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Author: Kari-Anne Håvardsen	<i>Kari-Anne Håvardsen</i> (signature of author)
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Identification and evaluation of innovation
opportunities emerging from new technology in
the Pre-Fabrication part of Norwegian Offshore
yards

By
Kari-Anne Håvardsen

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Abstract

The Oil and Gas industry is the largest industry in Norway, making the supplying industry an important and profitable industry. Norwegian Offshore yards provide the oil and gas companies with products and services to develop, build, maintain and demolish offshore platforms, onshore plants, ships and other equipment.

Competition is big between the offshore yards, and other countries' providing cheaper products steals customers, making it important for the Norwegian yards to be innovative and upgrade their companies to make them more competitive. With all the globalization that has occurred the competition has gotten even harder, and an unstable Oil price resulting in an unsecure market for the offshore industry, the pressure and expectations are even higher for the Norwegian Offshore yard to deliver.

A huge part of being innovative in the industry of pre-fabrication is to implement and use new technologies. These technologies help to reduce the delivery time, make the production more efficient, reduce the costs and increase the quality.

The purpose of this thesis is to identify and evaluate the potential for using new technologies at Norwegian Offshore Yards, helping them to stay innovative, be able to compete with foreign yards, and maintain the industry inside Norway.

Some of the technologies that have emerged after research for the thesis, and potentially can be implemented is digitalisation, by using cloud storage and cloud computing, sensorization with use of smart sensors, measuring real-time data, autonomization by making the machines and equipment automated and start using robots, and connectivity, connecting all the machines, devices and sensors together through internet in combination with AI. All of this combined has the potential to in the future result in a fully automated pre-fabrication, with no human interference, only human supervision.

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List of Abbreviation

AI – Artificial Intelligence

CPS – Cyber Physical System

3D – Three-dimensional

NDT – Non-destructive testing

TIG – Tungsten Inert Gas (welding method)

K-TIG – Keyhole TIG welding

RFID – Radio-Frequency Identification

RTLS – Real-time Location Systems

UI – User Interface

PHM – Prognostics and Health Management

CPI – Machine-cyber interface

AR – Augmented Reality

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1. Introduction

The introduction part is a briefly explanation of the industry, and the background for choosing this industry. It also contains a short presentation of some of the key companies within the industry. A breakdown of the industry is also conducted to narrow down the thesis to one specific segment. The object and limitation of the thesis is also presented.

1.1 Industry

1.1.1 Offshore yards

The Petroleum industry is the largest industry measured in value creation, state income and export value (Regjeringen, 2014). The industry is a key player in the Norwegian economy and financing the welfare system. In addition to the income from the industry, it also results in an industry based on delivering services and products to the petroleum industry. As a result of this growth in supporting industry for the offshore industry the knowledge and experience have made the industry able to compete in the global market, and has expanded the market (KarriereStart).

1.1.2 Key Companies and what they offer

Aibel is a service company for the oil, gas and offshore wind industries. They have two yards, one located in Haugesund, Norway, and one in Laem Chabang, Thailand, as well as nine offices located in Norway, Denmark and South East Asia. Services they offer are modification, field development, renewables, yards, projects on track, flexile barriers, MOPUD, installation and service (Aibel).

Kværner delivers complete oil and gas platforms and onshore plants, and has specialised in engineering, procurement and construction. It is a global company with its main office in Oslo, and two big yards on Stord and in Verdal. The solutions and services the company offers are steel structures, topsides, concrete solutions, onshore facilities, subsea on a stick, decommissioning and services and piping technology (Kværner).

Aker Solutions is according to their home page “*a global provider of products, systems and services to the oil and gas industry*”. They provide products and services throughout the

lifecycle of an oilfield, field planning and studies, design of floaters and deep-water risers, offshore wind solutions, specialist engineering, project management and procurement service and wellheads (AkerSolutions).

Westcon is a family company with its main office and the largest yard located in Ølensvåg. The company has several departments: Yards, Power & Automation, Lifting techniques and Geo. Together they become a total supplier to the offshore, maritime and energy industry. It is the Yard part of the company that provides rig and ship repairs, maintenance, modifications, subsea, pipe technology and engineering (Westcon).

