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Abstract

In recent years, many industries have effectively used digitalization to attain control, and the term has been on the agenda of organizations for years. Digitalization and digital transformation are predicted to be crucial for leaders to plan for and implement across industries for the years to come. In the rapidly accelerating industrial environment, there is a widespread recognition that the role of digitalization is shifting – from a buzzword that everyone is questioning, to now be a catalyst of innovation and disruption. Due to this heavy focus on digital technologies, decisions must be made to avoid the risk of falling prey to competitors and disruptors.

Aibel AS has been awarded a major EPC contract by the SSE Renewables and Equinor consortium to deliver 2(3) HVDC platforms for the Dogger Bank project in the UK part of the North Sea. The converter platforms will be a part of the world's largest offshore wind farm, with a combined capacity of up to 3,6 GW, and are expected to produce enough energy to power the equivalent of 4.5 million UK homes. Through years of experience in complex offshore projects, Aibel knows what it takes to be profitable in such a project. However, the potential of digitalization and innovative digital technology could improve project profitability and increase their competitiveness for future contracts.

This thesis investigates how digitalization, digital technologies, and tools can be used to streamline and create value in an offshore wind platform project. It explores these new technologies' relevance to EPC projects in general and recommends how they can be implemented successfully. In addition, the study considers how digital change management affects technology implementation. To answer these objectives, the thesis addresses the following research questions:

RQ1: Which digital technologies and tools can be implemented to create value and streamline an offshore wind platform project.
RQ2: How could these initiatives and technologies be successfully implemented.

The findings suggest that solutions like extended reality and smart devices in field operations, along with greater connectivity through digital yards, twins, and workplaces, allow more remote operations that are highly valuable. When combined with construction automation technologies, and gradually also artificial intelligence and machine learning, EPC projects can be enhanced in most areas with the aid of digital technology. The analysis also highlights the importance of digital change management in the facilitation and how the implementation process affects the profitability and success of technologies.

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Preface

This thesis is the concluding work of my Master of Science in Industrial Economics, and the research presented is conducted for the Department of Safety, Economics, and Planning. It was written in collaboration with Aibel AS during my final semester at the University of Stavanger in the spring of 2020.

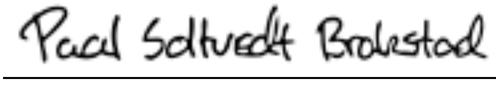
I wish to express my deepest gratitude to Per Tore Larsen (Project Director at Aibel AS) for making it possible to collaborate with Aibel on this project, as well as his hospitality, desire to contribute and not least for sharing his time and knowledge despite a particularly demanding situation during the COVID-19 pandemic.

I want to extend my gratefulness to Aibel AS for providing me with an office both in Haugesund and Stavanger (although restrictions due to COVID-19 shut down the offices), and also to all interviewees and conversations with Aibel employees throughout the work of my thesis.

I would also like to thank my supervisor and professor Dina Zhenisovna Kairbekova at the University of Stavanger for her inputs and guidance to the work of my thesis.

Finally, my family, friends, and girlfriend Elise deserve my appreciation for their patience, understanding, and support during the past few months.

Stavanger, June 15, 2019



(Paal Soltvedt Brakstad)

Abbreviations and Acronyms

AM	Additive Manufacturing
API	Application Programming Interface
AI	Artificial Intelligence
AR	Augmented Reality
AuT	Autonomous Things
BIM	Building Information Modelling
CAD	Computer Aided Design
E&C	Engineering and Construction
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement and Construction Management
EPCI	Engineering, Procurement, Construction and Installation
EIS	Executive Information System
4IR	Fourth Industrial Revolution
HSE	Health and Safety Executive
HVDC	High Voltage Direct Current
IIoT	Industrial Internet of Things
IoT	Internet of Things
LSTK	Lump Sum Turnkey
MR	Mixed Reality
O&M	Operations and Maintenance
PDMS	Plant Design Management System
QA	Quality Assurance
ROI	Return on Investment
RPA	Robotic Process Automation
SOV	Service Operations Vessel
TIC	Total Installed Cost
VR	Virtual Reality

Section 1: Project Background & Definitions

1 Introduction

Since the beginning of this century, digitalization has become a highly used buzzword that everyone is talking about. It has become something companies have to consider and deal with to be competitive. Connectivity and technology create countless opportunities for businesses and has proven its potential to empower millions of people. Due to the continued exponential growth of digital technology, the ability to leverage digitalization is critical for well-established companies, now and in the future.

Digitization, digitalization, digital transformation, industry 4.0, and the fourth industrial revolution are all terms that are increasingly popular throughout the industry. There are countless different definitions of what these terms truly mean, which has resulted in interchangeably use and ambiguous meaning to most people. The term digitalization originated in the mid-1900s and was related to the development of the first electronic computer. At first, it only referred to number generation, that is, the transformation of analog information into discrete number sizes that were represented in such a way that they could be processed by the new machines (Dvergsdal, Digitalisering, 2019).

Since then, technology and the ability to use the information have evolved tremendously, and today, the term has gained a broader sense. Now, it is also about using information technology to change the way we do things and to create new opportunities and enhancements. There is no recipe for how to succeed with digitalization, and it is also challenging to get an overview of the consequences, partly because the technologies are consistently being used in new contexts, and because the effect often arises in interaction with other factors. Also, when adding all sorts of related concepts, as mentioned above, it is no wonder why the use of digitalization is a complex process. When a topic or a word is not fully understood, it is likely to be dismissed, which is why it is time to treat digitalization and digital transformation like any other vital business process. Defining goals and strategies enables organizations to both create long-term value and the opportunity to take the lead in rapidly changing industries. Now is the time to make the necessary investments in order to not fall prey to competitors during this digital revolution.

EPC contracts is a widely used contract model in the Norwegian offshore industry in recent years. The model means that suppliers have overall responsibility from design to construction and delivery. The name denotes the main tasks of the supplier; Engineering, Procurement, and Construction. Comprehensive EPC contracts are often referred to as turn-key contracts where operating companies are expected to have turnkey products or components delivered. According to a joint study of ProjectTeam, Tiba, Maexpartners, M8International and D1g1tal AGENDA (2019), the EPC Industry has, through the last ten to 20 years, been suffering from low productivity growth, low degree of digitalization, low investment in R&D. Further, it argues that the positive evolution that other industries have experienced due to increased use of digital technology has yet to be accomplished in this industry. Nowadays, terms like EPC 4.0 and industry 4.0 are expected to replace the outdated traditional EPC business model and decrease CAPEX and increase project profitability. (Ritsche, Wagner, Schlemmer, Steinkamp, & Valnion, 2019)

Aibel AS continues to succeed in winning contracts in the up and coming offshore wind industry, and projects within renewable energy are becoming a more substantial part of their project portfolio. Wind energy is widely viewed as one of the most important renewable energy sources that will make up the new energy mix to relieve the world's dependency on fossil fuels. The industry has seen rapid technological development, with increasingly larger turbines and annual energy output per turbine. With clarifying the benefits of, and implementing digital technologies, as well as succeeding in the digital transformation, Aibel will continue to increase their already significant position in the offshore wind industry.

This thesis conducts a case study of Aibel AS, a leading international service company in the oil, gas and offshore wind industry, to identify and establish an overview of digital technologies that can help streamline their offshore wind platform project Dogger Bank. It builds on the assumption that for this project, Aibel has excellent opportunities to utilize technology to improve efficiency and increase profitability. Besides, the thesis will look at the implementation and the technologies' relevance towards similar EPC contracts in the future.

1.1 Project Background

Aibel AS has been awarded a major contract by the SSE Renewables and Equinor consortium to deliver 2(3) HVDC platforms for the Dogger Bank project in the UK part of the North Sea. The converter platforms will be a part of the world's largest offshore wind farm with a combined capacity of up to 3,6 GW and are expected to produce enough clean, low-carbon energy to power the equivalent of 4.5 million UK homes annually. Each of the platforms are capable of converting 1,2GW, 66kV AC power to ± 320kV DC power. The converting system shall be based upon an ABB HVDC Light system. Each platform will have a single HVDC transmission link connection between the wind turbine arrays and the onshore transmission network (Doggerbank, Aibel and ABB to deliver power grid solution to Dogger Bank Wind Farms, 2019). Beneath is a list with more detailed information about the project: (Doggerbank, Doggerbank, 2020):

A 50:50 joint venture between Equinor and SSE Renewables.
Consent was granted in 2015.
Located in the North Sea, approximately 130km from the Yorkshire Coast.
Water depth ranges from 20m to 35m.
The project is expected to be operational in 2023.
The WTGs will be installed on monopile foundations.
The transmission system will be High Voltage Direct Current due to long distance to the grid connection point.
The contract for difference is a 15-year contract, which will be indexed for inflation.
Aibel will deliver two high voltage direct current offshore converter platforms for Dogger Bank A and Dogger Bank B with an option for a third platform for Dogger Bank C.
ABB will supply its HVDC Light converter system, connecting the offshore wind farm to the UK power grid.
GE Renewable Energy will supply Dogger Bank with its ground-breaking Haliade-X turbine, bringing the world's most powerful wind turbine to the wind farm. The final number of turbines to be installed is yet to be confirmed in due course.
Operations and Maintenance (O&M) Base is planned to be located at the Port of Tyne

Table 1 - General information about Dogger Bank Wind Farms

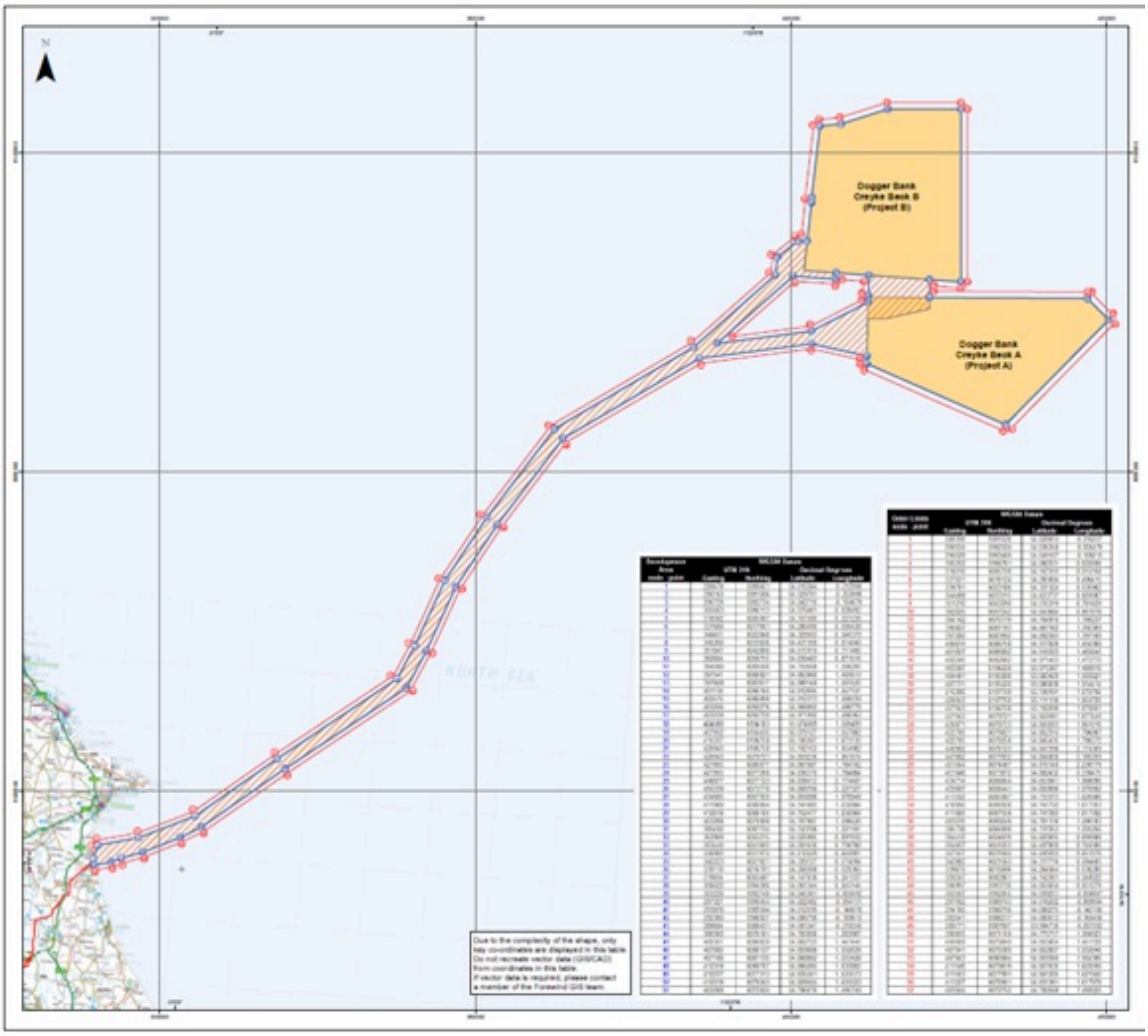


Figure 1 - Platform locations

The Dogger Bank A and B platforms will be located in the historic Doggerland area on the UK sector, as shown above, where Dogger Bank A is the furthest south of the two. They will have a steel jacket substructure with piles in each of the four legs. The platform topside is designed to contain the HVDC/HVAC equipment, including secondary supporting systems and platform utility systems. The design of the topside is based upon space requirements for the equipment, including maintenance access. The platforms will be mated offshore and operated onshore; thus, no residential quarters or helicopter decks are present. They are designed as a Type A Normally Unmanned installation with yearly maintenance campaigns. Access to the platforms will via SOV's.

