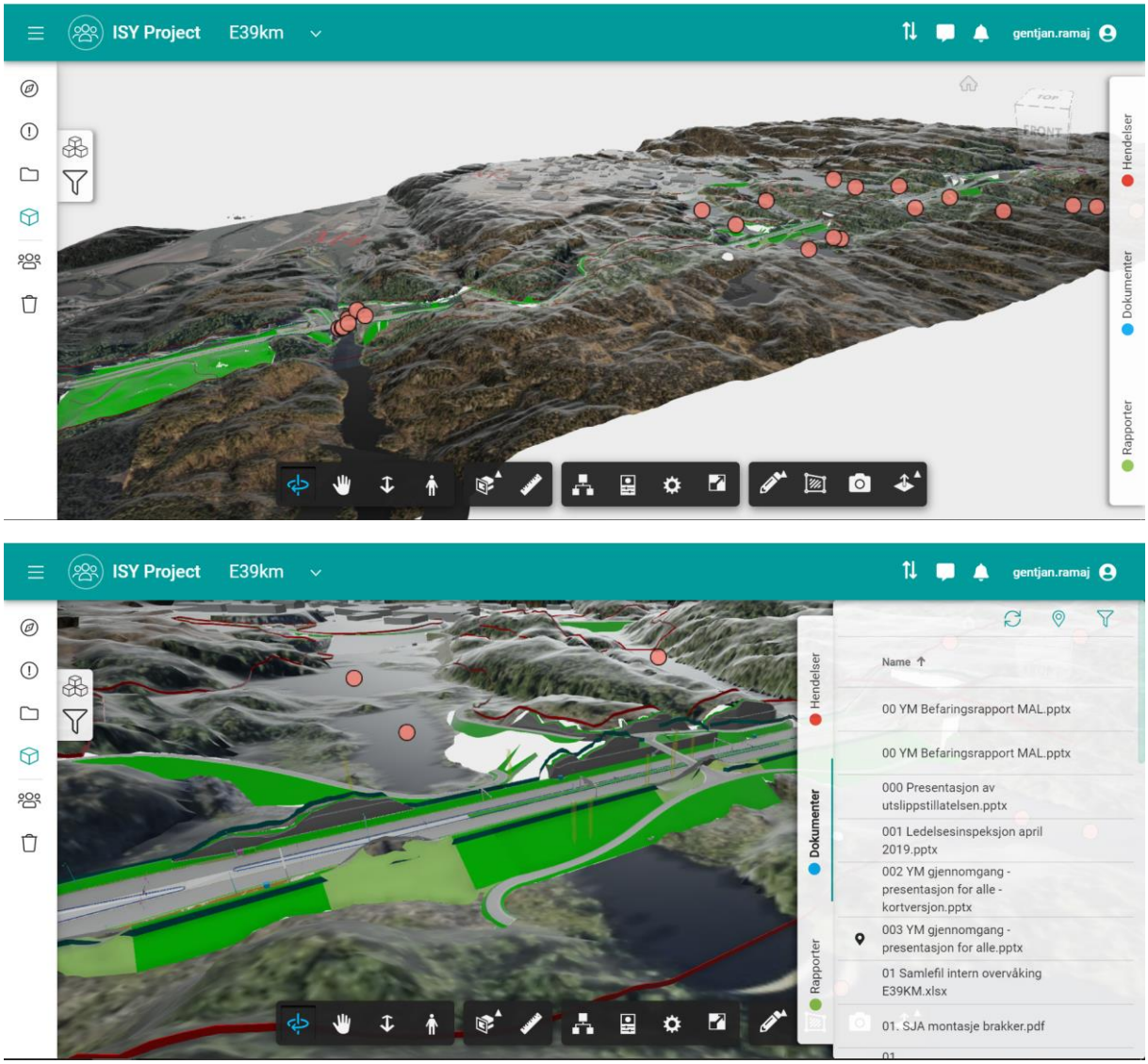


Figure. 13. Web-based solution E39. The red dot show the deviations reported.

3.7. BIM in design phase

As described above BIM is not just about three- geometrical model but it is much more related to information that model should give and what the end user can profit by the usage of that model. Due to the fact that all 3D components have a defined physical location it makes very easy to control if components clash with each other and in this way, we prevent conflict between design disciplines in an early stage. Different BIM platforms offer different features in terms of simulation and computations. All disciplines from structural design, electrical, mechanical,

environment, energy can be checked in an early phase if they are conform regulations before being send for approval.

In the new E39 Road Project, usage of BIM in design phase was clearly defined and it was required to match the criteria provided from the client in terms of structural design, geometry, property set of all components and follow an information structure to make easier collaboration in the next phases of the project. Since it does not exist a national or international standard about Dimensions of BIM the contractor AF Gruppen has established the following structure to be used from design team:

GEOMETRY	TIME	COST	SUSTAINABILITY	OPERATION	HSE
3D Model	Phase planning	Integrated description	Energy analysis	Final documents	Health
Quantities	Simulations	Cost validation	Environment analysis	System integration	Safety
Collision control	Visual validation	Risk analysis	Lifetime costs		
Survey data			Clime gases reduction		
Integrated calculations					
Parametric analysis					
Visualizations					

Figure. 14. The xD concept of Building Information Modelling.

The continually growing complexity of planning projects calls for a dynamic planning process which ensures a timely adjustment to modified planning conditions. This is more important whenever in national, and especially international, projects interdisciplinary teams are working on the same project at various locations with heterogeneous data. (A.Borrmann et al.)

The E39 project is in national level but it includes subcontractors from Sweden, Poland, China, Slovakia etc. Related to this, design will be carried out based on VDC (Virtual Design and

Construction) methodology principles. To minimize risks, crushes and reduce costs in the project the whole project will be built in 3D and all other interdisciplinary design aspects will be included before the project will start the execution phase.

People in AEC industry usually make no distinction between VDC and BIM, but they are different from each other. As explained above BIM is more about three-dimensional models including information about components. In this way we create physical and informational relations between each component. In the other hand VDC uses BIM to simulate how the designed model will behave in construction phase by including another dimension as showed in Fig. 14.

To facilitate design process and to have a common understanding of design steps, approval from government bodies of designs and the quality of the information that model includes, the design process has adopted and index mapping (MMI index) published from EBA (Entreprenørforeningen Bygg og Anlegg). The index map has been attached to the dependencies tree taken from BIM handbook published from (A. Borrmann et al 2018) to make it visually easier to understand.

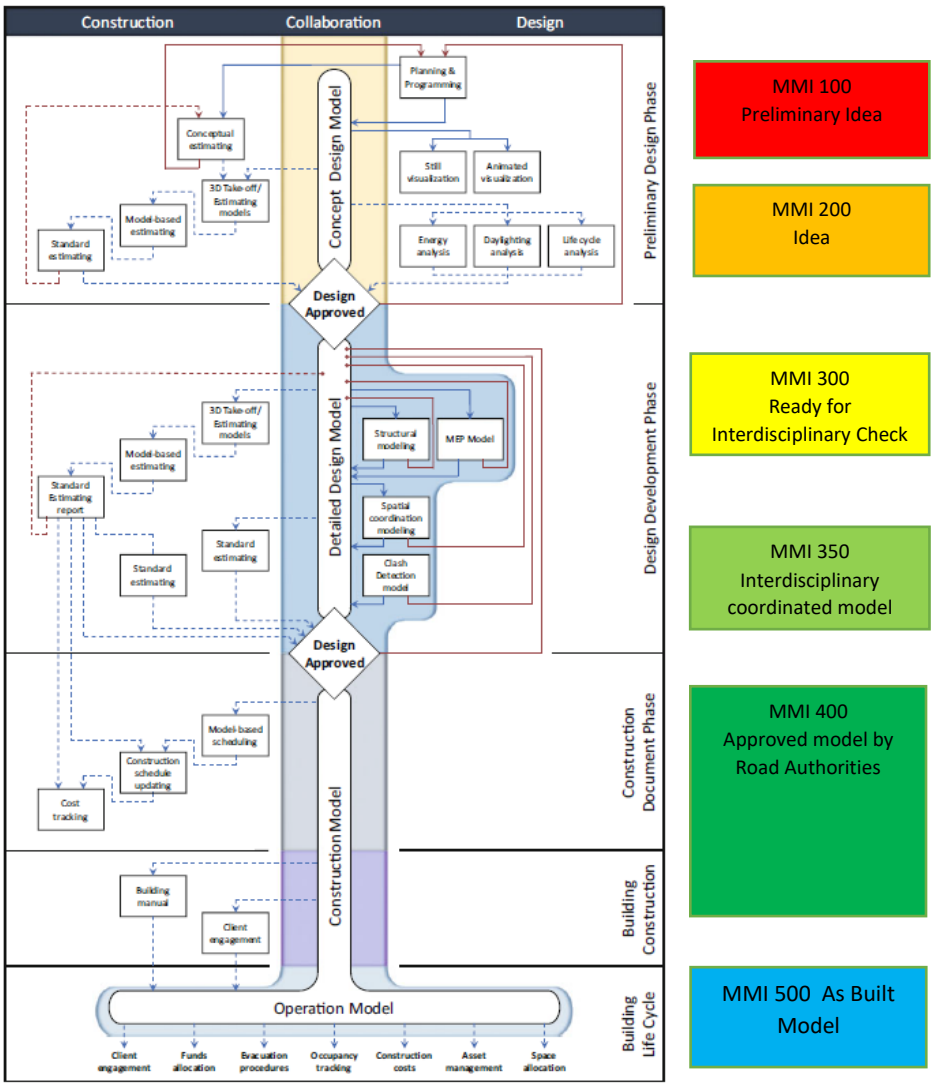


Figure. 15. The design dependency model taken from BIM handbook (A. Borrmann et al.) and the MMI corresponding index used in E39.