Nymo is located in Grimstad and Arendal, and is a company that provides services in engineering, procurement and construction for the oil and gas industry. More specific the services provided are engineering, drilling packages, process modules, living quarters, gas turbine systems, subsea and rig completion and upgrade (Nymo).

Luster Mekaniske Industri is located in Gaupne and is a company that is specialised in prefabrication of piping systems, for both offshore and onshore plants (Industri).

1.1.3 Background for choosing this Industry

The oil and gas industry is the largest industry in Norway, which makes the industry delivering to the oil and gas industry extremely important (Regjeringen, 2014). It is especially an important industry for the oil and gas cities, where a large number of the workplaces is within these companies.

Since it is a high competitive market it is important for the Norwegian companies to be able to compete with companies all over the world (Gjerde, 2015). And with technology constantly being developed and improved, there are many new opportunities and improvements that can be done in this kind of industry.

After writing a Bachelor thesis for a company in the offshore yard industry it became clear that this is an industry with a lot of uncertainty in the amount of work, and where they hesitate to use money on upgrading when the market is changing. Looking at the technologies that are emerging it will be necessary for these companies to keep up with this trend and benefit from it, rather than be defeated by it.

1.1.4 Challenges in the Industry

The yard industry in Norway is, as said, an extremely competitive industry, with Norwegian yards competing with each other and with yards all over the world (Gjerde, 2015). Like the competition from South Korea, which provides services and products at lower costs. The reason is that work power is cheaper, taxes to the government is less than in Norway, cheaper materials and much more use of robots and automated technology.

There are new technologies constantly being developed, and it is necessary to be updated and implement new technology, to be able to compete with other companies. This can be challenging for the companies, and it is therefore important that they focus on innovations that can benefit the company.

Customers of the offshore yards most likely want their project to be executed at the shortest amount of time, and as cheap as possible. It is important for the yards to create effective production lines to be able to compete and win contracts for projects.

Therefore, a decrease in the production time will be a competitive advantage, securing more work and potentially opening up for new customers.

1.2 Objective

The objective in this thesis is identification and evaluation of innovation opportunities emerging from technology trends for the Pre-Fabrication part of Norwegian offshore yards. The main focus will be on new and innovative solutions that will help the companies reduce their production and operation time. Time equals money, and time saved is money saved in this industry. The goal with the thesis is to find innovative opportunities from new technology that can help the Norwegian Offshore yards in the competitive market by choosing a segment of the industry to study closer, the Pre-Fabrication segment.

1.3 Restrictions in the thesis

The chosen industry is a large industry, with many different segments. Since there is a limited time available for the thesis, only a segment of the industry will be evaluated. It is an industry where products often vary based on customer specifications, and specific economic savings are difficult to calculate. The thesis is therefore limited to the technologies that will help the

companies save time. As a result of the limited knowledge about details in the technologies, the representative technologies are explained on a level necessary for evaluation in the thesis. The industry segment is also evaluated as a whole production line, without going too deep into each of the work operations.

1.4 Structure of the thesis

Six parts build up this thesis. The first part is an introduction explaining the background for the thesis, the chosen industry segment, limitations and the purpose of the thesis and the content.

Second part of the thesis is a short presentation of the methodology used in the thesis. The chapter also explains why this methodology is chosen, how the research has been conducted and the reliability and validation of the thesis.

A description of the theory relevant for this thesis is found in the third part. Here all the tools, models and technologies that is relevant for the thesis is described to build up a basic understanding for the topic in the assignment.

The fourth part is the mapping and analysing of the different opportunities that emerges from potential usage of new and innovative technologies. The possibilities will be presented, evaluated and measured against each other to find the best options for innovation.

As a result of the theory, mapping and analysing the fifth part of the thesis is a discussion where findings and results are being evaluated and discussed, highlighting benefits and challenges.

The sixth part is the conclusion. Here the result from the discussion forms a conclusion on the object of the thesis, and recommends further developments on the object.

1.5 Breakdown of the Industry

The Norwegian offshore yard industry is a large industry with many companies involved, and a breakdown of the industry is needed to get a better understanding of the aspects of the industry.