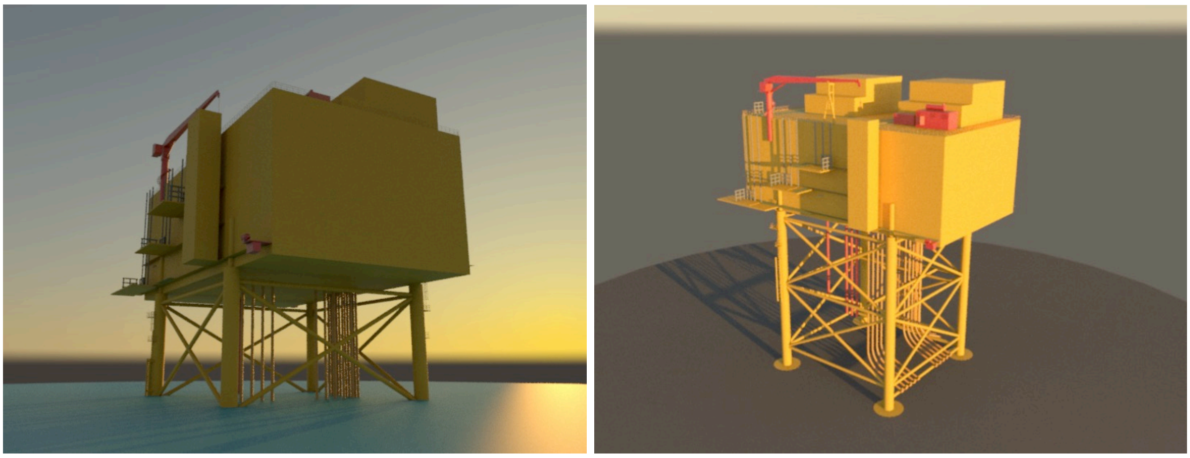


Figure 2 - HVDC Converter Platform illustration

The design life of the structure is 25 years. MSL is 27m - Platform height above MSL: 21m - Air gap to 100-year diffracted crest > 2.0m Topside figures: - Size: 65 x 37,7 meters - Height: 33,15 meters Jacket figures: - Size: 37,7 x 37,7 meters - Height: 48 meters

Table 2 - Key figures for the platform solution concept

To capitalize and further enhance the digitalization initiatives in the organization, Aibel's project management team has proposed the following objectives for the digital investments in the project: *Better collaboration, reduce cost, better information sharing, increase efficiency, increase quality and introduce new technology.*

The contract awarded to Aibel is a lump sum turnkey (LSTK) EPC contract. As the contract compensation is a lump sum format, all risk of cost overruns is on Aibel's side, and they will do their utmost to better efficiency and reduce costs to increase project margin. Subsequently, this means that every working hour or penny reduced in the project directly affects the bottom line of Aibel. The company aims to be a frontrunner within digitalization and has consequently provided significant funding to digitalization initiatives in the project.

1.2 Objectives and Limitations

The scope of this thesis is to evaluate how digitalization, digital technologies, and tools can be used to streamline and create value in an offshore wind platform project. Additionally, it explores these new technologies' relevance to EPC projects in general and recommends how they can be implemented successfully. The six objectives mentioned above will be the foundation for further research throughout this thesis, with the ultimate goal of fulfilling or generate a better understanding of how to fulfill these goals. Both past literatures, public and internal documents will be thoroughly examined and presented to reach this objective. Also, a qualitative analysis through interviews with relevant personnel in Aibel will be conducted to improve the quality of data and gain useful input to digitalization approach and utilization in this and future projects. By doing this, the company's and the technologies' improvement potential is easier to explore, and their effect on an EPC project is easier to determine. With this in mind, the thesis addresses the following research questions:

RQ1: Which digital technologies and tools can be implemented to create value and streamline an offshore wind platform project.

RQ2: How could these initiatives and technologies be successfully implemented.

Because digital technologies and tools are somewhat different in utilization and extent, the range of benefits varies in between them. Whether they have collaborative, cost-reducing, information sharing, streamlining, quality improvement benefits, or even all of them depends on the actual technology and will be examined to varying degrees. With the contract compensation format in mind, it is the cost-reducing and efficiency-enhancing initiatives that will have the most significant impact on Aibel's profitability and will thus be the most focused objectives in this thesis. It is in the authors believe that increased quality and improved collaboration are potential positive side effects of implementing cost-reducing and efficiency-enhancing technologies. Another limitation is that the digital technologies explored have been limited to those derived from the project charter of Aibel and those with specific relevance to EPC projects. Examining and evaluating all existing digital technologies was too vast to explore thoroughly. Finally, the complexity of digital technologies from an IT perspective is beyond the writer's expertise and will not be investigated.

1.3 Structure

The thesis is organized into five sections, each containing chapters, and subchapters. To begin with, section 1 provides the theoretical groundwork for the paper. In addition to including objectives, limitations, method, and structure, section 1 introduces the reader to the Dogger Bank project, the EPC model, digitalization, and associated buzzwords. Then, section 2 further investigates and explains EPC contracts, with historical background, digitalization, EPC 4.0, and the future of EPC projects, to further establish an understanding of what type of project and challenges Aibel is facing in the Dogger Bank project. In section 3, relevant technologies are analyzed in terms of their technical maturity and their potential in the industry. Following this screening of technologies is the evaluation of the digital initiatives in section 4. Chapter 6 start the section by explaining how digital change management affects the implementation of new disruptive technologies, followed by an implementation guideline in chapter 7. Chapter 8 provides some example of realizing the value of digital investments before chapter 9 summarize digitalization improvements. Finally, the last section comprises a general discussion around the main topics of the thesis and a conclusion to the work that has been completed.

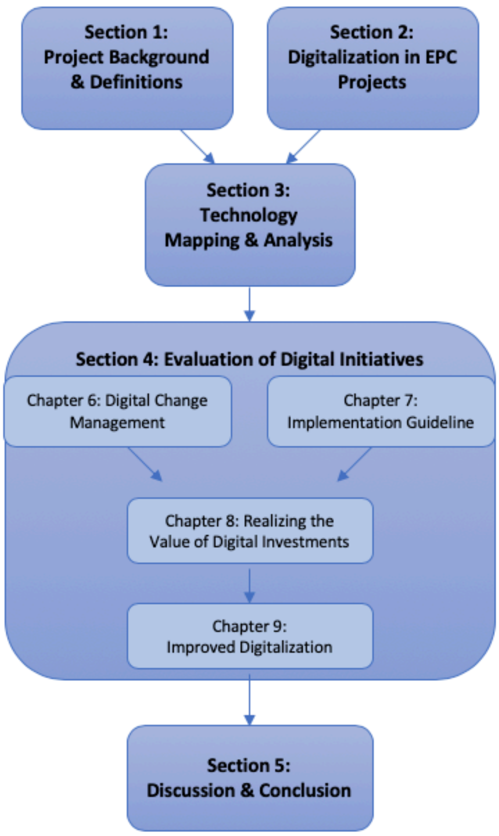


Figure 3 - Thesis structure

1.4 Methodology

The methodology used in this thesis was initially a comprehensive literature review using web-articles, reports, videos and books to explore and establish an overview of digitalization and related terminologies. Further, the literature review included research into EPC as a contract strategy and the adoption of digitalization in EPC projects. In addition to publicly available literature, documents from Aibel with Dogger Bank project details and digitalization approach was studied. Simultaneously as this review was conducted, the author visited Aibel's offices in Haugesund on several occasions, where relevant discussions occurred and presentations from Aibel personnel were presented as input to the thesis. Together this review of public literature, internal documents, and meetings with Aibel formed the foundation for the thesis and helped formulate the research questions and the structure of the thesis.

Secondly, interviews with key personnel in Aibel was conducted to get better insights into the use of digital technology and opinions around digitalization in the company. In collaboration with the supervisor, a collection of interview objects was selected based on relevance and experience with the topics to be deliberated. All interview objects were from different departments, projects, and hierarchical positions and had key insights because of their hands-on experience from working with digital technology in Aibel. The specific composition of interview objects was gathered to obtain different views on the questions asked, and thus develop a better foundation for subsequent data analysis. A semi-structured interview approach was chosen since it favors fewer questions with long discussions and increasing the likelihood of more subjective, honest, and detailed answers. Another key benefit from this type of interview is that it opens up for supplementary information both within the exact question, but also if the interview object has something relevant to add outside the scope of the question. The latter proved its significant value as one of the main findings in this paper is based on this supplementary information from the interviews.

The conversations with Aibel personnel were completely anonymous. Names and other sensitive information obtained throughout the interviews was not used at any point in this thesis, to create a safe atmosphere and allow for honest and subjective opinions. An overview of the interviewees is shown in the table below.

Interviewee Number	Date	Relevance (Job Title)	Duration (min)	Number of words Transcribed
1	04.05.20	Project Director	62	4872
2	28.04.20	Project IT Manager	36	3394
3	23.04.20	Digitalization Manager Aibel	56	5376
4	28.04.20	Performance Improvement Manager	42	3444
5	23.04.20	Yard Manager - Infrastructure	49	4258
6	27.04.20	Construction Manager	36	2925

Table 3 - Overview of the sampled interview objects (all interviews were conducted through Microsoft Teams due to office restrictions during the COVID-19 pandemic).

In addition to discussing digitalization and the use of digital technologies, the interviews also revealed that several preconditions for success and how these new technologies should be adequately implemented could be useful to establish. Therefore, a significant part of the analysis in section 4 was to emphasize the importance of digital change management and to create a guideline on how to implement these new digital technologies discussed later in the same section. Throughout this qualitative research, data collection and analysis have been iterative and happening at the same time, resulting in much back and forth between the two to assure the quality of the findings.

2 Theory – Explaining the Buzzwords

Digitization, digitalization, and digital transformation are some of the most commonly used catchphrases in today's industries. These terms have vague meanings to most people and have many different interpretations. The persistent confusion regarding the differences between them makes it hard for businesses to cope with the required changes that they are making or should be making to stay competitive in the industry. This section focuses on developing a broader understanding of the many different terms related to digitalization to a point where a theoretical foundation is established.

2.1 Digitization – Making Things Digital

Digitization is where it all began. The process of converting data from analog to digital is digitization. More precisely, Oxford Learner's Dictionaries explains digitization as the process of changing data into a digital form that can be easily read and processed by a computer (Oxford Learner's Dictionaries, 2020). In this digital form, information is organized into discrete units of data, called bits, that can be separately addressed in multiple-bit groups called bytes. Computers and other digital devices can process this binary data, which makes it easier to preserve, access, and share information than with analog data. Digitization is still used in several meanings, but today it is mainly used in the context of digitizing business processes and introducing paperless solutions (Bloomberg, 2018). As DNV GL highlights in their report on Digitalization and the Future of Energy, digitization is about making things digital, without any different-in-kind changes to the process itself (DNVGL, 2019).

2.2 Digitalization – Business Opportunities Created by Digitization

Digitalization and digitization are closely associated and often used interchangeably. The difference between the two is that digitalization is the process of leveraging digitization to improve business processes. It utilizes digital technologies and data to change a business process and enhance efficiency, revenue, and create a digital foundation as the core. The word itself is a verb that denotes a transformative process where something becomes digital – a digital process, a digital organization, or a digital society (Dvergsdal, Digitalisering, 2019).

In the organizational context, it can be defined as the transformation from IT being a support tool in the business to being part of its DNA. This means that business models and practices, as well as organization and processes, are designed to leverage today's and tomorrow's technology (Sannes & Andersen, 2016). In other words, methods are converted to be more efficient, productive, and profitable. According to EY, digitalization means that companies are refining their horizontal and vertical value chains through the use of digital technology. The horizontal value chains involve the suppliers and customers, while the vertical includes operations such as marketing, sales, product development, procurement, manufacturing, and distribution, that are linked and integrated via digital information flow (Geissbauer, Vedso, & Schrauf, 2016).

I-SCOOP (2018) takes a broader approach and explains that digitalization means turning interactions, communications, business functions, and business models into (more) digital ones. This often covers a mix of digital and physical as in omnichannel customer service, integrated marketing, or smart manufacturing with a mix of autonomous, semi-autonomous, and manual operations (I-Scoop, 2018). Depending on different perspectives, digitalization can be understood or defined in three different ways; Firstly, businesses define digitalization as enabling, improving, or transforming business operations, functions, models, or activities by leveraging digital technologies with a specific benefit in mind. Secondly, digitalization of a particular environment or area of business, such as a digital workplace, could mean something different. A digital workplace is more than just reducing the use of paper. Enabling personnel to work more digitally through the use of mobile devices or other technologies creates new opportunities to engage differently. This requires more than just digitized data, specifying that digitalization is more than just implementing new technologies without the necessary knowledge of how to use it. A third approach to what digitalization means goes beyond business and refers to the ongoing adoption of digital technologies across all possible societal and human activities (I-Scoop, 2018).

2.3 Digital Transformation - Business Models with Digitalization

Digital transformation looks different for every company; hence it can be hard to pinpoint a definition that applies to all. It is imperative for all businesses throughout industries, and seemingly, everyone has to successfully digital transform to remain competitive and relevant as the world becomes increasingly digital. DNV GL explains digital transformation as the use of digital technologies to change business models to provide new revenue and value-producing opportunities (DNVGL, 2019).

According to Siemens (2020), on the other hand, digital transformation refers to the adoption of data and digital solutions for business activities and processes by the adoption of re-imagined processes that take full advantage of well-defined digital strategies (Siemens, Digital Transformation, 2020). Both of these definitions sound quite similar to digitalization, and there are many similarities between the definitions of the two terms in the literature. Nevertheless, these words are fast-moving, global megatrends that are fundamentally changing current value chains across industries and public sectors. While digitalization is about taking numerous of digital technologies into use, digital transformation is the combined business value and cultural change that is required to take full benefit from these technologies.

It is central to point out that it is not only companies and organizations that experience a digital transformation, whole industries – and even individuals' behavior and approach to communication are influenced by the rapid digital development. As stated by the Norwegian Digitalization Agency, it is often not enough to digitize or digitalize today's services and processes. To meet higher demands for efficient, user-friendly, and open management, new ways of thinking and new solutions to social missions have to be established. In this transformation, one must do a combination of three things; stop doing something, doing something new, and doing old things in new ways (Digitaliseringsdirektoratet, 2019). In other words, digital transformation is not necessarily about taking established processes and digitizing them, but rather thinking about how to use technology to achieve the same purpose in a new, improved way.

To better understand and manage these concepts, a general suggestion on how to explain and differentiate them is presented. *Digitizing* is the process of converting analog data into digital form. *Digitalization* is the process of leveraging digitization to improve business processes. It is the increased use of digital technologies in an organization to create revenue, improve business, and create a digital foundation as the core by leveraging today's and tomorrow's technology. *Digital transformation* is the continuous improvement in all areas of business by the integration of digital technologies and provides new revenue and value-producing opportunities. Whatever definitions are used, they are having a profound impact on the industries and will continue to do so in the years to come (DNVGL, 2019).