An important part of VDC is involved planning in the project. In the project will be used Last Planner System (LPS) and the structure for delivery will be divided into clear and defined work packages. Various participants sit together in meetings to plan work packages with activities in order to reach important milestones. The aim of involving the participant in this way is to create a greater interdisciplinary understanding throughout the project. The facilitators will constantly challenge the participants to cut unnecessary activities and the least time spent.

VDC itself will be implemented by using ICE (Integrated Concurrent Engineering) methodology. ICE concept was firstly introduced in Norway in 2005 in Oil and Gas industry (Hermundsgård 2018) to come in its time in response to the traditional sequential design, which has long been the dominant one the way to work. Sequential engineering is basically based on

solving problems involving disciplines across the organization. Each discipline performs its own tasks and pass it on to the next phase as in a relay team, often with limited exchange of information or discussions about problems in the project. Such a limited exchange of information can lead to misunderstandings. In response to this ICE, is a working method used in several industries and starting to get implemented in the design process in construction projects to make the projects more efficient. The ICE design sessions consist of informally coordinated, but highly focused, simultaneous development of interdependent models and analyses by all team members. The sessions resemble traditional meetings in that a designated facilitator communicates the agenda and monitors the session's progress. However, in ICE the participants continuously form and dissolve "sidebar" conversations to share information or solve emergent problems. The physical orientation and movement of engineers in the room passively communicates the structure of many such conversations to the entire group. (Stanford University)

This interdisciplinary coordination and collaborations come with some advantages and disadvantages, but it is very necessary on projects with a high degree of uncertainty and technical challenges as the project AF Gruppen is building.

3.8. BIM in production phase

Using building information modeling, design teams get more work done with fewer people. A smaller design team means lower costs and less chance for misunderstanding, because the documents are coordinated by the computer and therefore can be more complete, the cost of changes and coordination in construction administration is reduced. (Autodesk 2003) This is well supported from MacLeamy curve presented in 2004 which makes the correlation between cost of changes and project phases. (Fig. 16)

As explained above the BIM is a very important tool in the hands of design team but also in construction, less time and money are spent in process and administration because document quality is higher and construction planning is better. More of the owner's construction dollar goes into the building instead of administration and overhead in design and construction. (Autodesk 2003). Early BIM in construction can reduce costs for both main contractor and

subcontractor who are interested to bid. Using 4D and 5D simulations, respectively time and cost, can reduce uncertainty and deliver better quality of work the first time.

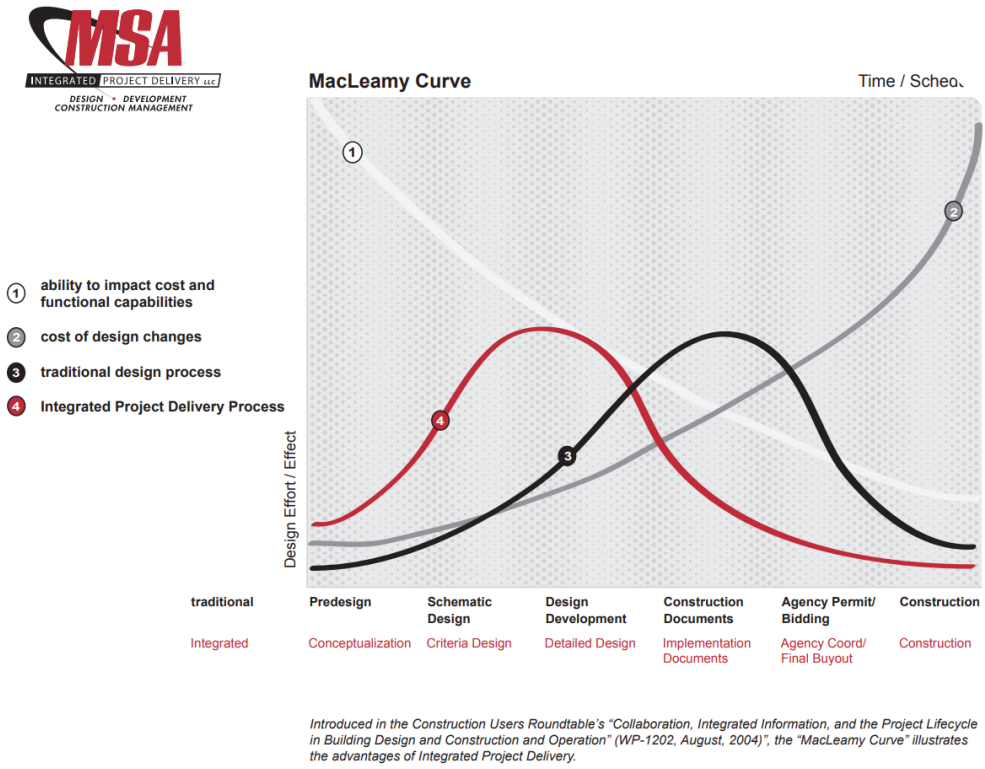


Figure. 16. BIM shifts planning effort and design decisions to earlier phases.

3.9. BIM in operation phase

BIM in operation phase is not new as a concept but implementation through asset lifecycle has very few examples that have been successful. BIM has been widely adopted by the construction sector, though Facility Management (FM) is still based on a variety of disparate FM systems. The operational phase requires comprehensive set of well-structured information regarding the building asset. Therefore, a BIM model filled with the multifarious information from the pre-use phase ought to be exploited through its integration with existing FM systems. (Nical, A. et al)

From the life cycle costs (LCC) perspective, the operational phase of construction project is often considered the most important. Life span of projects in construction industry is considerably long and operational phase takes up most of its time. During operational phase, most costs are associated with energy consumption, operation, maintenance, repairs and

reconstruction or demolition. With the arrival of BIM, industry was given an opportunity to utilize information models during operational phase. Such models increase quality and efficiency of operational phase, and the possibility to reduce costs. (Per Matejka. et al 2016)

A simple way to reduce these costs is to use a model that has all the information related to quality, product data sheets, technical clarifications and even the rescue plans in case of emergencies. This kind of information must be already in the model before the contractor delivers the project to the client so the information systems and the information flow must be built in a way that creates less interruptions and breaking points.

Parsanezhad (2015) sets out that information management in order to be efficient must be based on sustained collection, analysis and flow of information across the multidisciplinary environment throughout the life-cycle of the building asset. Such a holistic approach is defined by the buildingSMART alliance, as a "business process for generating and leveraging building data to design, construct and operate the building during its lifecycle".

That means that the model should be accessible throughout the lifecycle of the asset, from design to operation phase. The IFC (Industrial Foundation class) files come in help by standardizing the model structure including descriptions of object in the model and the information uploaded.

In the Fig 4. It is described the concept of OPEN and BIG BIM that are required to achieve this level of integration throughout asset life cycle and below it is described the linear connection between BIM in design, production and operational phase. As shown in the figure below (Fig 15.) Building Information Model (BIM), which is mainly created during design process, is part of Project Information Model (PIM), which provides information for Asset Information Model (AIM) used in operational phase of the project. For some, PIM also covers all AIM processes. (Per Matejka. et al 2016)

By achieving this the contractor or the organization that is behind implementation of that investment will profit in terms of performance, reduced cost, increased information flow, etc.

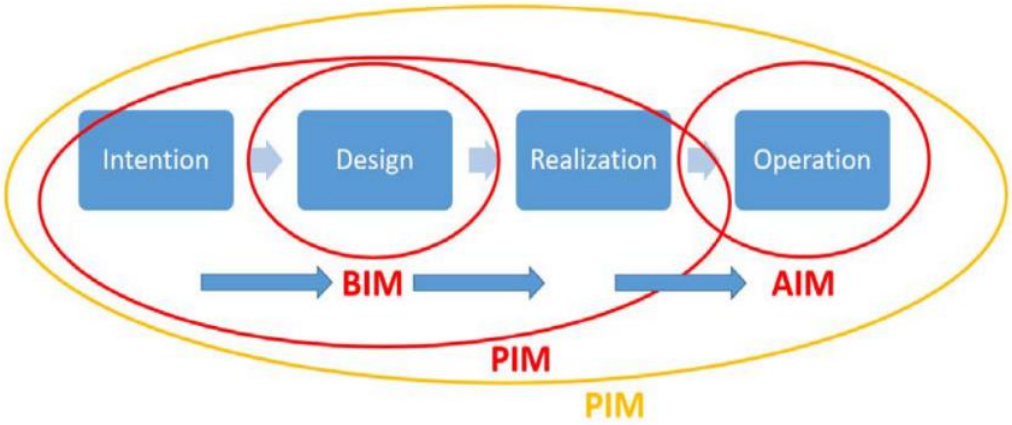


Figure. 17. BIM, AIM and PIM relationship

This integration comes also with some challenges related to technological development and the way to implement the BIM strategy inside organization.