To be able to break the industry into segments, a generalisation of what the different companies offers is needed. The segment Engineering is all the services regarding studies, planning, designing and project management, shown in *Table 1*. The Pre-Fabrication segment is the part of the industry where the yards pre-fabricate pipes and structures for their projects, shown in *Table 2*. Shown in *Table 3* the Maintenance segment is all the projects regarding maintenance of ships, platforms and equipment. Last the modification part is all projects where work is done to upgrade or change already existing equipment, platform or ship, shown in *Table 4*. (Tables provided by supervisor and his assistant.)

Industry segment		Engineering
Value creation flow	Process flow	Dialogue with the customers, studies, designing, mapping of the requirements, modelling, following procedures, project management, modification, completion
	Skills	Knowledge, experience, qualified personnel, certifications
	Cost/ cost structure	Amount of work, size of the project, specifications, time perspective
Market	Needs covered	Offshore industry
	Main customer groups	Offshore companies
Key	Key challenges	Price, time perspective, quality
Other	Other factors	Global competition

Table 1 Breakdown of Industry, Engineering segment

Industry segment		Pre-Fabrication
Value creation flow	Process flow	Materials, specifications, production, testing, quality check, installation, completion
	Skills	Knowledge, experience, equipment, qualified personnel
	Cost/ cost structure	Workload, project size, time, equipment, power, personnel
Market	Needs covered	New platforms, equipment, pipes, structures, subsea equipment
	Main customer groups	Offshore companies and offshore industry, ships
Key	Key challenges	Price, time perspective, quality of the work, required specifications
Other	Other factors	Global competition

Table 2 Breakdown of Industry, Pre-Fabrication segment

Industry segment		Maintenance
Value creation flow	Process flow	Planning, scheduling, execution
	Skills	Knowledge, experience, routines, qualified personnel
	Cost/ cost structure	Price, time perspective, amount of work, quality of the work, required specifications
Market	Needs covered	Maintenance of platforms and onshore installations
	Main customer groups	Oil and gas companies, marine companies
Key	Key challenges	Price, time
Other	Other factors	Global competition

Table 3 Breakdown of Industry, Maintenance segment

Industry segment		Modification
Value creation flow	Process flow	Studies, planning, modelling, improving
	Skills	Knowledge, experience, routines, qualified personnel
	Cost/ cost structure	Price, time perspective, amount of work, quality of the work, required specifications
Market	Needs covered	Maintenance of platforms and onshore installations
	Main customer groups	Offshore and marine industry
Key	Key challenges	Price, time
Other	Other factors	Global competition

Table 4 Breakdown of Industry, Modification segment

There are potential for improvement and adding new technology in all of these industry segments, but the one chosen in this assignment is the Pre-Fabrication part of the industry. This is the part of the industry where the work is done inside workshops at the yards, and it is an important segment for the companies to have the desired range of products for their customers.

1.5.1 The Pre-Fabrication segment

The Pre-Fabrication segment consists of the fabrication of mainly structures and pipes. According to Safa, Shahi, Nahangi, Haas and Noori in their article regarding Automated Measurement Process to Improve Quality Management for Fabrication (Safa et al., 2015), prefabrication can be defined as: *“a manufacturing process, generally taking place at a specialized facility, in which various materials are joined to form a component part of a final installation.”*

When yards are building platforms and/or ships they fabricate pipes and structure that are used in building these as a part of their project. Pipes in different metals are stored at the yards, and when it is needed they are being bent and welded to fit at the platforms and ships. Structures are also metal parts welded to be support for equipment, stairs and railing.

The projects are customized based on customers' wishes, and looking at this industry segment the customization part is a service the companies provide to their customers.

Today human workers mainly perform the production, but some of the companies have started using bending machines and welding robots to help make the production more efficient and save time.

2. Methodology

The second chapter in the thesis describes the different methods, and the methodology used in the thesis. The research approach is described, and an evaluation of the reliability and validity of the thesis is conducted.