2.4 Industry 4.0

Industry 4.0 is a term used to describe the effects of the 4th industrial revolution in the industry, manufacturing, and value chains, where digitalization and integration are key concepts. The first industrial revolution was to use mechanics steam, among other things, to streamline work processes. The second one was about increasing productivity in the form of electricity and mass production. The third was primarily about automating individual processes using mechanical installations and more computing power. Industry 4.0 is the next step for businesses that have already extracted significant impacts through lean, continuous improvement. It uses digitalization of products and services, as well as technology integration both horizontally and vertically in the value chain to bring out the next level of cost-effectiveness and increased productivity, as well as create new business models and customer platforms. Klaus Schwab, the founder and chairman of World Economic Forum states; *"We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before"* (Schwab, 2016).

The reason why we now see a technological development without comparison in history is that available computing power has had an exponential development that more or less doubles every two years since the beginning of the 1970s (Montoya & Kita, 2018). For a long time, this doubling represented only a modest increase in the scope, as the doubling of computing power was relatively small. About ten years ago, however, we passed the breaking point of exponential development, and we now regularly double enormous amounts of computing power. Data storage and transfer rates follow similar developments. It is the combination of these exponential developments that is why the technologies explained here will change the world in the years to come, creating the foundation for new opportunities we could never have imagined through the fourth industrial revolution.

Industry 4.0 is closely related to digital transformation as the concept expands the possibilities and increase the importance to organizations by a series of new digital technologies. The revolution combines and connects digital and physical technologies, such as artificial intelligence (AI), Internet of Things (IoT) and Industrial Internet of Things (IIoT), additive manufacturing (AM), robotics and simulations, cloud computing, Big data and analytics, system integration, cybersecurity, and others, to enable businesses to make more informed decisions and run more flexibly, responsibly and interconnected (Hanley, Daecher, Cotteleer, & Sniderman, 2018). According to PwC, Industry 4.0 is driven by three main components as shown in figure 2;

1) Digitalization and integration of vertical and horizontal value chains. This idea was briefly touched on in subchapter 2.2 and includes improved process efficiency and quality management through real-time operations planning internally and integrated planning with execution towards suppliers and partners.
2) Digitalization of product and service offering. Companies can master change management to meet the increasing needs of end-customers by the implementation of smart sensors, data analytics, and digitized products with a focus on wholly integrated solutions.
3) Digital business models and customer access. Leading companies within digital solutions are expanding and changing business models by not only providing a software solution but also complete, data-driven services and integrated platform solutions. This idea implies additional digital revenue and optimizing customer interaction and access (Geissbauer, Vedso, & Schrauf, 2016).

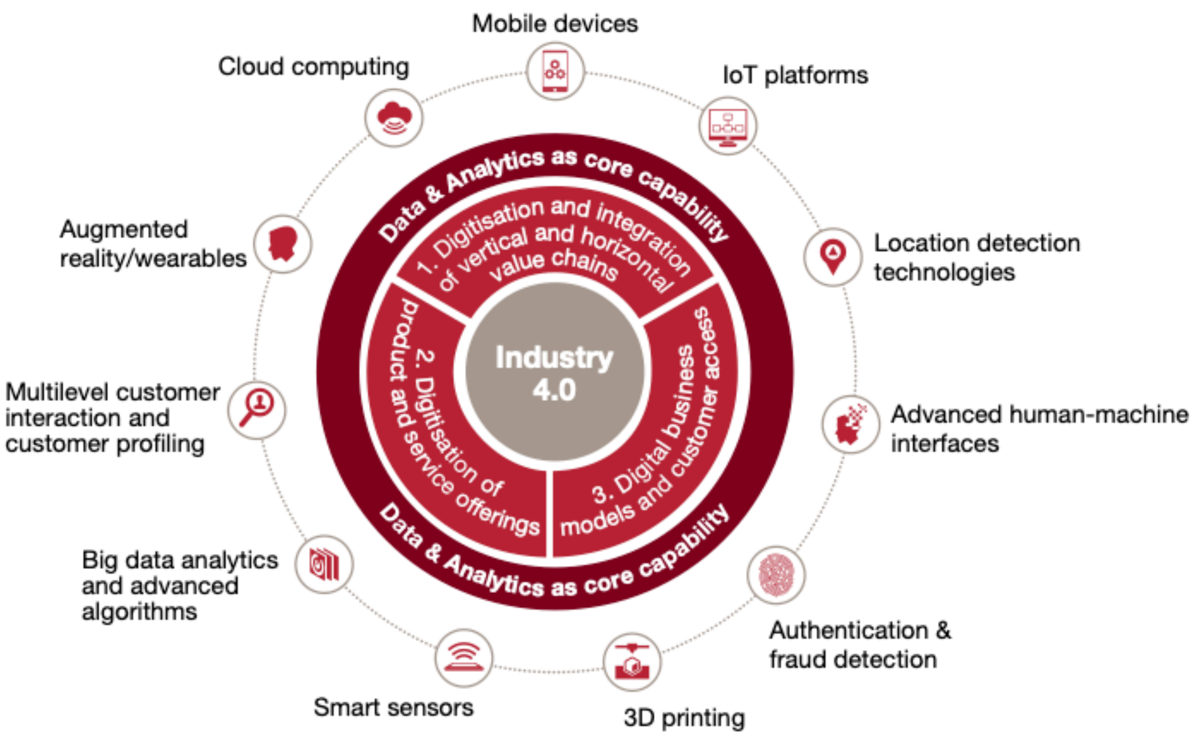


Figure 4 - Industry 4.0 framework and contributing digital technologies (Geissbauer, Vedso, & Schrauf, 2016).

2.5 Internet of Things

PWC defines the Internet of Things (IoT) as a collective term for technology that provides opportunities to remote monitoring and control of products and components through the internet (PWC, 2020). Trend Micro describes IoT as an extension of the internet and other network connections to different sensors and devices, affording even simple objects, such as light bulbs, locks, and vents, a higher degree of computing and analytical capabilities (Trend Micro, 2020). IoT arose in the late 1990s and was made possible by technologies such as wireless and mobile communications, small and powerful computers, sensor technology, and interwoven systems. The first uses, among other things, were an attempt to keep track of and organize the assets of consumers by inserting small electronic markers into the assets that could communicate with the internet. For most people, IoT means that things in the home are connected to the internet and can deliver data to make our everyday life better or easier. For businesses, however, it can contribute to more efficient operation with a better overview and more data. The technology is not a novelty in itself, but its adoption is. This is primarily driven by the availability of cheaper and more efficient wireless components that are increasingly integrated into the products we surround ourselves with (Visma, Internet of Things (IoT), 2020).

2.6 Industrial Internet of Things

Industrial Internet of Things (IIoT) applies the Internet of Things framework in manufacturing capacity to devices and smart machines. The two terms are the same, except for where the things are applied. IoT usually applies to consumer-level devices such as fitness bands or smart home appliances. IIoT, on the other hand, are connecting devices in industries such as oil and gas, power generation, or healthcare to the internet where system failure or unplanned downtime can result in life-threatening or high-risk situations (GE Digital, 2020). IIoT provides better visibility and insight into the company's operations and assets through the integration of machine sensors, middleware, software, and backend cloud compute and storage systems (Gilchrist, 2016). Today, industrial devices can be filled with smart sensors, connected to wireless networks, gathering, and sharing real time data. The three main infrastructure components that establish the foundation of IIoT are sensors, the network, and the analytics. These components are enabling technologies, including IoT, cloud computing, big data analytics, artificial intelligence, cyber physical systems, extended reality, human-to-machine, and machine-to-machine communication. IIoT is taking shape because the foundation components are now sufficiently technically mature and cheap enough for projects to be financially viable. This allows the specific technologies above to be explored, tested, and combined to find out how to maximize the benefits of IIoT in different projects (Miller, 2018).

With increasing wireless network bandwidth and decreasing the cost of smart sensors, even the smallest devices can be connected to provide input to critical decision-making. Through monitoring and tracking the sensors, their data and status can communicate with other devices and make business processes more efficient by collecting and analyzing the data from the devices (Ranger, 2019). As sensors get cheaper and smarter, networks (5G in particular) become more pervasive, and people get more familiarized with the different technologies, the value of, and interest in IIoT will continue to grow. In section 3, the different technologies will be further explored in relation to EPC projects.

2.7 Digital – Technologies or Tools

Another helpful clarification to establish is the equalities and differences between digital technologies and digital tools. These terms are also in the reviewed literature used interchangeably, which results in unnecessary confusion. Digital technologies are electronic tools, systems, devices, and resources that generate, store, or process data. In contrast, a digital tool uses digital technology to create a tool to perform a specific task. This can be anything from phone or tablet applications, writing software, translator, 3D model, and more (Victoria State Government, 2019). In simple words, technologies are how to do it – tools help do it.

Section 2: Digitalization in EPC Projects

3 EPC as Contract Strategy

Engineering, procurement, and construction contracts are commonly used in the petroleum, power, and renewable energy sectors for large-scale complex infrastructure projects. Beyond that, the shipping industry also relies heavily on the use of this contract strategy – which means that the yards are accustomed to this type of contract. The form of contract sets out the relationship between the owner and the contractor for the provision of professional or technical services. In an EPC contract, the contractor has the responsibility to design, construct, and deliver the facility, plant, or project, and the name denotes what tasks are involved. Comprehensive EPC contracts are often referred to as turn-key contracts, where operating companies are expected to have turnkey products or components delivered (Lieu, 2018).

From the beginning of the 1990s and onwards, there were extensive changes in roles and structure in the Norwegian petroleum sector, which evolved into what is today's EPC model. The contractors assumed greater and more complete responsibility for the execution of the projects, and the products were increasingly described based on requirements for function and performance (Norsk Oljemuseum, 2016). This resulted in the contractors taking the overall responsibility for the design and implementation of major parts of development, project management, detailed design, and interface control, which was previously carried out by the project owner. What was previously organized into sequences with a natural start and end, was now conducted as parallel activities focusing on the involvement of the contractors at an early stage as more pervasive and simultaneous activities. The transition to total deliveries has resulted in significant restructuring and redistribution of tasks in the customer and supplier chain. Consequently, EPC was introduced as a contract strategy in its time to counteract the cost scaling that took place in the 1980s (Nilsen & Braadland, 2014).

For owners of projects, EPC contracts allow effective risk management as the owner only has to engage with one contractor who, in turn, will manage all relationships with subcontractors.

Further, the model allows contractors to allocate and specialize in the work they undertake and is used where the owners need someone to engineer a solution with the required functionality. In addition to delivering a complete facility or plant, from inception to completion, it also requires contractors to deliver it for a guaranteed price and date. This guarantee means that the contractor will incur any additional costs and may also incur financial liability if the plant is not complete to the specified level upon completion (Lieu, 2018). Key takeaways that arise from an EPC contract is the flexibility, value, and certainty compared to other types of contracts. However, the way of utilizing the contract model has not changed considerably in the past 50 years. With low productivity growth, low degree for digitalization, and low investment in R&D, the EPC model still has high potential in reducing costs and streamline projects (Ritsche, Wagner, Schlemmer, Steinkamp, & Valnion, 2019).

4 Digital Transformation in EPC Projects

Leading corporations within the Engineering, Procurement, and Construction industry are seeking market and shareholder differentiation in capital cost savings, schedule acceleration, and increased safety. The companies are rediscovering themselves in the world of fluctuating oil prices, evolving customer demands, emerging geopolitical forces, and shrinking margins (AVEVA, Digital Acceleration in the EPC/EPCM Industries, 2019). Achieving better efficiency and cost-effectiveness has become an uphill battle with endless disruptive technologies that complicate project managers life and support to create chaos instead of profitability. However, some EPC companies are already accelerating their journey on the transformation roadmap by adopting and implementing the appropriate technologies. According to Tata Consultancy Services' report "Towards Next-generation EPC companies", taking a rational approach that does not disrupt existing business processes or affects long-term client contracts allows for adaption to thrive in a rapidly changing, increasingly competitive environment. (Franklin & Mirji, 2018)

Typical EPC projects involve a multitude of independent subcontractors and suppliers who does not have the incentive to embrace new technologies and methods during short-term jobs or contracts. Further, the scope of EPC projects varies to a degree in which developing repetitive tools and methods are challenging, and standardizing becomes difficult. Additionally, construction work often takes place in environments that are not well suited to hardware and software developed for the office. There are, however, according to McKinsey, an increasing number of E&C companies overcoming these challenges to transform projects or even business divisions digitally. Despite differing conditions in successful companies, they found similarities in practices that facilitated digital technologies and working methods to break barriers in the digital transformation. These similarities are summarized below (Koeleman, Ribeirinho, Rockhill, Sjødin, & Strube, 2019);

- Fixing paint points should be the focus, not installing IT solutions.
- Promote collaboration by implementing digital use cases.
- Reskill and restructure engineering teams.
- Capture value by adjusting project baselines.

- Connect projects to unlock impact across the enterprise.

Research by the McKinsey Global Institute found that 98 percent of mega-projects incur cost overruns or delays. The average cost is cited at 180 percent of the original value, with the average slippage being 20 months from the original schedule.
At the same time, the research indicates that cost reduction of 4 to 6 percent and productivity gains of 14 to 15 percent could be gained by a successful digital transformation based on the bullet points above (McKinsey Global Institute, 2017). Aveva demonstrates similar numbers, stating that EPC 4.0, as discussed in the next subchapter, can save 10 percent of total installed cost (TIC) based on a $1 billion size project. These savings are spread with 3 percent in engineering and design, 3 percent in procurement, and 4 percent in construction. Further, the impact of this new EPC strategy is 30 percent reduced working hours, 11 percent reduced material costs, and 10 percent reduced field labor costs (Aveva, 2018).