Currently, attempts to use BIM in late phases should be considered as bad practice and failure of proper BIM utilization in a project. However, in reality, many construction projects exist in the whole world and will surely continue to exist in the near future, in which BIM was not used from the beginning. (Per Matejka. et al 2016)

From 2016 to 2019 technological advancements are outstanding and the cloud services and web-based solutions can change rules of the game by providing completely open access int model and by that open access to information and data related to different phases of the project. This can lead to projects where BIM is not seen as something necessary during design and production phase but also in operational phase.

The future is heading to that even so in the literature could not find many successful projects that have used BIM in operational phase.

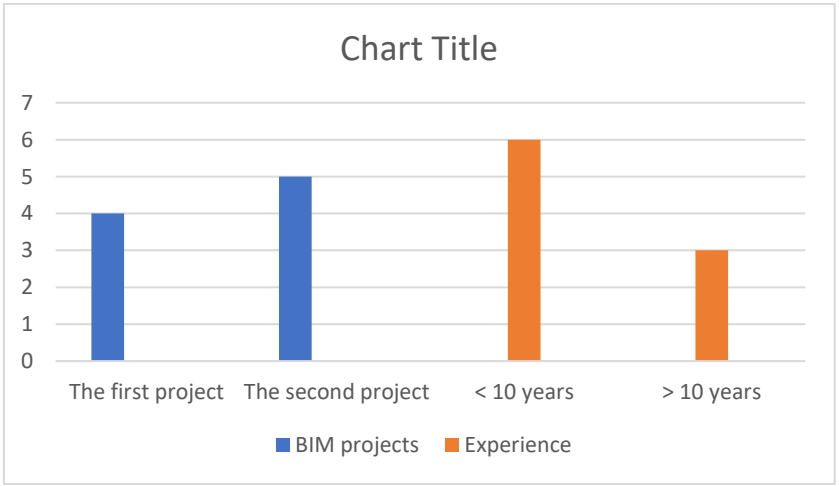
4. INTERVIEW RESULTS

In this chapter will be presented the interview results. As explained in the methodology chapter the interviews were hold in Kristiansand and with different key staff members in different positions in organization structure and different companies. The researcher has created a structure to filter the information and answer the research questions in an organized way. The structure is based in the different phases of project and connection of these phases with the BIM model.

The first part of the question is based in the introduction of respondent to the research and to take general information about the respondent experience in construction, how much do they know about BIM and in how many projects have they worked with BIM. In total were conducted 12 interviews but 3 of them were informal and it was not followed the same interview guide structure as with others so the results from these interviews will influence in the total overview of the research but not so much in the conclusions so these will not presented in charts below.

From 9 formal and voice registered interviews these were the results related to experience and in how many projects have they worked with BIM and 3D models.

None of the respondents had worked in more than 2 projects with BIM and this was a predicted result since the technology is new.



The researcher asked the respondents for their opinion on possibilities that fully integrated BIM offers and what they know about BIM level 3. They were asked also about their experience in

this project and other projects if they had other experiences and to make a comparison about the project related to BIM.

When asked about BIM influence in daily routines all the subjects answered that BIM influences their daily work and eight from nine of them answered that BIM increases the performance of work by saving time to find relevant information and to coordinate with others in the organization. Since five of the subjects had worked before in projects that BIM was used as a concept, the researcher asked them to explain a little about the differences between other projects and this one particularly.

Three from these five had experience from Residential Building construction so the differences were not considered due to limitations of the research in infrastructure projects. The main differences were on the integration part between different platforms and the use of global coordinates. Global coordinates were used to position the models of constructions and tunnels because it was easier to connect the platforms and make them work with the same reference system.

In terms of information flow inside organization and with other organizations all the respondents agree that information flow is improved but still a lot had to be improved.

When asked about the definition of BIM maturity level 3, five of the respondents had not heard that before and four of them were well informed since they work as BIM Coordinators.

When asked, if the project can deliver contractual requirements five from the respondents have answered “Yes” and four answered “No”.

The last part of the interview was based on the possibilities of improvement and how can we reduce the gap between theoretical possibilities and what have we achieved in practice, The researcher asked respondents questions about training, trends toward BIM, their difficulties in the project about the software and about the challenges with hardware systems.

When asked if they got training before coming to work in the project, seven of the respondents answered “No” and two “Yes”. These two were BIM coordinators.

All the respondents excluded BIM coordinators answered that they need additional training to perform better in their daily work. This confirms what researcher was afraid and shows problems in the approach of the contractor and subcontractors toward the BIM implementation. The companies involved were based more in the development of the system than in early involvement of end users.

The researcher tried to get answers from respondents about their knowledge in company strategy about BIM and how much were they updated with the documentation and BIM implementation strategy. Most of the respondents answered that they knew that some documents were published and they knew about the strategy of the company but they had not read these documents and they really did not knew were these documents were uploaded.

Finally, the researched asked respondents about the new BIM platform being developed "ISY Project Portal". What did they know and what did they think about that?

All the respondents knew that the platform was ready to be used with just a few options, but at the time the master thesis was written the platform was not fully operational as intended in the BIM implementation strategy.

Further the researcher, as agreed with the supervisor, decided to use a structure for discussions and conclusions based on the project phases.

- BIM in Design phase
- BIM in Construction phase
- BIM in operation phase

4.1. BIM in E39 Kristiansand-Mandal

4.1.1. BIM in Design phase

The design is done by a company named Norconsult and the researcher conducted 2 informal conversations with the Design leader representative for the project and with the design representative for construction in this project. They had not so much information about what the project and the contractor should deliver in terms of fully integrated BIM but they confirmed that for Norconsult this project is innovative and the state of the art technology and collaboration tools are being used. They follow the requirements and descriptions in BIM handbook published from Norwegian Road Authority and they collaborate with the BIM development team in AF Gruppen for the next phase of the documentations that is related with As Built Model. This will be delivered in 2022 so it was irrelevant to ask them for more information. They use Autodesk product like Revit to model and deliver detailed structural models and the Index described in (Fig 15) to show the stage of the model and the information it includes.

4.1.2. BIM in production phase

BIM in production is related to the contractor AF Gruppen and is currently in use and fully operational. All BIM products and the web-based solution are being used, are coordinated and communicate with each other.

The main platforms that are used in ground works are Gemini, Infrakit and web-based solution that collects the information from these platforms and filter it in the model ISY Project Portal. The Infrakit platform, with checklists features, geolocation, schedule plans and 3D capabilities, is the main tool that is used from equipment's in the field and to generate checklists about ground works related to quality of layers, explosions, rock formations. All these checklists are than uploaded to SharePoint and by a metadata system build already are automatically transferred into web-based solution.

The main concern where all the respondents agree is that the web-based solution is a program that has a lot of crushes and is very heavy to open in PC due to the quantity of information that includes. This reduces effectivity and increases frustration to the end users.

The groundwork team is using Synergi life as a tool to rapport deviations and the dangerous events in the project and all these events are registered automatically in the web-based solution

with a description and the exact location. The engineer responsible for this discipline can easily filter information and find hotspot areas.

When being asked about the efficiency of using BIM in ground works surprisingly all the respondents feel that BIM concept is not being used very effectively due to miscoordination and the delays in information flow and decision chain. The respondents answered that they have found missing information in models that describe groundworks and sometimes the models are not 100 % accurate.

The main structures in the project are being built from the biggest subcontractor in the project Kruse Smith. The researcher has chosen 3 key members working with information quality and BIM for Kruse Smith, two BIM coordinators and Quality Manager. When asked about BIM possibilities all three members from Kruse Smith agree that the possibilities are endless, and they are trying to use these as much as they can in the project. Due to the specific works Kruse Smith must deliver, the design company Norconsult has direct contact with Kruse Smith. All the product from suppliers like bridge bearings, bridge supports, guard rails are provided from Kruse Smith to Norconsult and after are uploaded in the model.

In terms of missing information, the respondents from Kruse Smith answered that they have found many times missing information or errors in the model and these are reported using collaboration tools offered from BIM platforms.

Just Kruse Smith uses BIM collaboration files to communicate with the design team, something that other respondents answered they use again conventional methods like email or direct contact. Kruse Smith uses Dalux, a mobile platform for checklists which then are uploaded after in the web-based solution via metadata system. Respondents from Kruse agreed that fully integrated BIM will make the branch move faster toward digitization and Kruse Smith itself is developing same tools as AF Gruppen is doing in this project.

4.1.3. BIM in operation phase

The web-based solution ISY Project Portal will be the platform where all the documents, product datasheets and other details of the project will be accessible after the project is constructed and handed over to the client. The maintenance companies will have full access to documentation about product that are used, the locations of these products and where are they scheduled for routine maintenance. This will open the door for an innovative and effective

maintenance by reducing cost and increase safety in the road. When asked about the possibility to deliver this kind of solution 5 from 9 respondents answered that this will not be fully possible, but it is the right step toward the future. In addition to that, based on the same methodology and system the client Nye Veier can integrate other sections of the road in the same platform. In this way the Client can have a total overview and fully control of the new road portfolio and manage that in a more effective way.

The respondents answered that possibilities here are huge but people in general are sceptic since the project is under development and a lot of uncertainty is related to that.