2.1 Qualitative Methodology

A Qualitative method is used when the user wants to understand a phenomenon instead of measuring it. Simplified Qualitative research uses only verbal analysing methods. The intention with qualitative research is to gain new and deeper understanding and knowledge (Patel et al., 1995).

2.1.1 Document and text analyses

It is possible to collect data by searching for written documents and texts, and to analyse this to answer the problem. What sources to use are decided by the issues, and the topics studied.

2.2 Quantitative method

The quantitative method of research is simplified described as a research method using statistical processing and analysing methods (Patel et al., 1995).

2.3 Reliability and validity

Reliability is how reliable things are, and are a measure on how trustworthy something is. All measurements that have theoretical or practical interest should have a high degree of reliability (SNL).

The validity of something tells how valid or durable something is (SNL). If a test is valid it needs to be reliable. However, it does not mean that a reliable test is also a valid test. This is because the validity tells if the test measures the property it is meant to measure, not the stability of the measurements (Patel et al., 1995).

2.4 Primary and secondary data

The webpage Business Dictionary (BusinessDictionary) defines primary and secondary data as:

“Data observed or collected directly from first-hand experience. Published data and data collected in the past or by other parties is called secondary data.”

2.5 Choice of method

In this thesis document and text analysis, and qualitative method, has been used to gather all the needed information. To get the most valid and reliable information, the information has been gathered from large companies, textbooks and scientific articles. All data in this thesis is secondary data, and there are no primary data.

2.5.1 Research approach

This thesis is mapping the different types of new technology Norwegian offshore yards has the opportunity to enable in their pre-fabrication workshops. The intent with this thesis is to give a systematic overview of the potential in enabling innovative solutions, making the companies more competitive.

2.5.2 Reliability and Validity of the thesis

The thesis is based on literature reviews and researches concerning new technology and technology trends. Some of the literature may be of a subjective nature, since the information is gathered from the suppliers and information sources, which can have biased opinion.

3. Theory

This section contains the theory needed to map and analyse the potential new technologies, and to further evaluate them. This theory will be the baseline for the thesis, and the further analysis and discussion. Theory on the concepts, analysing tools and the technology is provided.

3.1 Innovation

The definition of innovation varies, but according to Joe Tidd and John Bessant (Tidd and Bessant, 2009) all of them focus on the need to complete, develop and explore aspects of new knowledge, not just on the inventions. Innovation is often confused with invention, and as described in the book *Managing Innovation* by Joe Tidd and John Bessant (Tidd and Bessant, 2009), managing innovation can therefore be problematic, because people do not have the same understanding about innovation.

Joe Tidd and John Bessant (Tidd and Bessant, 2009) uses a simple model of innovation as the process of turning ideas into reality and captures the value of them. This model consists of four parts. The first part is the searching part, the second part is selecting the options that are most likely to help growth and development, the third part making a strategy on which of the options to carry though and why, and the fourth and last part is to implement, converting the ideas into reality.

According to the book *Managing Innovation* (Tidd and Bessant, 2009) there are four dimensions of innovation, called the 4P, as shown in *Figure 1*, which are:

- Product innovation – changes in things (products/services) that an organisation offers.
- Process innovation – changes the ways in which they are created and delivered.
- Position innovation – changes in the context in which the products/services are introduced.
- Paradigm innovation – changes in the underlying mental models which frame what the organisation does.