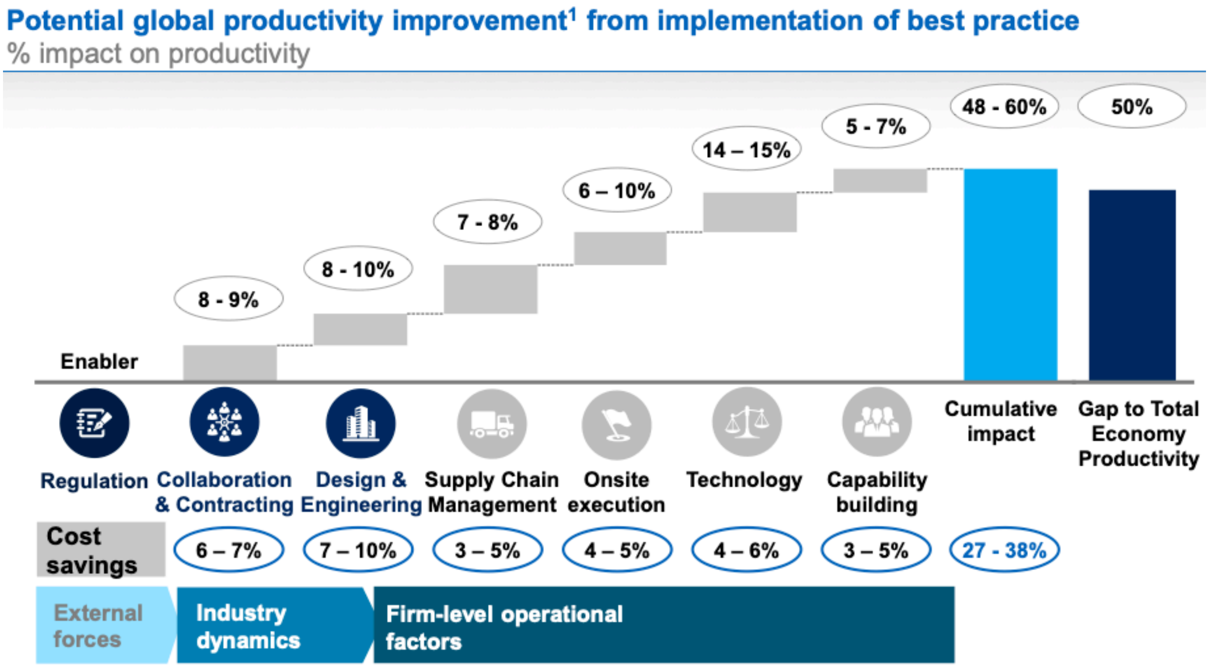


Figure 5 - The 7 Levers for a 50% increase in productivity, adopted from McKinsey&Company (McKinsey Global Institute, 2017).

In today's industries' smarter assets are being built. Robotic technology and interoperability through the Internet of Things are becoming default. In the design phase of these assets, automation begins and allows for earlier installations, which in turn leads to earlier operational deployments. With increasingly more intelligence in each stage of EPC contracts, higher efficiency, value, and quality are achieved, although more complexity and operational risk need to be accounted for. EPC companies are becoming exceedingly technically proficient in preparing to build smarter facilities and assets. Designing and building simulation models before any tooling or assembly has begun can be very useful in many industries, as with EPC projects. The value of being able to predict design and construction challenges before they become safety, schedule, or cost issues is compelling and an important part of the future of EPC. This suggests that their role as general contractors is extending, requiring them to stand out as true integrators of evolving technologies. To acquire this knowledge, they must be integrated within their organization, and with both customers and suppliers in meaningful and innovative ways (Franklin & Mirji, 2018).

4.1 EPC 4.0

As mentioned, the engineering, procurement, and construction industry is experiencing pressure from a rapidly more digital environment. Industry 4.0 is all set to take the manufacturing industry to the next level, and EPC 4.0 follows to do the same for the engineering and construction industry. EPC 4.0 represents the fourth industrial revolution in the engineering, procurement, and construction industry through adopting digital technologies and solutions across the value chain to improve collaboration, project execution, and decision-making in complex environments (Supe, 2017).

To develop a broader understanding of the EPC 4.0 concept, it is useful to take a look at the history of EPC projects with related strategies and developments. The first EPC strategy was all about doing projects on a drafting table and in paper deliverables, with a small group of people collaborating to make real-time updates. EPC 2.0 introduced computer-aided design (CAD) systems and distributed spreadsheets together with the use of computers to lead in the conception, modification, and optimization of design. In EPC 3.0, engineers were moved into low-cost centers and sub-out fabrication to reduce siloes and increase productivity, although the latter was difficult to achieve. The fourth step in this revolution is about taking control of data, empowering the workforce to realize reduced costs, reduced delays, improved efficiency, and a safer workplace. EPC 4.0 offers a data-centric approach for the industry to collaborate through a unified viewpoint. AVEVA argues that, with the aid of digitalization, EPC 4.0 is projected to reduce time spent in front-end engineering design dramatically (Sabharwal, 2020). This will enable engineers to spend more time on higher-quality deliverables, ensuring fewer errors and unexpected costs in procurement and construction. Additionally, learning from and applying these best practices can empower engineers to work together more efficiently and encourage better communication at every phase of procurement and construction (Franklin & Mirji, 2018).

An example of an innovation that may prove to be a major player in the EPC 4.0 strategy is a digital twin. Rather than updating and reissuing P&IDs manually, having equipment datasheets floating around in different systems, sending out-of-date piping and equipment specs to suppliers, or manually analyze checklists, all lists and datasheets can be aligned with 3D models and schematics on a digital twin (Elgebrandt, 2018). Having a digital twin ensures high-quality deliverables every time with a more unified data handover process, avoiding procurement errors and delays, and reducing costs at every step of the journey. Digital twins and other relevant digital technologies towards EPC projects will be more thoroughly evaluated in the next section.

4.2 The future EPC Strategy

Rethinking and redefining strategies and the way EPC companies do business is one of the necessities to stay competitive in the digital age. A benchmark study by the Mechanical Engineering Industry Association (VDMA) in cooperation with PWC illustrated that technology-oriented business models will lose considerably in importance and market share towards 2025, while digital, data-driven services are on the rise and will more than triple their market share in the same timeframe (Stephan, 2019). For that reason, rethinking and redefining work processes by utilizing digital technology, especially on large complex projects, is something engineers have to manage. This knowledge involves the utilization of specific digital tools, but also the adoption of skills and flexibility needed to acquire value from them. Attaining this knowledge is easier said than done, and one of the findings in the study is that the EPC as an industry is struggling to lure so-called “digital natives” away from start-up firms and large IT-companies. The demand for young technology-driven digital specialists are vast, and it is in the author’s belief that the EPC companies must find a way to be more attractive to the professionals of tomorrow, to master the digital change.

Furthermore, organizations can invest millions in these “young digital talents” or new digital systems, processes, or technologies without having any business gains at all. If the organizations are not facilitating the required company structure, culture, and management commitment to adapt to the new transformation strategy, all investments will be worthless. Harvard Business Review (2019) claims that people’s mindset to change and the current flaws in organizational practices are reasons why some digital transformation initiatives fail (Girard, Irvin, Tabrizi, & Lam, 2019). Backing this statement, DNV GL confirms and argues that internal barriers related to company culture and employees are much more common challenges preventing successful digital transformation than external barriers such as regulations or industry standards (DNVGL, 2019).

Section 3: Technology Mapping & Analysis

5 Digital Technologies, Tools & Concepts

The following section examines and identifies what digital technologies, tools, and concepts are available, and that comprises the industry 4.0 concept. While Industry 4.0 and its technologies were mentioned in chapter 2.4, this section dives deeper into the different technologies both in terms of technical maturity and usefulness. Although these concepts are divided into separate subchapters, several are closely related. For example, it would be impossible to exploit digital twin and big data analytics without smart sensors, and it would not provide any value to use extended reality and other visualization tools without a comprehensive 3D or building information models.

Every year, Gartner publishes what they believe are the top 10 strategic technology trends for the present year that will drive significant disruption and opportunities for the next five to ten years. Over the last couple of years, the use of digital technology has evolved tremendously, and today, one type of technology can have a range of applications. A drone, for instance, can be utilized for search and rescue, agriculture, shipping and delivery, and many more (Naveen, 2017). For that reason, some of the technology trends from Gartner's report might not apply to every industry. However, through years of publishing what they believe are the top 10 annual strategic technology trends, they have shown high accuracy in their research, and hence the report for 2020 will work great as a foundation to the mapping of digital technologies (Jones, et al., 2019).

5.1 Big Data, Cloud Analytics, and Smart Sensors

Big data is large volumes of quantitative or qualitative data, which are essentially management and decision-making tools. By collecting and analyzing large amounts of data, the organizations get betting insights that lead to better decisions and strategic business moves. The term describes data sets that are so large and complex that they are difficult to handle with conventional tools (Visma, Big Data, 2020). According to Gartner (2013) big data involves the three V's;

- *A large volume (Volume)*
- *A large variety of information (Variation)*
- *fast-changing (Velocity).*

The gathered information requires cost-effective, innovative forms of information processing to enable improved insight, decision-making, and process automation (Gartner, Big Data, 2020). SAS takes it one step further and suggests that big data involves two additional dimensions or V's;

- *unpredictable data flows (Variability)*
- *quality of data (Veracity)*

These additional V's are needed to manage triggered peak data loads from example social media, seasonal changes, or unpredicted events and to connect and correlate relationships, hierarchies, and multiple data linkages to ensure control of their data (SAS, 2020). The use of advanced analytic techniques and tools against extensive (from terabytes to zettabytes), diverse data sets, is called big data analytics. These techniques include text analytics, machine learning, predictive analytics, data mining, statistics, and natural language processing which, combined with remote cloud-based storage, provides the basis for the benefits mentioned above.

Digital Norway explains that big data often refers to many different types of data from several sources, and that to run analytics needs a lot of storage and reliable processing power. Instead of storing the data locally, one can easily store enough data from various cloud service providers, hence why the concept of cloud-computing and analytics are often named along with big data. Big data and cloud analytics are among the biggest drivers of machine learning, artificial intelligence, and automation, shaping the basis for future value creation. Using these techniques gives organizations a better understanding of what data is most important to the business and business decisions. The decision-making is transformed from being made based on assumptions, personal relations, and experience to being data-driven with endless simulations of vast data sets (DigitalNorway, 2019).

The emergence of cheap and powerful computing power helps us discover new hidden insights, through relationships between data that previously was impossible to discover manually. Big data and cloud analytics are, as well as statistical algorithms, machine learning and smart sensors enabling predictive analytics to reduce risks, optimize operations, and increase revenue through all industries, whether it is banking, retail, oil and gas, manufacturing, or others. It can help see business trends, understand customer behavior, optimize business processes, prevent disease, assess the quality of research, develop smart community solutions such as transportation and mobility, and much more. The potential of big data analytics is especially significant when combined with machine learning algorithms or artificial intelligence. CEO of the strategic advisory and management consulting company NewVantage Partners Randy Bean claims that the first wave of big data was about speed and flexibility, while the next one is all about leveraging the power of AI and machine learning to deliver business value at scale (Bean, 2017).

Data from smart sensors is a key source of data to employ big data analytics in the industrial industry. Smart sensors are sensors that take input from the physical environment and built-in compute resources to understand if something is wrong. They have predefined functions based on the application and enable a more accurate collection of environmental data, to ensure better monitoring, control mechanisms, and minimize downtime (Rouse, 2015). Smart sensors are becoming increasingly smarter and equipped with diagnostic functions, thereby facilitating predictive maintenance in the years to come (SICK, 2020).

An example of how Big Data Analytics can be profitable in an IIoT platform is where massive data streams are analyzed online using cloud-based advanced analytics. The data can be stored in distributed cloud storage systems for future analytics performed in batch formats. When this massive amount of data is continuously being fed into cloud storage and processed again and again, the analytics can gather information and statistics due to more powerful or refined algorithms than before. Process engineers then can use this information to optimize operations to boost productivity and efficiency and reduce operational costs. This is the ultimate business benefit of using IIoT. Increased efficiency and accelerated productivity, thereby reducing unplanned downtime, resulting in profits (Gilchrist, 2016).

5.2 Digital Twins

A digital twin is defined as a virtual representation of a physical product or process, used to understand and predict the physical counterpart's performance characteristics (Siemens, Digital Twin, 2020). They are used throughout the product lifecycle, to predict, simulate, and optimize the product before investing in a full-scale physical product. Technologies like augmented reality and virtual reality are emerging to digitalize and streamline the construction industry. IBM (2018) argues that thus far, the latest technological developments in sensors, miniaturization, robotics, drones, and computing power with smart algorithms, are giving a sense of how to combine digital and physical aspects to build cheaper, greener, and more durable buildings in a shorter timeframe. Instant access to all the information above, down to the smallest details about everything involving the construction, is achievable with a digital twin. They also have a similar description of what a digital twin is and define it as a virtual representation of a physical object or system across its lifecycle. It uses real-time data and other sources to enable learning, reasoning, and dynamically recalibrating for improved decision making (Mikell, 2018).

Digital twin technology as a concept was developed way back in the 1960s by NASA for the moon exploration mission Apollo 13 and Mars Rover Curiosity. Although the concept has been highly familiar since 2002, only as recently as 2017 has it become one of the top strategic technology trends. With the introduction of the Internet of Things, digital twins finally became cost-effective so they could become as imperative to business as they are today (Miskinis, 2019). Using the data from the sensors, the twin is essentially a link between a real-world object and its digital representation that continuously updates through the object's lifetime. In recent years, the virtual representation is widely used for visualization, modeling, analysis, simulation, development, and triggers the feedback loop of decisions and changes in workflows that are required to optimize the real object system (Intellectsoft, 2018).

According to a report on digital twins (2020), the value additions of a digital twin can be gathered into eight different categories (Kvamsdal, San, & Rasheed, 2020):

1) *Real-time remote monitoring and control*
2) *Greater efficiency and safety*

3) *Predictive maintenance and scheduling*
4) *Scenario and risk assessment*
5) *Better Intra- and inter-team synergy and collaborations*
6) *More efficient and informed decision support system*
7) *Personalization of products and services*
8) *Better documentation and communication.*

In other words, the digital twin concept offers many new perspectives to help engineers and businesses understand not only how products are performing, but also how they will perform in the future. Organizations can break down old boundaries surrounding product innovation, complex lifecycles, and value creation by learning more, faster (Mikell, 2018).

5.3 Hyperautomation & Autonomous Things

Automation is the process of automating and replacing tasks that once required humans, through the use of technology. Gartner (2019) takes it one step further and introduces Hyperautomation, where advanced technologies like artificial intelligence (AI) and machine learning (ML) are used to increasingly automate processes and augment humans (Panetta, 2019). There is no single tool that can replace humans. However, through a combination of tools like robotic process automation (RPA), intelligent business management software, and AI, the goal of hyperautomation is to increase AI-driven decision making and reduce human mistakes. Whereas automation replaces humans with machines to execute physical activities like welding or other operational tasks, Hyperautomation encompasses tasks like thinking, discovering, and designing these automations themselves with the combination of advanced digital tools. Put differently, Hyperautomation is about gaining continuous intelligence about the organization and visualizing how functions, processes, and key performance indicators interact to drive value. Gartner argues that the result of Hyperautomation is the creation of a digital twin of the organization and driving significant business opportunities (Jones, et al., 2019).