5. DISCUSSIONS

In this chapter the researcher presents the results from literature research and data collected from the interviews. The same structure as in the above chapter will be used to discuss the results but in addition to that some other element like theoretical possibilities and practical use will be added for every chapter. The results and the content in this chapter are based mainly on answers of subjects form their experience and knowledge for the field.

5.1. BIM in design phase

Through both literature study and interviews, a positive approach to BIM and the digitization is observed. All the respondents agree that BIM influences their daily work and performance and in most of the cases BIM has made easier for them to access information in the model and process more data for the same amount of time compared with conventional 2D paper-based drawings.

In terms of BIM in design the researcher points out that for all respondents agree that this project has a main goal of "Drawing free" and documentation must be inside the model. The usage of BIM handbook manual V770 is part of the contract and agreements between Design Company and the Main Contractor. In addition is agreed to use VDC approach including ICE and LPS (Last planner System). The BIM model is the center of information in communication between design team and people working in the field. Especially subcontractor Kruse Smith has direct contact with Norconsult design team through Skype meetings where BIM model is in center of communication and everything is presented by using the model itself by using VR technologies offered from Dimension 10. This increases collaboration and makes easier to understand the model by feeling the 1:1 scale.

It is observed that Kruse Smith uses BIM model to communicate through BIM platforms as Solibri using BIM Collaboration Files or BCF, making easier to explain where the problem is and keep track if the problem is solved. From some of the interviewers where pointed out that the technical clarifications notified by email through SharePoint system must be integrated to BIM model and maybe to web-based solution.

All respondents agree that the BIM model has improved information flow between design team and people in the field. Through the interviews is supported the MacLeamy curve presented in 2004 which makes the correlation between cost of changes and project phases.

The respondents from Kruse Smith agree that the use of MMI index, which is agreed in the agreement between Norconsult, Nye Veier and AF Gruppen, is very effective to keep track of the work packages and what is the status of BIM model.

In terms of effectivity, all the respondents agree that even they have found missing information in the model the BIM concept is being used more effectively in design then in production and operation phase. This is supported also form Autodesk paper where development of BIM in design is the first step toward full integration.

When asked about the full integration of designed BIM model in the web-solution the respondents answered that for the moment a lot of information related to product data sheets and some descriptions are missing so the upload of the detailed model in the cloud solution would not be so effective.

One thing that concerns most of the respondents is the late approval of the models from Norwegian Road Authority creating a lot of frustration for the team in the field and making the process very bureaucratic causing delay in production. Even the MMI index and data packages to be delivered are approved early in the project they keep changing and the Norwegian Road Authority does not keep in the same rhythm with design team. The respondents agree that this process has a lot of room for improvements.

Overall, however, BIM in design seems to be contributing to the simplification of work among users and has led to a better information flow. The challenges according to errors and deviations found in the models are not big and are solved in a short timeframe and the respondents agree that the goal of delivering fully "Drawing free" model is fulfilled since everyone in the project has access to model using PC or mobile devices but "Paper free" concept in terms of all documentation needed to build structures is not yet fulfilled and a lot documentation has to be uploaded manually.

The researcher points out that the project has built the framework and partially standardized the design process for the future infrastructure projects at least that will be built from AF Gruppen in collaboration with Norconsult this due to contractual requirements set from Nye Veier. This is supported from the interviews where the respondents were asked if they have experience from other projects with the same concept and all of them said that this is the first time that are working with a "Drawing free" concept in Infrastructure projects.

5.2. BIM in production phase

BIM in production is relatively new in Infrastructure project and this is supported from interviews when asked if the BIM concept is being used effectively in this project. They answered that they feel that BIM concept as they understand is being used better in Design phase than in production. It is observed that except subcontractor Kruse Smith, other contractors like AF Gruppen, Strøm Gundersen and some other smaller subcontractors continue to use conventional checklists to check the quality and document the finished works. BIM development team in AF, said that they are checking the possibilities to start using DALUX system to fill checklist and upload them automatically in the cloud solution but up to now they are still in the planning phase.

The use of Infrakit and Gemini for ground works has increased accuracy and helped for better control of logistic in the construction site. Some of the documentation needed to document the quality of ground works is generated directly from Infrakit and then uploaded in cloud solution. Event that Gemini itself offers the possibility to upload files directly in the system, this feature is not being used due to difficulties to make different programs communicate with each other due to different file formats. The documentation is usually exported from Gemini to pdf file and by that, using metadata is transferred into web-based platform.

When it comes to metadata system, both the contractors and client, agree that the designer Norconsult, sometimes does not deliver the right descriptions about work processes. This increases uncertainties and unnecessary job has to be done in terms of coordination with the design team.

Synergi Life, the program to rapport deviations in quality and HSE is actively being used and it is fully integrated in the cloud solution by providing in real time where deviation occur, how dangerous they are in terms of personal safety and environment. In addition, the same program is used to rapport quality deviations but some of the respondents answer that more integration is needed to complete the whole panorama since deviations are attributed to one area without giving descriptions in detail where in construction or where in the ground works has happened the deviation. This makes harder for Quality Engineers to keep track and for the Client to check if these deviations are fixed. At the time the master thesis was written this problem was solved and a lot more possibilities and options were added to the software. Now the user of the software ca chose exactly where the deviation happened and a red dot would appear in the web-based platform as show in the Figure 13.

Overall, BIM in construction phase is being used actively and not just the 3D model but most of the digital tools like Infrakit, Gemini, Synergi Life and Dalux are integrated in the cloud solution ISY Project. Cloud solution is being used in meetings between subcontractors to coordinate work and most of the documentations is accessed from there. Even the respondents agree that the cloud solution is very heavy to open in normal PC and it requires a very long time to filter the information is a very good step toward fully integrated BIM and by learning from mistakes can create a framework for future jobs. BIM development team in AF Gruppen agrees that the cloud solution has some problems, but this is normal for something that is still under development.

In the third part of the interview the researcher focused more in the possibilities to improve the solution and what is needed to make this solution and BIM as a concept work better in the project and increase efficiency.

Firstly, the researcher asked the respondents if they had got any BIM training before starting to work in the project and surprisingly, excluded BIM coordinators, none of the other respondents had got BIM training. From the researcher perspective this tells a lot and explains some of the frustration, lack of control in navigation and lack of information flow between design team, the contractors and the client itself.

The researcher went further while focusing on training and asked the respondents if they needed training in this phase of the project. Mostly of the respondent including two of the BIM coordinators answered that they would like to get additional training to perform better in daily work or to be specialized in one or two processes.

For the purpose of the research and from the contractor perspective as collaboration partner the researcher added some questions about workload and if the respondents have worked with team member that had not knowledge at all about BIM. The respondents asked 100 % that the workload now is lighter than with conventional methods, but they had worked with team members that had no or very little knowledge about BIM and this increases artificially daily workload. In concept BIM itself and digital tools being used have reduced the workload, make the construction more effective but a lot of focus should be given in staff training.

Focused in the possibilities to deliver a better product, a better strategy and a better solution the researcher would like to pinpoint some of the suggestions given from the respondents on how the BIM concept could be improved in E39 project.

Suggestions:

1. Early involvement of the subcontractors in the design process.
2. Use of just one model and not a list of models
3. Improve the descriptions in the model
4. Run crush analysis before sending the models for construction
5. Involve more staff in the meeting so they can be familiar with the BIM concept
6. Involve the Road Authority more by explaining the difficulties that come by late approval
7. Integrate more digital tools in the web-based platform.

Based on these suggestions the researcher has observed that the concept advertised and requested from the client is being delivered partially form the contractor due to difficulties in development of platform and slightly misunderstanding the importance for better management.

For the researcher could it be very useful to monitor how the cloud solution will be improved and what features will be attributed in the future.

5.3. BIM in operation phase

It appears that all the respondent have an understanding that the BIM model must be a living object and by this they support A.Borremann when he describes that BIM forms by himself a living object that should be used through the lifecycle of the project. By making operational the cloud solution where it integrates the 3D model for different disciplines, documentations about the quality of work done, documentations about the impact in environment and other support documentation, AF Gruppen is another step toward fully integrated BIM and the use of models throughout assets lifecycle.

When asked if AF Gruppen can deliver fully integrated BIM in this project the respondents agreed that AF is in the right path, but this is the first project that is trying to achieve this in huge scale with a complex project as E39, so they are sceptic about the final product.

Since no other examples were provided from respondents about another project that has delivered the same BIM maturity level, the researcher can assume that the expectations can be lower than what project is delivering. This relates to the fact that most of the respondents were not familiar with contractual documents about BIM implementation strategy and some of the respondents were not familiar with routines and procedures about information channels in project and usage of BIM. All respondents state that BIM must continue to be used through the operational phase and by this supporting Sanchez et al. (2014), on how the life cycle of BIM models can continue into the management part of a road project

When asked about possibilities of BIM level 3 in operational phase none of the respondents connected usage of BIM in disaster preparedness and pollution management in the future but this in fact is predicted and planned from the client Nye Veier as part of the purpose for the usage of BIM throughout asset lifecycle. Especially when designing tunnels, fire safety and ventilation can be considered in more detail by integrating the 3D model into simulations of different scenarios, which can then be used to develop and coordinate emergency response efforts. (A. Stone, 2013).

Overall, the respondents agree that project has made a huge step toward fully integrated BIM by offering a cloud solution to be used after the projects is constructed and by creating a standardized solution about information flow in the project.