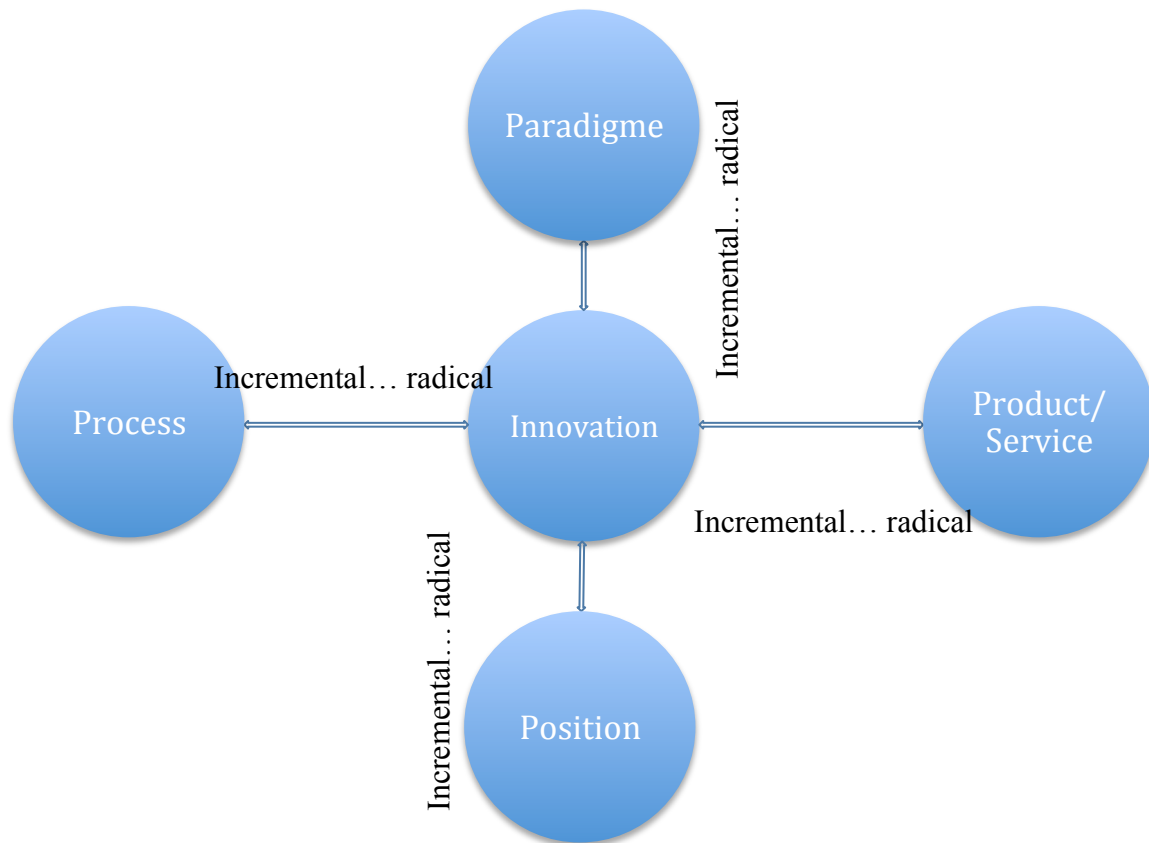


Figure 1 Innovation model, from the book *Managing Innovation* (Tidd and Bessant, 2009)

3.2 Competitive advantages

(This section is from the students project in the subject OFF590.)

Companies with a broad scope compete in many segments within the business, and have a variation in the products they offer (de Wit, 2014). Companies with a narrow scope aims at just one or a few segments, and therefore becomes more limited. There are parts of the industry with specific demands, and this makes it possible for companies to narrow their focuses on niches as a competitive advantage. To develop a competitive advantage there are several actions the companies can do to outdo the rivals. Some of them according to de Wit (de Wit, 2014) are:

- Compete on price. Buyers generally prefer to pay the lowest possible price for a product or service. It is therefore important for the companies to be able to compete on price by having low cost products, value chains and resource base to match other rivals.
- Offer different features. Companies can make their products or service more unique by having different features and functions. To be able to offer this the companies must

have different and specialised resources and value chains, and have the required technology and knowledge as well as the capability to offer the features.

- Sell a bundle of products or service. By offering a package of products or services together can be unique and value adding, as well as giving the customer of a getting what they need in one place and that the products and services fits good together.
- Have a great quality on the products and the services. In the competition against other rivals it is important to have the best product or service, and the customers can often be willing to pay more for a higher quality.
- Product and service availability. To have the product or the service available at the right time, place and way can be even more important for the customers than the quality or the features.
- To have an appealing image can be an advantage. When competing with other rivals the image can attract costumers if it is appealing, and it makes the companies look trustworthy.
- A good relationship with the customers and suppliers is an advantage. The customers prefer to feel like they know or have a familiarity with the company they deal with to feel safer, also it is more likely to get better deals or have more influence under dealing with suppliers if there are good relationship between the company and the supplier.