5.3.1 Autonomous Things

The terminology for the devices that are automating tasks and replacing humans is Autonomous Things (AuT). These devices include robots, vehicles, drones, smart home devices, software's, and are expected to either partially or fully automate the tasks involving humans today (AIMultiple, 2020). Although autonomous vehicles and smart home devices can, with time, become useful for EPC projects, the most relevant technologies today are robotics and drones in construction. These are getting increasingly more autonomous, cooperative, and flexible, and thus easier for humans to interact with (Dr Ghaffarzadeh, 2018). The idea of the AuT is to enhance machines with sensors, AI, and analytical capabilities to a degree in which the machines complete tasks automatically without any direct human interface. Conjointly these technologies can capture enough information and data to make data-based decisions. Gartner claims that due to the tremendous development in the related technologies, like decreasing the cost of sensors and cameras, and more capable AI hardware's and software's, autonomous things are expected to have a significant impact in businesses within a few years (Jones, et al., 2019).

5.3.2 Drones

Alongside Industry 4.0 and EPC 4.0, there is also an aerial revolution happening across the globe. In numerous sectors, especially construction, drones have emerged as a highly viable commercial tool facilitating on-site safety and project monitoring to a level that was not previously possible. Drones can be equipped with cameras, GPS units, thermal and infrared sensors, and collect data to be sent directly to a chosen software for analysis. Amongst other things, drones can be used to measure dimensions of tall and complex structures, providing a safe and secure means of inspection. By gathering data, pictures, and videos, drone information can be used for land surveys, building inspections, providing visual material for clients and staff, monitoring on-site activities, security surveillance, and mapping data. For example, 3D models of large areas or objects can easily be created using drone technology and be combined with ground-based laser scanning and conventional surveying (Patterson, 2018). Commercial drones have, as long as they can pass federal aviation and zoning hurdles, enormous potential to cut costs, time and risk while improving workflow, accuracy, communication, and efficiency. Because of the restrictions of its use, it may be advantageous to hire professional drone companies to execute the desired tasks before the limitations are lessened (Anderson, 2015).

Although not relevant to the Dogger Bank project, underwater drones could potentially have streamlining effects to yard operations and inspection activities. Pier inspections and diving to check the docks before boats enter are comprehensive and costly tasks EPC contractors must take into consideration. During one of the interviews with personnel in Aibel, it was clarified that divers could cost between 40 000 and 50 000 NOK because of very strict HSE procedures. Instead, it appears profitable to invest in an underwater drone at approximately 90 000 NOK, which then can be reused in many projects, both for inspection of docks and seabed.

5.3.3 Robotics

The second key technology in autonomous things is robotics, including smart robots, mobile robots, delivery robots, personal robots, and robotic appliances. In manufacturing and construction businesses, all of the above can be applied. However, especially precise and repetitive work like welding, together with dangerous tasks like handling power tools, is valuable to replace. The ability to control and run a robot remotely reduces waste, streamline project work, and reduces the number of professionals needed to perform single tasks. Empowering operators with robots does not only have efficiency and productivity gains but also the potential to reduce risk and job-related injuries – something that will always be far more important than increasing margins (Timmermann, 2019). Below is a figure of different levels of automation in the construction industry, adopted from the Society of Automotive Engineers' reflection on autonomous vehicles (International, 2019). Although autonomous vehicles seemingly are more widespread and focused on, it is appropriate to draw parallels to construction both in terms of safety and efficiency enhancements.

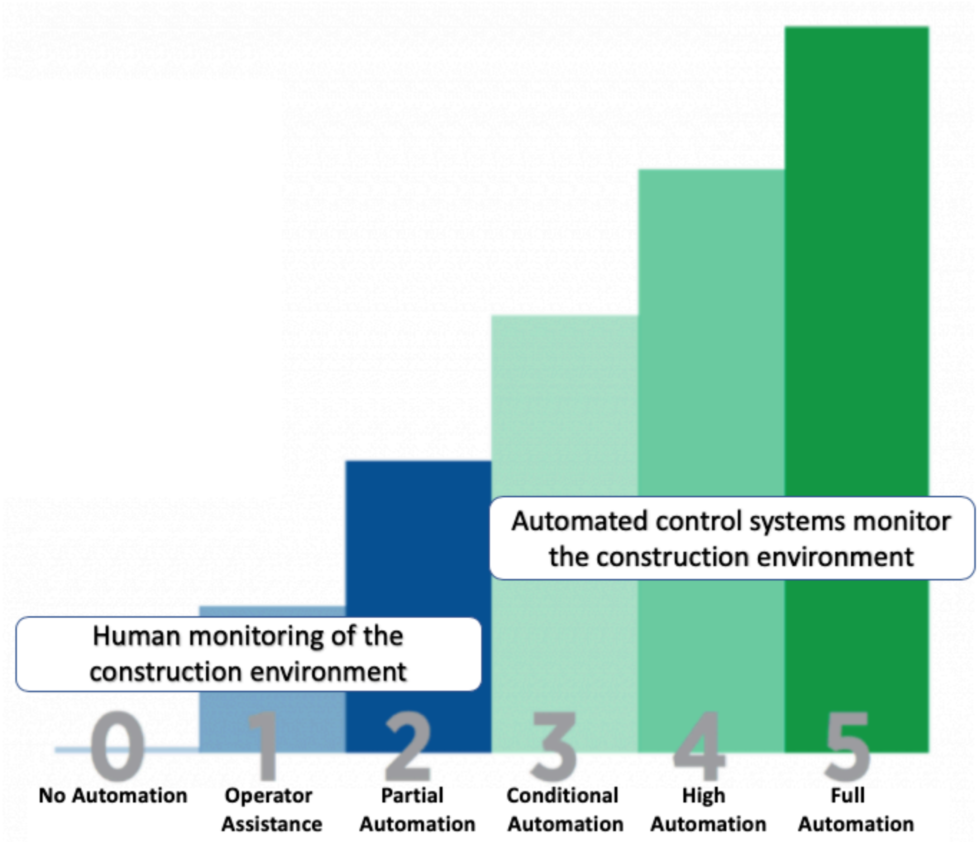


Figure 6 - Levels of Construction Automation adapted from SAE International's Levels of Driving Automation (International, 2019).

Level 0: No Automation

Humans are entirely in charge of the construction site, with no automated processes or tasks.

Level 1: Operator Assistance

Operator tasks are assisted by autonomous things, i.e. robotics for welding or drones for capturing video, but operators are needed to provide data input and control the machines.

Level 2: Partial Automation

The machines are smart enough to repeat processes and able to store and use historical data. Operation requires supervision and assistance in case of unexpected incidences.

Level 3: Conditional automation

Autonomous operation until the system encounters a situation it is not comfortable with and sends out alerts to humans to take over. Example: Oil spills on the floor where the robot is working.

Level 4: High Automation

Same as level 3, except the system continues with full autonomy, but sends out alerts to humans that an incident has occurred and may need to be investigated manually.

Level 5: Full automation

Construction work solely reliant on automated processes, things, and machines. Humans are not needed at construction sites. In other words, until level 5 is reached, humans are needed for maintenance, special incidence, and supporting activities.

5.3.4 Robotic Process Automation

Robotic Process Automation is a form of business process automation technology based on metaphorical software robots or artificial intelligence and has the potential to streamline business operations and projects significantly. It allows users to configure scripts to activate specific keystrokes in an automated fashion (Gartner, Robotic Process Automation (RPA), 2020). Automating repetitive tasks related to the data flow from one function to another with RPA can offer huge savings. An example can be when creating an invoice, a repetitive task in the account receivable process that easily could be automated using an RPA bot. Taking it one step further and combining the RPA bot with multiple machine learning, packaged software and automation tools, will allow the entire accounts receivable process to be hyperautomated. This means that the hundreds of tasks, including creating an invoice, are automated. A typical EPC project includes feasibility studies, in-depth technology reviews, regulatory assessments, project finance reviews, and complex budgeting. The number of repetitive tasks previously done by humans involved is therefore massive and offers a significant opportunity to streamline and enhance the efficiency of EPC work tasks (Bhatt, 2018).

5.4 Multiexperience, Mobile Devices, and Tablets in Field

Another key finding in Gartner's technology trends for 2020 is multiexperience. Multiexperience is, according to the Quality Engineering & Software company Cigniti about leveraging various modalities, digital touchpoints, apps, and devices to design and develop a seamless experience for the customers (Cigniti, 2020). Whether it is interacting with the customer across the web, mobile, app, or other modalities, the idea is to have as many touchpoints towards the customer as possible to achieve a consistent customer experience. By the year 2023, Gartner argues that more than 25% of the mobile apps, progressive web apps, and conversational apps at large enterprises will be built and ran through a multiexperience development platform. Daniel Sun, VP analyst at Gartner, states that "Development teams should master mobile app design, development, and architecture because "mobile" is typically the gateway to multiexperience." And the gateway to multiexperience opens another through immersive experiences, the perception of being in one place when actually in another. Not only is the entertainment business wanting their customers to experience this, but also the industry could benefit from being able to visualize and familiarize how their products, assets, and facilities are. From simple AR overlays on smartphones to fully immersive virtual reality environments, the technology can simulate realistic scenarios and enables employees to practice operations and to interact with virtual people and objects (Jones, et al., 2019).

5.4.1 Extended Reality

Extended Reality (XR) is an umbrella term encapsulation Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and everything in between. XR is rapidly becoming familiar in most industries and supplementing human reality in unimaginable ways through devices like Microsoft's HoloLens, Google's Glass, PlayStation VR, Oculus Rift VR, and others. Although the term includes all types of virtual experience, the level of processing, information collection, storage, and power are quite different between the technologies (Wendt, 2020).

5.4.1.1 Augmented Reality

Augmented Reality is arguably the most widely adopted and has already been implemented in many industrial industries. AR allows extra layers of information to be brought into reality, for example, by supplementing with text, audio, or images. It enables the interaction between a virtual experience and the real world to appear in front of you. There are only two necessities for AR to work; a camera to capture the environment and a processor to actively simulate a virtual object and place it in that environment. Hence, AR is by far the simplest of the three XR subsets. Today, limitations to the use of AR for business purposes lies in the slow growth of native processing power in devices where AR will take place. In the years to come, the cost of the devices will lower together with increasing processing power and remarkable design improvements to lower weight and better comfort (Hilken, Ruyter, Chylinski, Mahr, & Keeling, 2017).

5.4.1.2 Virtual Reality

Instead of placing the virtual objective on top of the real-world environment, Virtual Reality creates an entirely simulated environment with enclosed glasses, controllers and other sensory stimulators. In this way, employees or customers can visualize the actual asset instead of relying solely on design drawings and models. In addition to visualizing through VR, combining the VR headset with sensory additives such as headphones and haptic devices makes the immersive experience easier to reach. The use of VR requires heavier and more powerful hardware than AR, thus the headsets are bigger and often combined with a computer for more advanced operation (Wendt, 2020).

5.4.1.3 Mixed Reality

A hybrid solution of the two technologies above is called Mixed Reality. This is the newest technology within XR to superimpose an interactive experience over the real world so that both physical and digital objects can co-exist and interact in real-time. The most commonly known example of Mixed Reality is Microsoft's HoloLens and its integration with other software's. Using HoloLens in a videoconference call, for instance, enables people to interact with each other by "touching" the simulation with their hands and transforming what was formerly an impersonal method of meeting business to another level of interface (Lorek, 2018). A more in-depth example of the potential of XR in the Dogger Bank project, and also EPC projects in general is presented in chapter 8.

5.4.1.4 Examples of Opportunities by Using Extended Reality in EPC Projects;

Engineering Challenge:
Engineers responsible for design often have never seen one in real life, thus design error around constructability, operability, accessibility, and maintainability can cost millions if not caught early in the project process.

Solutions with XR:

Iterative 3D model visualization in different office locations. The virtual reality part lets other people be "present" in the room and review a model collaboratively without traveling across the world. Engineers can now see the model virtually before making vital project decisions.

Procurement Challenge:

In a project size like Dogger Bank, there are millions of parts and pieces of inventory to track, and manage between warehouses, yards, work front and transit.

Solution with XR:

RFID tracking of assets, hence time-saving in finding the correct parts. Multiexperience makes it easier to navigate and find the correct locations throughout the project.

Construction Challenge:

As construction errors account for a large percentage of the project budget in such projects, any field activity done more than once either because of poor quality and design or change in methods will have a negative effect on profitability.

Solutions with XR:

AR can have a considerable impact on reducing construction errors by having standardized and highly automated AR work instructions. Virtual AR assistant to guide technicians through tasks. When budgets get tight, and schedule delays are closing in, it is harder for the technicians to cut corners if an AR assistant has concrete digital work instructions.

5.4.2 Tablets and Mobile Devices

One of the undoubtedly most familiar and capable digitalization technologies is the use of mobile devices and tablets instead of paper and pen. Through the last decade, tablets, laptops, and mobile phones have had a great journey, and their capacities are proven beneficial for several industries. Whether it is operators bringing the devices to the yard/facility with job descriptions, drawings, 3D-models, instructions, navigations or supervisors reporting status, checklists, capturing videos or pictures, or even supervisors tracking personnel, communicating with the back office or ensuring safety is followed, the uses of these devices are immense. The benefits of mobile devices and tablets in field are many. However, they can all be gathered into improved efficiency and increased productivity, although many other benefits are being enhanced on the road to achieving this (Jones K. , 2018). In chapter 8, an example of how tablets and mobile devices can be used in field/yard operations is presented to illustrate their benefits.

5.4.3 5G Networks

Modern smartphones have been around since 2007 and were quickly followed by third-party apps and tablets. Since then, internet speeds, processing power, and a broader selection of applications have made access to tools and information available anywhere. Given that the adoption of IoT and other technologies keeps escalating, innovation in connectivity is key to the success of future deployments. With the release of 5G, faster internet speeds, higher levels of reliability, and increased capacity are enabling significant process and data management improvements. According to Ericsson, 5G has three major areas of usage and applications that expand beyond what 4G was capable of delivering; Enhanced mobile broadband enabling high volume and high-speed data transfer, critical IoT for mission-critical applications that rely on large bandwidths, and massive IoT for connectivity for millions of devices (Ericsson, 2019). The aforementioned use cases for mobile devices and tablets will, together with all other processes in the projects which require connectivity, be enhanced by 5G networks to meet the wide variety of needs.