The researcher points out that people directly connected with usage of BIM are not very familiar with routines and contractual documents agreed for BIM usage in the project during production

phase and future for operational phase, but they have high interest to learn and are very positive and supportive for the technology. When it comes to the BIM in operation the respondents agreed that more information is needed to be included in the final web-based solution. The additional information like product data sheets must be primary and all the maintenance documentation for bearing, tunnel fans, electrical and mechanical information not just in tunnel but in bridges, emergency rooms, culverts and every part of the road tat has elements that need routine maintenance. In addition, more focus must be given to the registration of deviations in quality because these hotspots areas where the deviations have occurred can be the weak areas where maintenance is required more often and could cost more to maintain.

As supported from the theory the web-based platform and IT systems for implementing BIM methods are now available for all phases of the life cycle of a building (design, construction and operation). The BIM model has been created during the construction phase and relevant data from the model can be extracted and integrated into the Asset Information Model (AIM) for use in the operation phase. The data can then be maintained on an ongoing basis and passed over to future users or owners of the building at a later stage of the building.

6. CONCLUSIONS

6.1. BIM in design phase

The study conducted, shows that those involved in usage of BIM in design phase are largely positive for development of new technology and this can be related to the extended use of software that support 3D models and a longer experience with the usage of BIM concept. The research shows that for the people working with BIM in design it is important to have a framework or a standardized way of working and this is partially achieved by introduction of standards like V770 BIM handbook and ISO standards related to BIM

When it comes to data exchange and collaboration, it appears that BIM as a concept is used very actively in the design phase by using collaboration files like BCF and meetings using VDC approach where BIM model is in the center of discussion. In terms of collaboration and contractor involvement early in the design phase respondents from subcontractors pointed out that they were not involved enough in the design process and this is related with the challenges that they have now with procurement of materials and finding suppliers for some solutions that they were not prepared when they signed the contract. Another important thing that subcontractors points out is the delay in approving of work models from Norwegian Road Authority, Statens Vegvesen. This has caused frustration and economical costs for both Main Contractor and subcontractors. This part is also not so covered in contract and has a lot of room for improvement in both technical and contractual approach in the next project.

The research shows that the goal of delivering a “Drawing free” project is achieved but the concept “Paper free” has a lot of room for improvement in terms of documentation for quality of works done and documentation to be delivered for the usage in operation phase. technology.

Overall, BIM in design seems to be contributing to the simplification of work among users and has led to a better information flow but the research finds out that the respondent would feel better with a standardized solution that the whole industry can use instead of the different solutions contractors are developing on their own using intern standards. This means that in terms of theoretical possibilities the respondents are aware that the possibilities are big but the project is using to some extent these possibilities in practice due to restrictions in digital tools developed and the lack of experience.

The research shows that the respondents generally agree that cloud solution ISY project portal is a very good solution for the exchange of data and extract information but for the moment the solution is under development and has many bugs. It is recommended that the development team continue with the good work and focus also on training people to use all the features offered from this innovative solution.

6.2.BIM in production phase

This level of integration of BIM in production phase for infrastructure projects is quite new and the respondents agree with this. The research finds out that even the project E39 is trying to deliver one of the most integrated BIM systems, people working in this project and the end users of the system in fact have little or no experience with BIM in infrastructure projects and the knowledge that they have about BIM is related more to Residential Building industry.

When it comes to integration of digital tools together, offering a simple and centralized solution, the research shows that this is partially achieved by making operational web-based solution, but still a lot of tools are yet not integrated, and the system is still under development.

Overall, BIM in construction phase is being used actively and the users are positive for the effects not just by using 3D model but most of the digital tools like Infrakit, Gemini, Synergi Life and Dalux. Some of these tools are fully integrated and some under process to be integrated in in the cloud solution ISY Project Portal.

In terms of data exchange and information flow the cloud solution is being used in meetings between subcontractors to coordinate work and most of the documentations is accessed from there. There is no doubt that the project that utilizes the potential of fully integrated BIM can save time and money. There is also positive that errors found in the project are easily changed and little cost is related if you compare with conventional 2D projects. The use of AR and VR realities in the design and operation phase will offer the possibilities of checking the errors and fix the while the engineering team is in field. This potential is not fully explored but a lot of effort is given to introduce AR SiteVision solution next year in the project. Some of the respondents answer that there is a lot of possibility to save a lot of time and money by performing this solution and by this we confirm the theory written in the chapter 3.

The research shows that the concept of fully integrated BIM in the project is not yet fully achieved, especially for production phase, but it is a very good step toward the future. A lot of

documentation is being upload in the cloud solution and the positive effect is filtering system and elimination double documentation by using an effective metadata system.

It is also important during the construction phase to prioritize hiring personnel in BIM roles like BIM coordinators and staff related to IT. The quantity of information, the coordination process and necessity for digital tools is being increased but not so the number of BIM coordinators in the projects. They are needed not just for development but in training of people to use these tools. In this way all the people would feel that they are part of a new technological advancement and the golden rule of management to achieve an ownership of the project would be achieved faster and more effectively.

Related to knowledge, training and the time to adapt with the new technology most of the respondents answer that the project would not deliver a fully integrated BIM in production phase but will be the framework for the future projects.

Focused in the possibilities to deliver a better product, a better strategy and a better solution, the researcher would like to pinpoint some of the suggestions given from the respondents on how the BIM concept could be improved in E39 project.

The elements which needs to be improved from the contractor as a developer

1. Early involvement of the subcontractors in the design process.
2. Use of just one model and not a list of models
3. Improve the descriptions in the model
4. Run crush analysis before sending the models for construction
5. Involve more staff in the meeting so they can be familiar with the BIM concept
6. Involve the Road Authority more by explaining the difficulties that come by late approval
7. Integrate more digital tools in the web-based platform

In the researcher perspective the development of the web-based solution is being seen more as an additional tool in the project than a key development that could change the project management as a whole.

6.3. BIM in operation phase

Management, operation and maintenance are currently not so well related to BIM. In the most cases asked through the informal conversation the research has found that none of the respondents have worked or know any project that is using BIM during operation phase. The biggest concern is that there is no such system that can handle 3D model, documentation and plans for the future operations of the asset.

In the E39 project this problem is being addressed and a cloud solution with integration possibilities is introduced and is now operational. The integration of 3D model with documentation and with as built models using scanning technology is now partially in use.

The documentation about product data sheets, checklist for works done, documentation related to impacts in environment and deviations in quality are being uploaded in the cloud solution and automatically connected to the objects related to that checklist using a metadata system. This gives the possibility the next operation or maintenance company to access the documentation and find the necessary information directly in this cloud solution.

The research found that all the respondents feel positive and support the solution, but much effort must be given to the training of people, making the solution easy to filter information and to operate better in terms of technical crashes.

The research points out also the necessity of a standardized solution for all the projects and not in just one as E39. The respondents feel that much effort, time and money is being used to develop tools just that would be more for internal use than for the benefits of the society as a whole so they suggest that the main Construction Companies to collaborate together with Nye Veier to develop a standardized version of cloud solution and in this way creating a safe and quicker path toward full integration.

The researcher identified Lean principles as improved reliability and effectivity in a BIM level 3 Project. However, there are two main obstacles for using the full potential that lies within the digitalization of the AEC industry: 1) the existing software tools are not completely adapted to digitalization and 2) external stakeholders that slow down the production.

Since the project is in the middle of production phase it is impossible to see practical benefits of the system for the operation phase, but we can assume that all described above would be a reality.

Focusing on the points that can be improved and based on the third part of the interview, the research shows that in order this concept to be fulfilled and be fully operational more focush should be given in the upload of right documentation, registration of deviations and more training about the staff that is already working and the staff that will follow the project during operation time.

Finally, the research, throughout interviews, come to conclusion that the project will be able to deliver partially fully integrated BIM, but it will be a good example and they could learn from mistakes to deliver a better BIM system for the future.

7. FUTURE WORK

The research itself has been limited in just infrastructure project and particularly in just one case study. The reasons are explained above but the most important is the fact that this was the only case project that was trying to deliver BIM at maturity level 3.

In my opinion it would be interesting to focus on other projects and to follow the project also in the operation time. The researcher has not found any project in the Norway that BIM model delivered from the contractor during construction time was being used in routine maintenance after project handover.

So, the researcher recommends these points as possible future works:

1. BIM in operation phase, benefits and challenges in the same case study
2. Compare the benefits and challenges in different projects with the same level of BIM maturity levels.

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9. APPENDIX A – INTERVIEW GUIDE

The main purpose of this study is to explain what road project "E39 Kristiansand Vest – Mandal Øst" is trying to deliver in accordance to BIM implementation strategy and to try to uncover challenges that are related to data quality and the information which will be uploaded in the BIM model.

Main points and objectives that I will try to provide an answer are:

1. What are the theoretical possibilities of level 3 Fully integrated BIM?
2. What are challenges in accordance to data quality and information?
3. How to close the gap between theoretical approach and practice?

Description of the topic.

Building Information Modeling (BIM) is the digital tool of Design & Construction industries to improve the flow of data through the building process, increase effectiveness, shorten building time and deliver a product with high quality and minimized deviations.

Last years, with more capacity of data processing and new technology is making possible and a necessity to have a fully digitalized workspace in all aspects of construction beginning with design and ending with maintenance.