5.4.4 Digital Frontline Worker

Digital frontline worker is about putting frontline utility workers at the forefront of the digital transformation and let those who are the face of the company show digital commitment, zeal, and courage towards the digital future (Mcgann, 2019). This is an area Aibel is already passionate about, intending to give the operators and footers access to the newest and best digital tools to streamline everyday activities. These include tablets and mobile devices, 3D printers, welding robots, AR glasses, HoloLens, and other visualization tools. As one of the interviewees stated, "Digital field reporting, work packages offshore, checklists and visualization are some of the most timesaving implementations and should be very easy measures to implement across our projects." There are still, however, some work packages, checklists and processes that are not yet digital in Aibel's projects. An example of the streamlining effect of such an effort is illustrated in chapter 9.1. Allowing frontline workers to utilize the digital tools in operations is typically a digitization initiative that needs to be in place for a company to transform digitally. A sub-goal in the digital transformation is to remove paperwork in the entire organization. Thus, it is appropriate to start with the individuals in the field as these tools are often easiest to quantify the value of. Following this paper-based transition is the optimization across workflows by connecting various systems and tools for seamless information flow. This continuous improvement can then be followed up and sustained through a digital yard.

5.4.5 Digital Yard

Ingesting all data not only from fieldworkers but from all different digital processes and tools in the yard into one specific yard management software constitutes the term digital yard. By collecting and analyzing the data from field workers, work processes, electronic checklists, security systems, drones, robots, and eventual other tools, yard owners will obtain a better overview of the entire facility. Moreover, a combination of such a software solution together with a dashboard view to follow real-time processes and warning signals if something critical is about to occur will enhance predictability and security.

Digitizing yard activities can enable more efficient everyday work for operators and supervisors if the relevant activities and processes are digitized correctly. By implementing mobile applications to handheld devices, an easier and quicker delegation of tasks, finding out who is at work and reporting directly in the applications is facilitated. Employees can report progress on the job/project on the mobile device, and at the same time, keep all parties involved updated (Søgnen, 2019). In addition, adding other expansions to the mobile software like 3D-model of work tasks, an overview of available tools, or highlighting the competence of each worker within the application could be useful to streamline the yard activities. Replacing what was previously done by pen and paper and implementing digital solutions like this can have huge benefits and initiate the process of digitizing the yards towards "digital yard". A more digital yard will enhance predictability through land surveys, data analytics from yard activities, and building inspections as well as safety through on-site activity monitoring control. When the digital yard then is connected to all other digital systems in the organization like IoT (Internet of Things) system, PDMS (Plant Design Management System), EIS (Executive Information System), or similar, operational nirvana is within reach. This means, as stated by the software and mobile app developer ProntoForms (2020), the point in which technologies are learning from each other and becoming predictive in their cycle of continuous improvement (ProntoForms, 2020).

5.5 Building Information Modeling

A building information model is a multidimensional data representation of a building, and the process of creating the model is called building information modeling. National Institute of Building Sciences defines BIM as *"a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward"* (Harris, 2007). BIM has been heralded as a cutter of costs, savior of client, contractor, and supplier relationships and ensures all graphic, physical, commercial, environmental, and operational data on a project is stored on a 3D model. The 3D model is then used for optimization of schedule, costs, operations, maintenance, and visualization by all parties involved in the contract (Offshore Technology, 2017).

As mentioned before, EPC companies require as much reduction in development time as possible. Since virtually every project is different from the preceding, the importance of the right design tools is vital in today's competitive market. The engineers can utilize BIM at the design stage to make a full-scale replica of the asset being delivered in a virtual environment exactly similar to the real-world environment. Using the various features in BIM programs, the model can be analyzed, simulated, and optimized before any construction starts to reduce the number of errors and to estimate the cost and schedule of the project better. Further, EPCM Holdings argues that due to rapid relocation to new projects after completion, useful data from the previous project is left unanalyzed by the companies. Instead of sorting, categorizing, and feeding data into a master database to optimize new projects, this data is ignored. By analyzing historical data and utilizing LIDAR scans in the field to compare with modeling, the BIM models would also become even more precise and valuable. This lack of seamless information flow across the organization is a topic that the interviewees from Aibel also deliberate about and will be discussed later in the paper (EPCM Holdings, u.d.).

5.6 Additive Manufacturing (3D-printing)

Additive Manufacturing (AM), more commonly known as 3D-printing, has, according to GE and McKinsey, the potential to revolutionize industrial manufacturing (Bromberger & Kelly, 2017) (GE Additive, 2020). The technology uses data computer-aided-design (CAD) software to direct hardware to deposit material in layers, shaping, and creating precise objects. Rather than removing access material from the object being produced in traditional means, a 3D printer delivers a perfect physical product according to the design from the model. 3D printing allows users to produce parts that are lighter, stronger, and more durable than traditionally made parts. Build times are faster and engineers can add precise features and complex geometries without increasing cost. Additive manufacturing is not only revolutionizing the manufacturing industry, but also the way we work. Decentralizing and improving quality by utilizing AM close to the facilities will reduce the transport distances and costs, as well as limiting the need for spare part storage. When steels and other critical materials can be certified and approved from being 3D printed, it is not hard to imagine that additive manufacturing indeed will revolutionize the industry.

Even though 3D-printers today is used as a utility tool and not for steels and materials that need certification, the benefits are already there. The technology can facilitate a virtual warehouse with drawings of all parts. An example is if a valve on an offshore platform or in a yard is damaged. Especially offshore, it is difficult to get a new one right away. Instead, with a local 3D-printer available, it could print out the correct valve and replace it in a fraction of the time it would take to be delivered a new one. Within a few years, it is reasonable to assume that modification and maintenance projects also will be affected by the introduction of certified 3D-printed materials (Bromberger & Kelly, 2017).

5.7 Copiable Platforms

A substantial digitalization opportunity in the Dogger Bank project is that the design of the 2(3) converter platforms to be delivered are completely identical. As described in the project background in chapter 1.1, Aibel is contracted to deliver two platforms, with an option on a third. For that reason, all information from the engineering, procurement, and construction of the first platform can be copied and used again on the second and third, as long as all tags, names, numbers, documents, and processes are changed during replication. Especially engineering hours could be drastically reduced, but also procurement and construction errors could easier be avoided in the second and third platforms.

5.8 Cybersecurity

A common thread throughout the mapping of technologies is increased capacity and connectivity within and between the different technologies. With smarter mobile devices, tablets, robots, drones, yards, construction sites and offices, cybersecurity, and its importance will only expand. The more advanced the technologies get, the more advanced knowledge about safe and secure use is required. With the increased connectivity between assets and systems, the vulnerability increases and could facilitate security breaches. As every additional link between systems adds another possible point of attack, resources need to be allocated to prevent any security incidents. It only gets even more critical as the digitalization further develops needing less human interaction a more machine decision making. For instance, cyberattacks to machine-operated production facilities or other fully automated processes could have severe consequences. Therefore, the importance of safe data use among employees must be emphasized, and it is appropriate to include this in the training of employees when implementing new technology. Cybersecurity engineers have to be prepared for and conduct frequent threat analyzes and risk assessments. The improvement of cybersecurity has to follow technology and digitalization development. Artificial Intelligence and Machine Learning are key enablers in realizing this, as companies hopefully will be able to predict and protect against cyber-attacks more effectively (Press, 2019).

Section 4: Evaluation of Digital Initiatives

Whether classifying it as digitalization, digital transformation, or the fourth industrial revolution, the related technologies and tools could potentially have a game-changing effect on the future of the engineering, procurement, and construction industry. In the following section, the main findings from the interviews and the reviewed literature is analyzed and evaluated in relation to the Dogger Bank project and other EPC projects in general. Also, some illustrations of how these digitalization initiatives could be profitable is presented. Figure 7 shows a summary of the discoveries that are considered with the ultimate goal of improved business, projects, and processes through digitalization. The results build on insights from people and organizations working on the front line of digitalization and EPC projects. Four different categories are presented as essential to capitalize on, and further develop fulfill these goals. By considering, assessing, and improving these categories and the processes behind them, Aibel´s digitalization objectives for the Dogger Bank project will be easier achievable.

Digital Technologies, Tools & Concepts	Digital Change Management	Implementation Guideline	Quantifying Value	Improved Digitalization
Big Data, Cloud Analytics & Smart Sensors	**A Chaning Industry:** • More fixed-price contracts • More international competition • Less travelling	**Step 1:** Diagnose the Problem	**Example 1 – Visualization:** Yard inspection/verification with and without digital tools	• Paperless solutions • Simplified daily activites and tasks • Process improvement activities • Better information flow • Improved quality • Improved productivity • Improved business processes • Increased safety • Overall streamlined projects • Competitive advantage
Digital Twins		**Step 2:** Secure Early Executive and Employee Support		
Hyperautomation & Autonomous Things	**Social changes:** • Knowledge • Interest • Habits • Attitude	**Step 3:** Identify the Customer and Establish Ownership		
Multiexperience, Mobile Devices & Tablets in Field		**Step 4:** Finance a Support Team		
Building information modeling	**Company changes:** • Collaboration • Scalability • Standardization • Application / uses	**Step 5:** Train the Employees **Step 6:** Be Transparent and Communicate	**Example 2 – Information sharing:** Workflow with and without tablets/mobile devices in field operations	
Additive Manufacturing	**Management commitment:** • Engagement • Communication	**Step 7:** Manage Change During Implementation		
Cybersecurity		**Step 8:** Evaluate and Follow-up		

Figure 7 - Summary of improvement categories

6 Digital Change Management

Although change management was not a specific theme in the interviews, all interviewees somehow got into the topic and had several opinions about either a changing industry, social changes, or corporate changes following the digital transformation. Lack of reasonable processes, tools, and techniques to manage change to achieve a required business outcome was a general concern from the respondents. To be better prepared for future digital implementations, this chapter delves deeper into how these changes affect the industry, the companies' ability to handle the necessary changes, and how management commitment affects the implementations.

6.1 A Changing Industry

As mentioned in section 2, the fourth industrial revolution in the engineering, procurement, and construction industry is rapidly changing the industry to a more digital environment. Not only is the industry changing to become more digital, but it is also shifting towards renewable energy. Simultaneously, four other essential industry changes that could have a significant impact on the industry have been frequently mentioned in the interviews as a reinforcing factor for digitalization challenges.

First, there is an ever-increasing proportion of fixed-price contracts in the industry, which entails some needful measures among the contractors. Except for owner-initiated changes, the contractor is fully responsible for all cost overruns. This makes estimations of costs and profits crucial for the contractors to classify projects as successful. The main challenge with the increasing proportion of this contract model is that the increasing use and development of hard quantifiable digital tools and technologies complicates cost estimation. With a contract model that has remained almost untouched for the past 50 years, the contractors know how to estimate the costs in the old way and need to adapt the financial metrics to new digital solutions while trying to remain competitive.

Remaining competitive is the challenge with the second industry change occurring. Global spread of broadband capacity has opened a number of occupations to international competition with the rise of digital economy. China, India, Russia and other parts of the world are successfully competing for what were once indisputably carried out domestically. Even the case study company in this paper utilize yard overseas to save costs. More international competition for the contracts emphasizes the importance of succeeding in the digital transformation. Being a frontrunner of digital technologies, tools, and solutions make both domestic and international contracts easier to access and compete for.

A third industry change has exploded this year and seen its full potential during this year's COVID-19 pandemic. Digital meetings and presentations have been forced upon all industries due to the lockdown of countries, cities, and also offices, factories, and production facilities. Despite the challenges posed by the coronavirus, productivity has remained among employees in most organizations, according to a survey by Willis Towers Watson (Faragher, 2020). The interviewees in Aibel also had a similar experience and agrees that the growing use of digital meetings and presentations are a definite cost-saving appliance. By using digital tools for meetings and presentations, businesses facilitate measures like:

- Less frequent visits to various locations, i.e. facilities, offices, or customers.
- More testing, verification, inspection, follow-up, and evaluation through video calls.
- Video meetings can be combined with GoPro helmet cameras, AR glasses, or similar for visualization of the facility, asset, or yard.
- More cost effective compared to physical meetings.
- Contribution to environmental protection.

This flourishing use of digital tools for remote collaboration during COVID-19 will undoubtedly leave its mark in the industry and facilitate less travel in the future, even when the society is back to normal.

6.2 Social Changes

Today's society, and also the industry, is made up of a lot of older people who have not grown up with the latest technology. For example, the average age of those working offshore in Norway is 53 years (Industri Energi, 2017). In the coming years, the Norwegian industry will go through a generation shift. The younger generation is more tech-savvy and eager to learn and adapt to new technology. For them, being able to use new digital technology and applications in work situations is appealing instead of confusing. Not only is it about interest, but also the rudimentary technological skill and knowledge that younger generations have. As mentioned in chapter 4, the demand for young technology-driven digital specialists are vast, and EPC companies must find a way to lure these talents away from start-up firms and large IT-companies. It is reasonable to assume that the effect, potential, and reception of digital tools could increase due to the social trend and the increase of technology-interested and knowledgeable professionals in the industry. In the long run, this will also reinforce the changes towards the industry.

6.3 Company Changes

The third change that emerged through the conversation with Aibel deals with company or organizational alterations. Whereas social changes rely on culture, habits, and attitude, the company or organizational changes also include communication and collaboration. With a company the size of Aibel, it is inventible that different projects have different needs in terms of digital technology. One project may be willing to introduce new technologies and tools, while another does not see the value. Different internal environments and projects within organizations are fighting for different digital solutions, systems, and tools with contradictions, making it more challenging to collaborate and work seamlessly across the organization. Moving people from project to project often requires training in new systems or work methods. Absences of a common understanding of the concept of digitalization, along with each project running their digital initiatives and budgets, make it challenging to establish standardized solutions across projects and departments and thus also for the entire organization.

Similar, as reviewed in chapter 4, two of McKinsey's (2019) bullet points in their study on successfully digital transformed companies involves internal collaboration and connecting projects to unlock impact across the enterprise. This emphasizes the importance of communication throughout the organizations to succeed with the scalability of digital initiatives. Along with scalability, standardization of successful digital initiatives is crucial to spread reasonable solutions across the organization. To enable new digital technology to be standardized in projects and work processes, the companies need to facilitate the required company structure and break internal barriers related to company culture and employees. As one of the employees in Aibel said, "*We are not mature enough. There is too little control over the use, utility, and challenges associated with each project's experience with digital tools and technologies. If a project succeeds with a tool, it is unlikely that a project on the other side of the organization will benefit from this information."*

6.4 Management Commitment

A necessity that must be in place for digital change management to succeed is commitment from the management, and desire to succeed with digital initiatives and in the digital transformation as a whole. Without support, ability, and willingness from the management team, organizations will struggle to succeed with digital implementations and digital transformation. Strong engagement and belief from the management that innovative technology is positive and leads to business improvements rather than confusion and destruction are fundamental in reaching success. More often than not, digital investment arguments lose against budget reasoning, because immediate savings are desired, and not how much one should invest now, to save later. If investments and their opportunities disappear, organizations will never move forward through the digital transformation.