Building owners and operators are driving the industry to achieve higher levels of BIM maturity by demanding process improvements and technological innovations that reduce costs, increase value from suppliers, and increase sustainability.

To achieve this level of digitalization it is needed a level of data that is intercorporated in one place (model) and that is accessible from every direct stakeholder of the project. This would say that everyone from the design team to building team, maintenance and public agencies will work with one digital model that has all information from technical specification, building specification and maintenance data, creating in this way a total lifecycle data management system.

The challenge is that most of the industry is moving from BIM level 1 to level 2 and what the project that I intent to study want to achieve is BIM level 3 and maybe beyond. This increases uncertainty in an unprecedented level since are few examples and the framework of what we want to achieve is not clear.

To give an overview of and to make the study framework understandable for everyone that want to get information about BIM in the construction Industry, the study will begin with a description and the development history of BIM technologies and what is agreed among industry actors on BIM level definitions.

When discussing the use of BIM in the perspective of infrastructure, it is key to hold a clear difference between terms of BIM and 3D model.

As defined by the National Building Information Model Standard Project Committee:

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

A basis premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.

According to that BIM can support not just 3 geometrical dimensions but can go further to additional dimensions like time, cost, health and safety, environmental impact, facilities management, operations and maintenance.

To come to this kind of solution we need to upload the right quality and the right amount of information inside BIM model. This is not easy when working with different stakeholders which maintain different levels of Quality and Management systems. In this term it is important to find a solution and to create a framework for the information and the quality of data that will be part of the BIM solution. This is for the moment the most challenging thing and where the industry is struggling in order to achieve optimal flow of data and all parties to have full understanding of model.

As a NTNU student, I represent just NTNU in this research and all data that will be collected in forms of interview and informal communication between colleagues will be used just to help AF Gruppen and other organizations in this project to uncover challenges that are related with

BIM usage and try to deliver the best possible BIM experience for everyone involved in the project.

The following interview question will be asked, and the interview will last between 30 to 45 minutes.

- **Introduction questions**.

1. What is your position in AF Gruppen? Norconsult? Nye Veier?
2. How many years of experience have you in the Construction Industry?
3. Do you know anything about BIM?
4. How much experience have you with BIM?
5. Have you worked in any other projects with BIM?
6. How do you rate your own level of interest and knowledge about BIM?

- **Research question 1**. What are the theoretical possibilities of level 3 Fully integrated BIM?

1. Does BIM influence your daily work?

2. Does BIM influence your performance at work?

3. For what do you use BIM?

If the respondent has answered that he or she has experience in using BIM from previous projects questions 4 and 5 will occur…

4. How different is BIM in this project with others that you have worked?

5. What is different?

6. How do you think BIM influences information flow between you and others in your organization?

7. Has BIM helped collaboration between organizations that are stakeholders in this project?

Question 7 will be different depending on which organization is interviewer working, AF Gruppen, Norconsult or Nye Veier.

8. Have you heard about BIM maturity level 3? If yes, what have you heard and how do u understand that?

If the interviewer answers that he has knowledge about BIM level 3 the question 9 will follow…

9. What will be effects of this level of integration?

10. Do you think that it is possible to deliver level 3 BIM in Road Projects with the level of knowledge and the level of technology that we have now?

- **Research question 2.** What are challenges in accordance to data quality and information?

11. According to what you know about BIM, do you feel that concept is being used effectively in this project

12. If yes, why do you think so.

13. If no, why do you think so.

14. Has It happened that you have found missing information in the modell? What for example?

15. Do you use collaboration features offered from BIM platforms to communicate or you use conventional methods (email, sms, mobile)

16. Have u been introduced to any routines or procedures about BIM usage?

17. Do you know what is Implementation strategy? If yes, what do you know about it?

18. Do you know what is the objective of this project related to BIM implementation strategy?

- **Research question 3.** How to close the gap between theoretical approach and practice?

19. Have you got any BIM training before starting to work into this project?

20. Do you think that you need training to perform better in your daily assignments?

21. Have you worked with someone in the project that has no knowledge about BIM at all?

22. How fast do you think is the branch moving into BIM? In Norway we are catching up.

23. Do you think the workload is heavier now with the use of BIM or with the use of old methodologies?

24. Do you have the necessary hardware infrastructure to perform your daily work?

25. Do you have any knowledge about introduction of paperless checklist programs into project?

26. If yes, what do you know?

27. Do you have any knowledge about introduction of project Portal BIM platform (ISY project portal) into project?

28. Have you used it before?

29. If yes, for what?

30. If no, why so?

Closing

31. In your consideration, do you suggest any aspect that I can research further?

32. Can I contact you again if additional questions come related to this research in the future?

10. APPENDIX B – SCIENTIFIC ARTICLE

Tommelein, I.D. and Daniel, E.I. (2020). "Structural template and formatting instructions for IGLC28 papers." I*n:* Tommelein, I.D. and Daniel, E. (eds.). *Proc. 28th Annual Conference of the International. Group for Lean Construction (IGLC28)*, Cusco, Peru, pp. xx–xx, doi.org/10.24928/2020/92. Online at iglc.net.

FULLY INTEGRATED BIM MATURITY LEVEL 3 – EXPERIENCES FROM E39 ROAD PROJECT, NORWAY.

Gentjan Ramaj [1]

ABSTRACT

Building Information Modelling, BIM, represents the consistent and continuous use of digital information across the entire lifecycle of a built facility, including its design, construction and operation. In the last decade, digitalization and the improvement of internet solutions has transformed a wide range of industrial sectors, resulting in a tremendous increase in productivity, product quality and product variety. The BIM revolution has arisen in AEC industry also. In recent years, maybe all large vendors have published software products with powerful BIM functionalities and the concept that originated from 1980s has now become an industry practice.

In this paper I approach the topic of fully integrated BIM level 3 in road projects in Norway and particularly in a project that is under construction, "E39 Road Project Kristiansand Vest- Mandal Øst". The project started in 2018 and is predicted to finish in early 2022. The difference in this project, from other road projects that are being built in Norway, are the contractual requirements for digital tools and especially for the BIM requirements. The opportunities and challenges that follow this kind of transition in terms of information systems and data quality will be explored through this paper.

KEYWORDS

Lean and BIM, BIM level 3, integration, road projects.

INTRODUCTION

According to one study by the Association of German Chambers of Commerce and Industry (DIHK), 93% of companies agree that digitization will influence every one of their processes. Following this statement, also the AEC industry will face significant changes by digitalization and automatization in the near future. As part of the development BIM guidelines to be used in Norwegian commercial buildings were introduced in 2008 and a manual for implementation of BIM in road projects was introduced in 2015 (NPRA, 2015). This manual defines the requirements for BIM models in infrastructure projects.

In 2016, the Norwegian Parliament founded a public company called Nye Veier that plans, builds, operates and maintains public roads in parallel to the well established Norwegian Public Roads Administration. Among several contracts. Nye Veier has big ambitions to make infrastructure projects more effective in terms of construction and operation by using digital tools.

Nye Veier has signed a contract with a contractor to build the 20 km highway E39 Kristiansand Vest-Mandal Øst in the south of Norway. Nye Veier consider this contract as innovative in terms of BIM implementation through the project lifecycle. As showed by Fosse et al. (2016) – who uses the Lean-BIM interaction matrix developed by Sacks et al. (2010) – several lean effects namely waste reduction, value increase and continuous improvement can be achieved in a project as a result of BIM. A BIM Implementation Strategy was completely defined, and development steps of digital tools to be used were part of the contractual agreement.

Since BIM is defined in different ways around the world, a lot of uncertainty covered the contract and the implementation phase. The challenges were in terms of definition of BIM maturity levels to be delivered, digital tools that had to be developed, the contractual requirements to be fulfilled and the management approach to deliver something that would satisfy both parts.

The contractual requirement about BIM was to deliver fully integrated BIM at maturity level 3 like defined by Digital Build Britain (2015) by developing new digital solutions, new BIM platforms and to make the model accessible for everyone by using web-based platforms to upload, download and filter the necessary information in the model. However, there is not always a full alignment between BIM design manuals, contractual requirements in tenders and the final BIM (Fürstenberg and Lædre, 2019). This is not easy when working with different stakeholders which maintain different Quality and Management systems. Therefore, there is a need for a framework for information and data quality that will be part of the BIM solution. This is for the moment the most challenging part and where the industry is struggling in order to achieve optimal flow of information and have full understanding of model from everyone involved in the project. Information management like defined in ISO 19650 (2018) is essential for mitigationg the risk of information overflow. Information overflow produces waste like reported on in Womack and Jones (1996). Hicks (2007) mapped the seven types of waste to information management.

This paper documents how the road project "E39 Kristiansand Vest – Mandal Øst" will deliver BIM at maturity level 3 and uncover challenges related to quality of data in the BIM model and the information flow between directly involved stakeholders.

In line with this the following research questions are answered:

- What are the theoretical possibilities of level 3 Fully integrated BIM?
- What are challenges in accordance to data quality and information?
- To what extent can the theoretical possibilities be exploited in practice?

The study is limited in just one Norwegian public road project and the results are limited to experiences from the involved actors.