Communication is by far the most essential tool to ensure that employees become aware of the change and want to participate actively in the change. Humans react differently when subject to change, and this must be taken into account by the management. The managers' and managements' commitment to involving the entire organization is thus vital for the message to reach everyone. Technology is rarely the reason why digitalization initiatives fail. The real reason is that organizations are not willing to accept it, or the technologies are being implemented because the industry or employees expects the company to use the technology without knowing the uses. Through greater management involvement and confidence, the general support from the employees will likely follow and thus also a higher likelihood of the successful implementation. A study from PWC on challenges in digital restructuring processes also supports the argument. It states that *"decision based on involvement has greater legitimacy, while involved managers and employees safeguard an important information and motivation function in the units where the changes are to be implemented* (Mortensen & Askeland, 2018).*"*

7 Implementation Guideline

In order to successfully digitalize, it is inevitable not to implement new digital technologies, tools, and systems. Hence, the way these are being implemented in businesses is essential for how successful they end up being. A common denominator in the interviews was that the implementation and the use of digital technologies and tools could be optimized and substantially more seamless than it is today. Lack of scalability, standardization, support teams, training, and collaboration across departments and projects are challenges that repeated during the interviews. Consequently, based on previous literature and the interviews, eight guidelines to follow when implementing new digital technologies and tools have been created and will be presented below. By following these guidelines, more agile, seamless, and effective implementation of digital technologies and solutions is attainable.

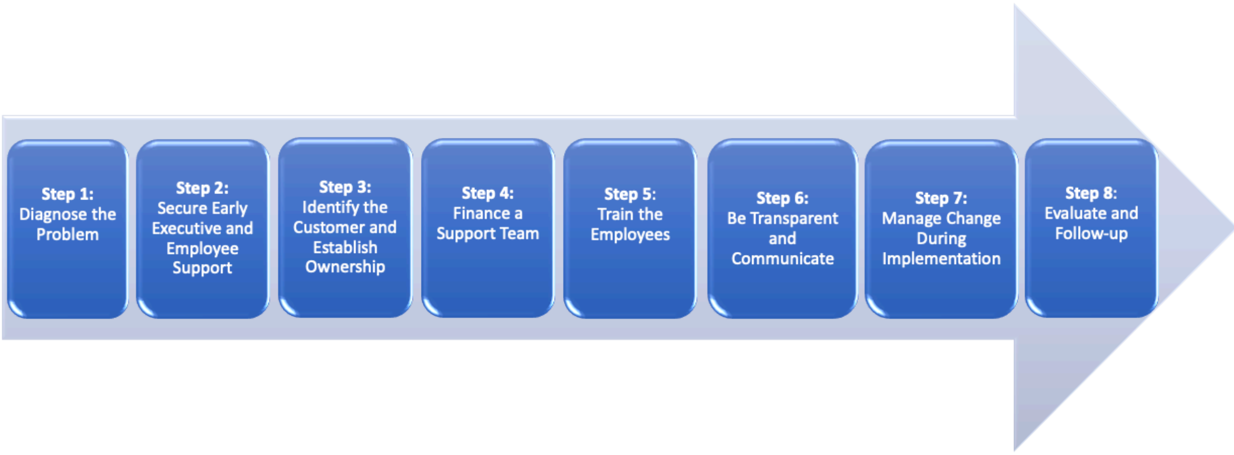


Figure 8 - Guidelines for implementation

7.1.1 Diagnose the Problem

When needing to solve a problem using digital technology, it is important to start from scratch. First and foremost, a clear view of what does not work must be established along with how new technology or tools will help solve the challenge. This includes correctly diagnosing the problem with the existing operation process to understand better what investments are needed. Having a clear picture of the desired features and functionalities before reaching out to suppliers can also save time and frustration. Many organizations are starting with the tools and technologies before finding out where and how to use them. It is easy to be influenced by competitors and customers that have invested heavily in robotics, artificial intelligence, or similar. However, there has to be a clearly defined scope and objective for the initiative to be successful.

7.1.2 Secure Early Executive and Employee Support

Once the problem has been diagnosed, and the scope clearly defined, it is critical to ensure the support of decision-makers as soon as possible. Success or failure is mostly dependent on having the right level of team commitment and executive support. Proving to the decision-makers how the new technology can be profitable, and getting support, will increase the pace at which the technology could be implemented. Running a pilot or proof of concept to work out kinks and gain buy-in could prove technical feasibility to top management and serve as convincing towards other projects or departments in the organization. When decision-makers are in support of the new technology, a higher likelihood of support from the employees and the users of the technology are obtained and ease the implementation process.

7.1.3 Identify the Customer and Establish Ownership

One of the unambiguous perspectives from the interviews was that there has to be a customer. Regardless if the customer is an internal project owner, department manager, or someone from an external company, not having a customer that is passionate about and wants the new technology is a source of failure. The initiatives must also have owners that assemble implementation teams and encourage accomplishment. Conventionally, these teams are IT-dominant, and having representatives from interdisciplinary functions increases the prospect of benefiting all departments and parts of the organization. Consequences of lack of customers or ownership are often costly, demanding for employees and have commercial risk.

7.1.4 Finance a Support Team

Demanding digitalization initiatives and improvements need a proper support team supported by internal project funds to ensure that the projects and the employees receive the support they need. The support or improvement team can consist of both internal and external resources, preferably with a multidisciplinary background so that the supporting team is of a similar level of computer-knowledge as the employees. For the most part, IT support is good, but the uses, opportunities, and improvements that the technologies provide are less evident and accessible. Likewise, there needs to be acceptance for such a support team, and it must be easily accessible to all employees, regardless of project, position, and location.

7.1.5 Train the Employees

Along with a functional support team, training of employees must be present. Classroom lessons, e-learning, online user manuals, and guidelines for use, are convenient to invest in when implementing complex technologies. New digital solutions are great, but without knowing how to use them correctly, the investments are not of much value. Help centers, forums, and digital training materials allow employees to feel safe and access the right information without a major inconvenience. A large investment in new technology requires a correspondingly large investment in user involvement, training, and support. User adoption is alpha and omega, and low return on investment could be expected without it.

7.1.6 Be Transparent and Communicate

With new technology, transparency and information sharing are central in making the rollout as seamless as possible. Sharing information on the advantages and giving responsibility to employees collectively increase credibility. Implementing new technology is a huge undertaking, and there is no reason to hide any information from employees on what will happen if the implementation fails or does not meet its expectations. Positive and negative feedback throughout the implementation will also enable future improvements that other departments or projects can use. By communicating the information to other parts of the organization, positive experiences will be sustained, while repeating errors is avoided. This seamless exchange of information between projects and departments is crucial to the fulfillment of the scalability and standardization of digital technologies and solutions.

7.1.7 Manage Change During Implementation

Chapter 6 alone emphasizes the importance of digital change management. As mentioned, managing change is an important factor in achieving the expected business benefits of an investment. Having a dedicated project manager or key personnel who has freed up time to handle the changes during the implementation can be valuable. Together with looking at the implementation as a process improvement project and not an IT project can help deal with changes during implementation. If the technologies or tools are large and complex, establishing a flexible, but a defined structure to solve the challenges and changes in the project at the right level with the right resources will allow an agile implementation. To easier handle and manage change during digital investments, it could be considered whether one or more managers with digital expertise should be included in the top management. Besides, including them in the top management emphasize previous arguments about how managers' commitment and presence in digitalization projects increase the likelihood of success.

7.1.8 Evaluate and Follow-up

After successfully implemented, good evaluation and follow-up separate the best from the second-best companies. Tracking the effectiveness and value of the implementations can be done by setting benchmarks for what the implementations are expected to accomplish. These benchmarks will reveal how the technologies are benefiting the projects in terms of cost, schedule, and performance. Also, this will ensure that the supplier of the digital solution delivers as expected. To enable this evaluation and follow-up, the company's ability to define roles and responsibilities is important. Enhancing competence through relatively limited extra effort can create good routines and standardize the implementation of new digital systems, which in turn can contribute to more profitability.

8 Realizing the Value of Digital Investments

It is essential to have an active plan and to monitor digital investments and initiative to get the money's worth out of the effort. As briefly discussed earlier in the thesis, realizing, measuring, and capturing the value of digital investments is often difficult due to the complexity and scope of digital technologies. For example, measuring the value from changing management software or going from Skype to Teams can be challenging. For that reason, this chapter will present some examples of how the workflow changes with the utilization of digital tools and provide as accurately estimated saving as possible for the various processes. The research throughout this thesis has shown that the digital technologies and tools realize improvements in three categories. They either have automation, visualization, or information sharing improvements. Examples of the two latter categories are presented in the next subchapters.

8.1 Visualization Examples

As the industry embraces technology innovations to address workforce challenges, augmented reality solutions have the potential to transform jobsite operations for construction inspectors by saving time, cutting costs, and improving safety with intuitive equipment and connected intelligence. Conventionally, the inspection process is done manually, often requiring more than one person from interdisciplinary areas, and can take a long time to document and circulate the information to others. With the use of AR-glasses or MR-headsets for remote inspection or verification, one person can walk around the construction site and capture real-time video and stream it live through a videoconference call. Devices can accurately track user location as they move around a large job site. With instant access to an intuitive searchable digitized database, the inspector can accurately align and compare what is being built to the building information model. Through the videoconference call, users can interact with and view the same as the inspector and thus execute a satisfactory remote inspection at a lower cost, time, and improved safety. Underneath is an estimation of cost savings with remote inspection from Aibel's yard in Thailand. Once purchased, the devices can also have other useful applications, for instance, employee training, job instructions, accurate measuring, QA in prefab, or visualization for customers.

<table>
<tr><th colspan="3">Conventional Inspection/Verification</th><th colspan="3">Remote AR/MR Inspection/Verification</th></tr>
<tr><th>Process</th><th>Amount</th><th>Cost (In NOK)</th><th>Process</th><th>Amount</th><th>Cost (In NOK)</th></tr>
<tr><td>Airline tickets for employees from Norway to Thailand</td><td>3 employees x 50 000 NOK</td><td>± 150 000</td><td>Procurement of AR/MR equipment and training (can be divided by number of campaigns needed)</td><td>2 devices x 30 000 NOK (Price of MS HoloLens 2) (Only 1 device needed, 1 backup in case)</td><td>± 60 000</td></tr>
<tr><td>1-week salary for the 3 + 1 employees</td><td>150 hours</td><td>± 150 000</td><td>Training/support of devices</td><td>1 x 2 000 NOK</td><td>± 2 000</td></tr>
<tr><td></td><td></td><td></td><td>Execution of inspection</td><td>2 hours x 4 employees</td><td>± 8 000</td></tr>
<tr><td colspan="2">Total estimated cost:</td><td>± 300 000</td><td colspan="2">Total estimated cost:</td><td>± 70 000</td></tr>
</table>

Table 4 - Cost estimation of yard inspection or verification with and without digital tool

8.2 Information Sharing Examples

Better information sharing across departments, projects, and throughout the organization, in general, was one of the key objectives by further developing and capitalizing on the digitalization initiatives in the organization. An example of improving the information sharing and thus save time, cut costs, and improve quality is by utilizing tablets or mobile devices in field operations. Similar to extended reality, an operator or supervisor can share live information with superiors when incidents occur. The major difference between the two technologies is the maturity both in terms of hardware and software applications in tablets and mobile devices favor. The figure below shows an example of the differences in workflow with and without the use of handheld tools. This admittedly only illustrates a single event; hence the value naturally becomes more substantial over time as more incidents occur and the processes repeat.

Assuming ten construction operators or supervisors in Thailand each have access to a tablet in the yard. If each of them experiences an incident like the one described below every day for a year, the estimated time and cost savings are as presented in table 5. Although the workflow example described below is accurate and may not occur in the assumed frequency, other similar processes in the yard that would benefit from having tablets or mobile deceives in field would likely make up for potential misconception.

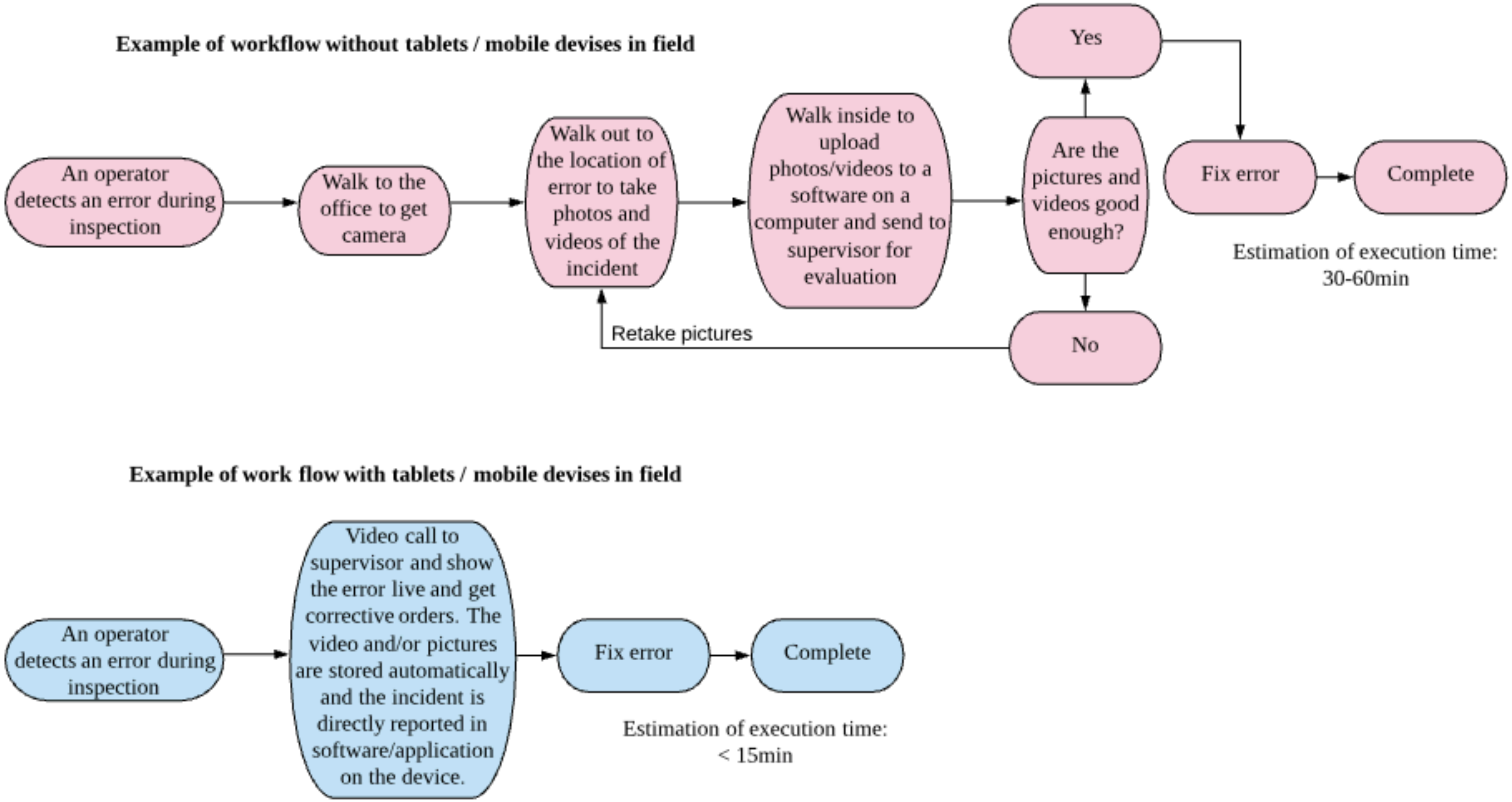


Figure 9 - Example of workflows with and without tablet / mobile devices is field

Without tablets / mobile devices				With tablets / mobile devices			
500 NOK / hour Avg 45 min per incident	Per week *(50 incidents)*	Per month *(200)*	Per year *(2400)*	*500 NOK / hour Avg 15 min per incident*	Per week *(50 incidents)*	Per month *(200)*	Per year *(2400)*
Hours	37,5 h	150 h	1800 h	Hours	12,5 h	50 h	600 h
Cost	18 750 NOK	75 000 NOK	**900 000 NOK**	Cost	6 250 NOK	25 000 NOK	**300 000 NOK**
Total estimated time to fix incidents per year:	± 1 800 hours			Total estimated time to fix incidents per year:	± 600 hours		
Cost of 0 devices	0			Cost of 15 devices *(5 extra in case)* (5 000 NOK per)	75 000 NOK		
Total estimated cost to fix the incidents per year:	**± 900 000 NOK**			**Total estimated cost to fix the incidents per year:**	**± 375 000 NOK**		

Table 5 – Estimated cost saving of devices in yard

9 Improved Digitalization

Paperless solutions
Simplified daily activities and tasks
Process improvement activities
Better information flow
Improved quality
Improved productivity
Improved business processes
Increased safety
Overall streamlined projects
Competitive advantage

Table 6 - Answers to "Can you describe what digitalization means?"

These are all answers from the six employees in Aibel working with or in close relation to digitalization. The question was simply, “Can you describe what digitalization means?”. Although the ten different bullet points to such a straightforward question are relatively similar, it is no wonder there is much of confusion surrounding the use and understanding of digitalization. Moreover, there was also a complete consensus between the interviewees that there is no common understanding of the concept within the company, nor in the industry.

For the industry to successfully digital transform, creating strategies that emphasize transforming the business and not focusing on technologies is central. In digital mature organizations, digital transformation is led from the top. The management must therefore have the necessary skills, understanding, and interest in involving digital in the overall business strategy. Thus, it is in the author’s belief that starting with a collective understanding of the terms and buzzwords throughout the organization is necessary to succeed.

Section 5: Discussion & Conclusion

10 Discussion

The scope of this thesis focused on how existing and developing digital technologies and tools could help streamline an offshore wind platform project and related EPC projects of the future. Low productivity growth, low degree of digitalization, and low investment in R&D are where the industry is at. Coupled with increasingly larger international competition, an increasing proportion of fixed-price contracts, and society with progressively more digital knowledge, the revolution cannot come fast enough. A study on digital technologies and their potential has therefore been conducted to overcome some of the challenges the industry face. These technologies were: big data, cloud analytics & smart sensors, digital twins, hyperautomation & autonomous things, multiexperience, mobile devices & tablets in field, building information modeling, additive manufacturing, and related sub-technologies.

A few years ago, the industry had hardly heard of digitalization, and an explanation of the related buzzwords was desperately needed. Together with a clarification of the fourth industrial revolution, industry 4.0 concepts, and the status of the EPC industry, the foundation for further technology mapping was established. Through an elaboration and assessment of technologies, their relevance to EPC projects, requirements for digital change management, along with a recommendation on how to succeed with the implementation, the scope of the thesis has in the author's belief been achieved.

The flexibility, value, and certainty that symbolizes the EPC contract model have proven to be possible to enhance digitally. In the design phase, further development of building information modeling, digital twins, and visualization tools can reduce errors. At the same time, big data analytics and robotic process automation can increase collaboration and streamline the procurement phase. In construction, value and certainty can be significantly increased by a higher degree of automation, through autonomous things, 3D printing, visualizations tools, and predictive maintenance. Some of the initiatives evaluated, such as those quantified in this thesis, should be relatively simple business cases to defend based on the value they add. Others necessarily require more detailed research, especially from an IT standpoint, before investment decisions are made. At the same time, it is important to remember that increased intelligence in each part of the EPC projects implies more complexity and operational risk. This must be accounted for and carefully considered before each technology is implemented.

Constraints to the adoption and implementation of the technologies addressed are mostly cost, skill, cybersecurity, and tradition related. Questions about whether technologies are mature and efficient enough to invest in arise as costs continue to drop even with exponential growth in functionality. Monitoring of the technological development and pilot tests on projects to measure actual profitability will enable informed decisions on the feasibility of the technology. As pointed out earlier, digital investment arguments often lose against budget reasoning without comprehensive piloting. With each separate project looking at the ROI of digital initiatives for their specific project instead of assessing the total lifecycle value of the technologies in all projects, there is no wonder why investment arguments often fall short. The scope and uses of digital technologies are enormous, and one specific tool can often be utilized in numerous projects and departments. This way, future investment decisions could more easily be in favor of new digital technologies.

As to which digital technologies and tools that can be implemented to create value and streamline an offshore wind platform project, it is unreasonable to look past multiexperience and smart devices in field operations for visualization purposes and improved productivity. These devices are ready, whether it is tablets, mobile devices, smart headsets, or extended reality glasses, and will altogether remove paper solutions and improve the projects in all the ten areas suggested by the Aibel employees. Implementing these across the projects will reveal where and how they are most advantageous. The workflow improvement and cost-saving examples in this thesis can be elaborated and should be sufficient to get them rolled out. Once introduced, it will be easier to develop the applications further and eventually combine them with more advanced technologies. These are often dependent on other lower level technologies and starting with streamlining measures such as smart devices is therefore recommended.

On the other hand, implementing various technologies and tools without a sufficient plan and preliminary studies contradict the implementation guideline presented earlier. Naturally, it is about finding the perfect balance between technology development and safe and sensible operation of the company. To be an industry leader in digitalization and technology, it is necessary to take on some risk. However, through a deep understanding of collaboration, the commitment of top management, and a clear strategy, the chances of a calculated risk are significantly higher, and thus chances of success correspondingly greater.

10.1 Main Challenges

Although there have been many challenges during the work on this thesis, some have proven to be particularly demanding. Firstly, exploring what for the author were relatively unknown fields such as digitalization and EPC projects was rather time-consuming. Especially combining the two fields, and their relevant technologies, conceptions and work processes, has been challenging. Further, as the conversations and interviews with personnel in Aibel clarified the need for an implementation guideline, the scope also changed to address digital change management and how to implement digital tools and technologies. Finally, an obvious challenge was to narrow down the scope of an enormous field of study and keep a red thread throughout the paper.

10.2 Future Research

Future research on digitalization initiatives to streamline the Dogger Bank project could be within several areas as this thesis display the enormous potential of digital technologies. Further investigating the examples in this thesis, regarding what hardware and software are best suited, how many devices are needed, and the specific uses in the project, could be of interest. Also, aligning the digitalization initiatives in the Dogger Bank project with previous and future projects in Aibel could enhance the benefit of the research to provide greater opportunity for granting and profit.

Concerning research on digitalization of EPC projects in general, different perspectives could be chosen, and either a strategic, organizational, or technical perspective are interesting points of view. Digital change management could also be subject to an independent study as the scope and importance of this field for successful digitalization is enormous. Otherwise, future research might apply the established mapping of technologies to further increase the level of detail in each technology. The potential impact that the various technologies can have on the industry is so great that each one could have been subject to a master's thesis in itself.

11 Conclusion

This research aimed to identify which digital technologies and tools that could be implemented to create value and streamline an offshore wind platform project. In addition, it studied how these initiatives could be successfully implemented and how digital change management affects technology implementation. Based on the qualitative analysis and the literature review, it can be concluded that the technologies and tools are at different stages of development and of different importance to an EPC project. Certain technologies are ready to create value and streamline the Dogger Bank, while others need considerably more research and facilitation before they can be implemented.

The results reveal that solutions like multiexperience, with extended reality and smart devices in field operations, together with greater connectivity through digital yards, twins, and workplaces, allow more remote operations that are highly valuable for the projects. Additionally, when combining these technologies with automation in the construction phase, and gradually also with artificial intelligence and machine learning, the old and outdated EPC model could be enhanced in most areas with the aid of digital technology.

However, the research also highlights that combining the right digital technologies and tools in the right areas, while developing a digital culture and understanding that supports the overall business strategy, is difficult to achieve. It also recognized that implementing various technologies and tools without a substantial foundation and facilitation will have a negative effect on profitability. There is little to no doubt that all technologies explored throughout this thesis somehow can streamline and create value in such projects. For that reason, the greatest challenges lie in designing for these technologies to be implemented in the best possible way.

No matter what technologies or tools are chosen, there will always be challenges with the implementation. Following the implementation guideline, while trying to acquire the most beneficial digital change management processes will, however, pave the way for a successful transition into a more efficient, profitable, and competitive digital business.

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Appendix A

Intervjuguide

Hei! Mitt navn er Paal Soltvedt Brakstad, og jeg holder nå på å avslutte min mastergrad i Industriell Økonomi ved Universitetet i Stavanger. I den forbindelse skriver jeg masteroppgave om digitalisering og effektivisering av Aibel sin del av prosjektet Dogger Bank ved hjelp av digital teknologi. Dette intervjuet er en del av flere intervjuer med relevant personell i forskjellige avdelinger hos Aibel for at grunnlaget for analyser og diskusjon i oppgaven har tilstrekkelig kvalitativt data som grunnlag. I masteroppgaven undersøkes det hvordan digital teknologi- og verktøy kan bidra til å effektivisere et offshore vind plattform prosjekt og tilsvarende EPC-prosjekter i fremtiden.

Intervjuet som gjennomføres er fullstendig anonymt. Navn eller annen sensitiv informasjon som kommer ut av intervjuet vil ikke bli brukt. Det er utformet som et semi-strukturert intervju hvor tema og til dels også spørsmålene er forberedt på forhånd, men det er også ønskelig med innspill som er relevante utenfor temaet som diskuteres. For at mine anbefalinger og konklusjoner i oppgaven skal bli så god som mulig, ønsker jeg så ærlige og subjektive meninger som mulig under intervjuet. Jeg vil gjerne benytte anledningen til å takke for tiden din og ikke minst ditt ønske om å bidra til datainnsamlingen i oppgaven.

#	Spørsmål	Relevans
1	Kan du starte med å fortelle litt om deg selv om din rolle i Aibel?	Generelt
2	Kan du beskrive hva du personlig mener med begrepet digitalisering?	Generelt
3	Hvordan synes du Aibel håndterer digitalisering i dag? *Føler du at det er en felles forståelse for begrepet innad i Aibel? At alle vet hva det innebærer?*	Generelt
4	Hvordan synes du at digital teknologi endrer bransjen i dag, og hva tror du er de viktigste endringene for fremtiden?	RQ2
5	I denne oppgaven ser jeg mer på digitale verktøy og teknologier som kan effektivisere prosjekter, istedenfor den overordnede strategien rundt digitalisering. Derfor er jeg interessert i å vite hvordan du synes de digitale verktøyene du bruker i hverdagen fungerer. Da tenkte jeg at du kunne begynne å fortelle litt om hvilke digitale systemer du bruker. *Hvordan var det før? Føler du at digitale verktøy har gjort det lettere og mer effektivt å få gjort arbeidsoppgavene dine?* *Er det noen av disse verktøyene du tenker kunne vært brukt bedre?*	RQ2
6	Er det noen spesielle nye digitale teknologier du har tro på at Aibel kan utnytte i fremtiden? Da tenker jeg mer på teknologier, og ikke selve verktøyene. *F.eks. droner, AR/VR, touchskjermer, robotteknologi, etc.* *Og i hvilken del av bedriften tror det eventuelt vil benyttes?*	RQ2
7	Hvilke ulike deler av prosjekter som har de største kostnadsdriverne varierer en del fra prosjekt til prosjekt.	RQ1

	I hvilke deler av arbeidet til Aibel tror du at det foreligger størst potensiale for kostnadsreduksjon og effektivisering ved hjelp av digital teknologi? Tenker spesielt i forhold til EPC-kontrakter. *Er det ingeniørarbeid, innkjøp eller bygging som har det største potensiale?*	
8	For å evaluere digitaliserings-initiativer må beslutninger tas. Kan du beskrive litt om grunnlaget for beslutninger i Aibel i forhold til implementering av digitale initiativ? *Hvilke kriterier må oppfylles for at et digitalt verktøy eller teknologi skal bli tatt i bruk i Aibel?* *Er det her noen forskjeller fra prosjekt til prosjekt?*	RQ3
9	I dag snakkes det om at digital teknologi innføres så raskt at ansatte ikke klarer å utnytte dem til det fulle. Når et nytt digitalt verktøy blir bestemt i Aibel, hvordan synes du implementeringen av det virker i praksis? *Får man vite om det i god tid før implementering?* *Får man god nok oppfølging fra dag én? Og eventuelt god nok støtte hvis man står fast?* *Hva mener du er det viktigste i implementeringen av et nytt digitalt system eller verktøy?*	RQ3
10	Har du eller kjennskap til digitale verktøy Aibel ikke benytter som du tror kunne vært verdifulle?	RQ2