CASE STUDY DESCRIPTION AND METHOD

The research was carried out based on a literature review and a qualitative approach to conduct the in depth interviews for a case study. The literature review formed the basis for the theoretical background and was undertaken using the search engines like Oria and Google Scholar. Oria is a Norwegian University library resource. The research has been largely done using the keywords as: Building Information Modeling, Building

Information Management, BIM standards, BIM in infrastructure, BIM strategy, BIM integration, BIM maturity levels, BIM level 3.

In-depth interviews are very favorable method for collecting empirical data and in this case, the researcher has chosen nine individuals to answer the interviews .The range in organization chart and the position of the interviewers is chosen carefully to get the best results.

All interviews are semi-structured, and the researcher approached open conversations with the respondents. According to Jacobsen (2005), open individual interviews fit well when relatively few units are investigated and when we are interested in what each individual says. This is very good in our case where not more than 10 individuals will answer the questions. It was possible to interview a larger number of individuals, but the researcher is interested to interview people that are directly related to usage of BIM. The research has tried to find the most important individuals that work with BIM and are directly related to the development of new tools for the exact requirements of the particular contract. Therefore, the focus has been on getting each one off the interview subjects to share as much of their experience in the topic as possible.

The interviews have all been conducted in person and the voice has been recorded with permission of respondent and later transcribed. The interview guide had been provided via email before the interview meeting, so the respondent had time to be informed about the topic and purpose of the study. In this way you can lose the effect of a surprise answer but in the other hand the interview is more formal. The interviews have been completed in about 40 to 50 minutes, depending on the amount of information the respondent has about the topic or the level of interest. The study included tender documents, contracts and project plans.

In the Table 1 are described the positions of the interview respondents.

Table 1: Case overview and the respective interviewee's position (C = Contractor, O = Owner Organization)

Project Name	Description	Respondents Position
E39 Road Project "Kristiansand Vest – Mandal Øst"	Four lane highway with a total cost of around 5 Billion NOK	BIM Coordinator, Developer [C] Assistant Quality Manager [C] Quality Manager [C] Quality Engineer [C] Construction Manager [O] Quality Manager [C] BIM Coordinator [C, O] Quality Check [C]

THEORETICAL BACKGROUND

BIM AND MATURITY LEVELS

Building Information Modelling is use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions. (ISO, 2018). BIM typically includes the 3-D geometry of the building

components at a defined level of detail. In addition, it also comprises non-physical objects, such as spaces and zones. Objects are typically associated with a well-defined set of semantic information, such as the component type, materials, technical properties, or costs, as well as the relationships between the components and other physical or logical entities. (A. Borrmann et al. 2018)

BIM is construction industry trend in both infrastructure and building, from concept design to construction process, but the concept can be used in retrofitting, recycling and demolition also. The opportunities that BIM offers today are endless. The use of other technologies as geolocation, laser scanning technology, the usage of API (Application Programming Interface) that makes possible to transfer data from one software to another and RPA (Robot Process Automation) makes BIM a game-changing concept if the right combination of investment and effort is given to develop the right tools for the right purpose.

Digital Built Britain (2015) has divided BIM implementation in different maturity levels as following

- BIM level 0

  Level 0 is based on 2D CAD drawings and on paper-based drawings. The information is transferred via conventional methods as email, fax and handed over in person.

- BIM level 1

  Level 1 BIM consists on 2D CAD drawings and 3D models for complex designs. The coordination between different software for structure calculations and for further in construction phase is not possible.

- BIM level 2

  Level 2 BIM is described as collaborative BIM. Federated model information is shared within a Common Data Environment. Level 2 is based on use of organized 3D tools where every discipline uses specific BIM tools with specific associated property data. 4D (time) and 5D or cost controlled engineering is performed using calculation systems that utilize model data and are integrated with BIM via proprietary interface.

- BIM level 3 and beyond

The jump from level 2 to level 3 is a big step to take according to Digital Built Britain(2015), which is acknowledged in the digital built strategy by defining four distinct delivery phase scales. These stages are illustrated in figure Figure 1 below. Digital Built Britain define the maturity levels more according the level of digitalization, and their definition should not be mixed with the one used by for example Svalestuen et al. (2018) or Styrvold et al. (2019), who defines BIM maturity according to the level of development, i.e. how detailed the BIM is.

BIM LEVEL 3

Level 3 BIM is based on the concept of fully integrated BIM. It is based on the implementation of BIG BIM, OPEN BIM and ISO standards for information flow, data exchange and process descriptions. These models are used throughout the entire lifecycle.

Cloud Services and web-based solutions are used to access project information, and the data is continuously and consistently maintained over asset life cycle (A. Borrman et. al 2018).

Up to today we have not seen may infrastructure projects with BIM usage in all life cycle phases with all information integrated in one model. Especially, when we speak about operational phase, BIM is used very little or not at all in most of the cases. And this comes from lack of integration or lack of information quality in the model itself. Sometimes the lack of standards and procedures make the usage of BIM in the operational phase harder and not efficient.

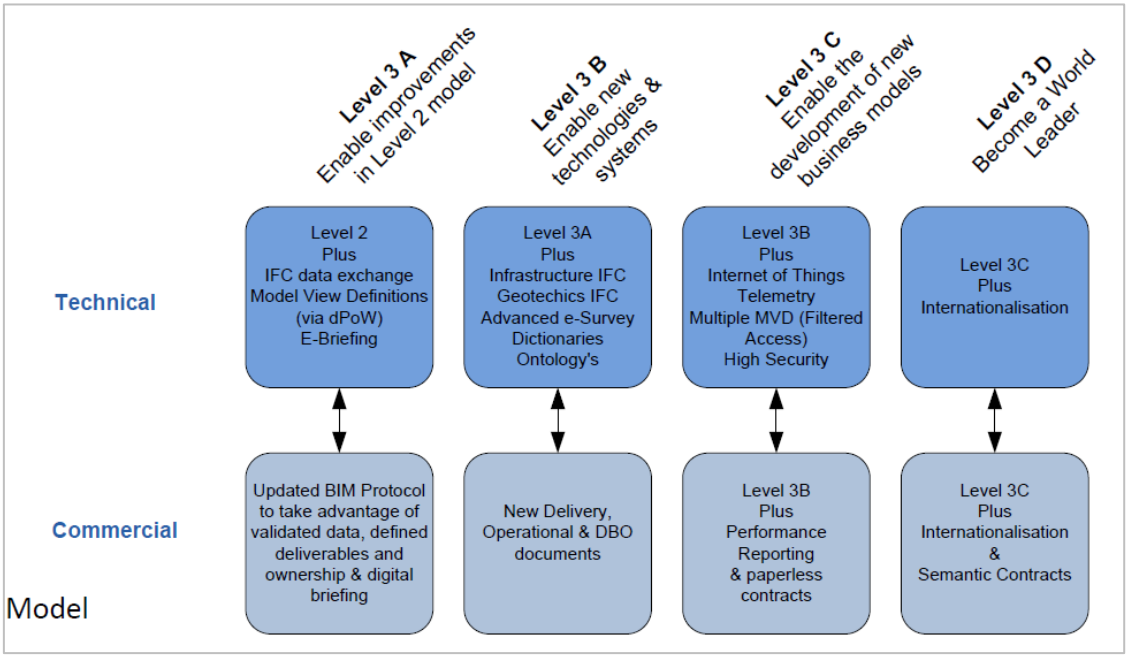

Figure. 1 **.** Level 3 BIM stages (Figure 5 in Digital Built Britain, *2015*)

BIM in operation phase is not new as a concept but implementation through asset lifecycle has very few examples that have been successful. BIM has been widely adopted by the construction sector, though Facility Management (FM) is still based on a variety of disparate FM systems. The operational phase requires well-structured information about the building asset. Therefore, a BIM model filled with the multifarious information from the pre-use phase ought to be exploited through its integration with existing FM systems. (Nical, et al., 2016)

From the life cycle costs (LCC) perspective, the operational phase of construction project is often considered the most important. Normally, the operational phase takes up most of the life span of projects in construction industry. With the arrival of BIM, industry was given an opportunity to utilize information models during operational phase. Such models increase quality and efficiency of operational phase, and the possibility to reduce costs. (Per Matejka. et al 2016)

Parsanezhad (2015) sets out that information management must be based on collection, analysis and flow of information across the multidisciplinary environment throughout the life-cycle of the building asset. Such a holistic approach is defined by the

buildingSMART alliance, as a "business process for generating and leveraging building data to design, construct and operate the building during its lifecycle". That means the model should be accessible throughout the whole asset lifecycle, from design to operation phase. Nye Veier test currently a system for Asset Information Modelling (AIM) which complies with the ISO 19650 standard.

The IFC (Industrial Foundation Class) files come in help by standardizing the model structure including descriptions of object in the model and the information uploaded. By the use of IFC and other standandarized methodologies to process information in the project together with a clear BIM impelementation strategy will the contractor or the organization that is behind implementation of that investment profit in terms of performance, reduced cost, increased information flow, etc.

Currently, attempts to use BIM only in late phases should be considered as improper BIM utilization in a project. However, many construction projects will surely continue to exist in the near future, even though BIM was not used from the beginning. (Matejka et al., 2016)

In the last years technological advancements are outstanding and in addition to commercial BIM softwares, are now being developed cloud services and web-based solutions. This can change rules of the game by providing completely open access into model by using every computer and mobile device to information related to different phases of the project. This can lead to projects where BIM is seen as something necessary also in operational phase and by this the required integration can be achieved.

FINDINGS AND DISCUSSION

Since the topic is new in terms of implementation in road projects for all of the respondents it was the first or the second project that they work with BIM and for all of the respondents it was the first project that they worked which was trying to deliver fully integrated BIM maturity level 3.

The questions asked to the respondents were based on the different stages of the project from design to operation phase and were asked about their personal experiences related to this new level of integration.

BIM in design phase was conducted by using the standards given from Norwegian Road Authority and of BIM handbook manual V770 published in 2015. In addition is agreed to use VDC (Virtual Design and Construction) approach including ICE (Integrated Concurrent Engineering) and LPS (Last planner System). The BIM model is the center of information in communication between design team and people working in the field. This increases collaboration and makes easier to understand the model by feeling the 1:1 scale. It is observed that stakeholders in project use BIM model to communicate through BIM platforms as Solibri using BIM Collaboration Files or BCF, making easier to explain where the problem is and keep track if the problem is solved. All respondents agree that the BIM model has improved information flow between design team and people in the field.

One thing that concerns most of the respondents is the late approval of the models from Norwegian Pubic Road Authority creating a lot of frustration for the team in the field and making the process very bureaucratic causing delay in production. Even the MMI (Model Maturity Index) that follows the use of IFC files and data packages to be delivered are approved early in the project they keep changing and the Norwegian Public

Road Authority does not keep in the same rhythm with design team. The respondents agree that this process has a lot of room for improvements.

Overall, however, BIM in design seems to be contributing to the simplification of work among users and has led to a better information flow. The challenges according to errors and deviations found in the models are not big and are solved in a short timeframe and the respondents agree that the goal of delivering fully "Drawing Free" model is fulfilled since everyone in the project has access to model using PC or mobile devices but "Paper free" concept in terms of all documentation needed to build the road is not yet fulfilled and a lot documentation has to be uploaded manually.

BIM in construction phase is conducted by the extensive use of digital tools and softwares that provide a lot of possibilities to integrate with each other and provide much faster ways to receive and upload information.

BIM in production is relatively new in infrastructure project and this is supported from interviews when asked if the BIM concept is being used effectively in this project. They answered that they feel that BIM concept as they understand is being used better in design phase than in production. BIM development team in the main contractor, said that they are checking the possibilities to start using "DALUX", a system to fill checklist and upload them automatically in the cloud solution but up to now they are still in the planning phase. The use of "Infrakit" and "Gemini" for ground works has increased accuracy and helped for better control of logistic in the construction site. Some of the documentation needed to document the quality of ground works is generated directly from Infrakit and then uploaded in web-based solution.

Synergi Life, the program to rapport deviations in quality and HSE is actively being used and it is fully integrated in the cloud solution by providing in real time where deviation occur, how dangerous they are in terms of personal safety and environment. In addition, the same program is used to rapport quality deviations but some of the respondents answer that more integration is needed to complete the whole panorama since deviations are attributed to one area without giving descriptions in detail where in construction or where in the ground works has happened the deviation. This makes harder for Quality Engineers to keep track and for the Client to check if these deviations are fixed.

Overall, BIM in construction phase is being used actively and not just the 3D model but most of the digital tools like Infrakit, Gemini, Synergi Life and Dalux are integrated in the cloud solution ISY Project. Cloud solution is being used in meetings between subcontractors to coordinate work and most of the documentations is accessed from there. Even that the respondents agree that the cloud solution is very heavy to open in normal PC and it requires a very long time to filter the information, this digital tool is a very good step toward fully integrated BIM and by learning from mistakes can create a framework for future jobs. BIM development team in the contractor part agrees that the cloud solution has some problems, but this is normal for something that is still under development.

BIM in operation phase will be provided by the cloud solution developed from the main contractor. It appears that all the respondent have an understanding that the BIM model must be a living object and by this they support A.Borremann when he describes that BIM forms by himself a living object that should be used through the lifecycle of the project.

By making operational the cloud solution where it integrates the 3D model for different disciplines, documentations about the quality of work done, documentations about the impact in environment and other support documentation, the main contractor is

another step toward fully integrated BIM and the use of models throughout assets lifecycle. When asked if contractor can deliver fully integrated BIM in this project the respondents agreed that it is in the right path, but this is the first project that is trying to achieve this in this huge scale with a complex project as E39, so they are sceptic about the final product.

Since no other examples were provided from respondents about another project that has delivered the same BIM maturity level, the researcher can assume that the expectations can be lower than what project is delivering. This relates to the fact that most of the respondents were not familiar with contractual documents about BIM implementation strategy and some of the respondents were not familiar with routines and procedures about information channels in project and usage of BIM.

All respondents state that BIM must continue to be used through the operational phase and by this supporting Sanchez et al. (2014), on how the life cycle of BIM models can continue into the management part of a road project. Overall, the respondents agree that project has made a huge step toward fully integrated BIM by offering a cloud solution to be used after the projects is constructed and by creating a standardized solution about information flow in the project.

The researcher points out that people directly connected with usage of BIM are not very familiar with routines and contractual documents agreed for BIM usage in the project during production phase and future for operational phase, but they have high interest to learn and are very positive and supportive for the technology.

CONCLUSIONS

In this paper, the level of implementation of BIM maturity level 3 in a road project being constructed in south of Norway was investigated. The results showed that the contractor has mainly been able to achieve the requirements in the contract but it has also a lot of room for improvements. By developing new tools and using the state of the art digital tools already in the market they have achieved better performance and the staff that is working in the projects agrees that the information flow in this project is much better than in the other projects they have been working.

Even that the level of achievement is different we identified the **Lean principles**, waste reductions and improved reliability in all project phases.

BIM in design phase. The study conducted, shows that those involved in usage of BIM in design phase are largely positive for development of new technology and this can be related to the extended use of software that support 3D models and a longer experience with the usage of BIM concept. The research shows that for the people working with BIM in design it is important to have a framework or a standardized way of working and this is partially achieved by introduction of standards like V770 BIM handbook and ISO standards related to BIM

When it comes to data exchange and collaboration, it appears that BIM as a concept is used very actively in the design phase by using collaboration files like BCF and meetings using VDC approach where BIM model is in the center of discussion. In terms of collaboration and contractor involvement early in the design phase, respondents from subcontractors pointed out that they were not so involved in the design process and this has caused challenges with procurement of materials and finding suppliers for some solutions that they were not prepared when they signed the contract. Another important

thing that subcontractors points out is the delay in approving of work models from Norwegian Public Road Authority. This has caused frustration and economical costs for both Main Contractor and subcontractors.

The research shows that the goal of delivering a "Drawing free" project is achieved but the concept "Paper free" has a lot of room for improvement in terms of documentation for quality of works done and documentation to be delivered for the usage in operation phase. technology.

Overall, BIM in design seems to be contributing to the simplification of work among users and has led to a better information flow but the research finds out that the respondent would feel better with a standardized solution that the whole industry uses instead that different contractors developing own solutions using intern standards. This means that in terms of theoretical possibilities the respondents are aware that the possibilities are big but the project is using to some extent these possibilities in practice due to restrictions in digital tools developed and the lack of experience.

BIM in construction phase. This level of integration of BIM in production phase for infrastructure projects is quite new and the respondents agree with this. The research finds out that even the project E39 is trying to deliver one of the most integrated BIM systems, people working in this project and the end users of the system in fact have little or no experience with BIM in infrastructure projects. When it comes to integration of digital tools together, offering a simple and centralized solution, the research shows that this is partially achieved by making operational the cloud solution, but still a lot of tools are yet not integrated, and the system is still under development.

Overall, BIM in construction phase is being used actively and the users are positive for the effects not just by using 3D model but most of the digital tools like Infrakit, Gemini, Synergi Life and Dalux. Some of these tools are fully integrated and some under process to be integrated in in the cloud solution ISY Project. In terms of data exchange and information flow the cloud solution is being used in meetings between subcontractors to coordinate work and most of the documentations is accessed from there. There is no doubt that projects that utilizes the potential of fully integrated BIM can save time and money. It is also positive that errors found in the project are easily changed for a low cost compared to conventional 2D projects.

The research shows that the concept of fully integrated BIM in the project is not yet fully achieved, especially for production phase, but it is a very good step toward the future.

BIM in operation phase. In the E39 project this problem is being addressed and a cloud solution with integration possibilities is introduced and is now operational. The integration of 3D model with documentation and with as built models using scanning technology is now partially in use.

The documentation about product data sheets, checklist for works done, documentation related to impacts in environment and deviations in quality are being uploaded in the cloud solution and automatically connected to the object related to that checklist using a metadata system. This gives the possibility the next operation or maintenance company to access the documentation and find the necessary information directly in this cloud solution.

We identified the **Lean principles** waste reductions and improved reliability in a BIM level 3 Project. However, there are two main obstacles for using the full potential that lies within the digitalization of the AEC industry: 1) the exixting software tools are not completely adapted to digitalization and 2) external stakeholders that slow down the production.

Since the project is in the middle of production phase we can just assume the practical benefits of the system for the operation phase, but we can not be sure that all described above would be a reality.
Finally, the research, throughout interviews, come to conclusion that the project will be able to partially deliver fully integrated BIM in this project, but it will be a good example and they could learn from mistakes to deliver a better BIM system for the next project.

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