A competitive advantage is sustainable if other rivals cannot copy or substitute it, or the developments in the environment make it redundant by other and better products or services being offered.

3.3 Analysing tool: SWOT analysis

A SWOT analysis is a tool that can be used to analyse a company's strengths, weaknesses opportunities and threats (Ghazinoory et al., 2011). It is often set up as a figure, as shown in *Figure 2*.

The strengths are what your business is doing well. There may be good delivery terms, cost-effective production, a better product or environmental profile. The weaknesses are what the company are bad at, and one can therefore more easily prioritize what should be improved

and insert the correct measures. Both analysis of strengths and weaknesses are internally (Brudvik).

Analysis of the potential of the business is to identify different potentials for business and what they can do to exploit them. It may be to establish themselves in new markets, hijack a greater market share, cooperation with or acquisition of other companies. The threats are challenges the business is facing. When one analyses the company's potentials and threats one looks at the external impacts that can help or prevent businesses from reaching their goals (Brudvik).



Figure 2 Example of template for SWOT analysis, inspired from Brudviks design (Brudvik)

3.4 Industry 4.0- Emerging Technology Trends

There is no definition of Industry 4.0, but it regards the integration of production facilities, supply chains and service systems to enable the establishment of value added networks (Ustundag and Cevikcan, 2018). The emerging technologies necessary to succeed in Industry 4.0 are according to Ustundag and Cevikcan (Ustundag and Cevikcan, 2018) big data analytics, autonomous robots, cyber physical infrastructure, simulation, horizontal and

vertical integration, Industrial Internet, cloud systems, additive manufacturing and augmented reality.

A framework with a network of sensors, real-time processing tools, role-based and autonomous devices where they communicate and interact with each other, collecting real-time data from manufacturing and service systems must be constructed (Ustundag and Cevikcan, 2018).

The book Industry 4.0: Managing the Digital Transformation (Ustundag and Cevikcan, 2018) states that before implementing industry 4.0 there are design principles that need to be considered to provide a demanding adaption of such systems with coordination and communication between the components. They are: Agility, Interoperability, Virtualization, Decentralization, Real-time data management, Service Orientation and Integrated Business processes.

3.4.1 Technology trends 2018

According to Jayson DeMers at Forbes (DeMers, 2017) there are seven technology trends that will dominate 2018. They are:

1. AI permeation, machine learning algorithms are getting better and more founding, and is therefore incorporated into a more diverse range of applications, and become more mainstream.
2. Digital centralization, consumers want to be able to manage everything from as few devices and central locations as possible.
3. 5G preparation, the 5G network has potential to be almost 10 times faster than 4G, making it better than most home internet services, resulting in a new generation internet.
4. Data overload, consumers relying more on digital devices for most of the daily tasks will result in companies getting access to and start using personal data, which means less privacy, more personalised ads, but also positive things like better predictive algorithms in healthcare.
5. White-collar automation, more advanced AI will increase the use of automation in jobs, and change work places.
6. Seamless conversation, improvements in recognising speech and use of robotic speech and chatbots will make it possible to communicate with devices, both ways.

7. UI overhauls, for interacting with devices and apps, desktops will become less used, and visual and more audible communication will be the next generation UI.

3.4.2 Standardising

The businessdictionary (Businessdictionary) defines standardization as:

“Formulation, publication, and implementation of guidelines, rules, and specifications for common and repeated use, aimed at achieving optimum degree of order or uniformity in a given context, discipline, or field.”

Investopedia (Investopedia) says that *“standardisation is a framework of agreements to which all relevant parties in an industry or organization must adhere to ensure that all processes associated with the creation of a good or performance of a service are performed within set guidelines. This ensures that the end product has consistent quality and that any conclusions made are comparable with all other equivalent items in the same class.”*

These definitions show that the meaning with standardization is to gain consistency and maintain a certain quality on similar products, services and operations. An example is the wood product industry where there are international standards to maintain consistency in products, ensuring the customers that a two-by-four is the same regardless of which store he buys it in (Investopedia).

3.4.3 Digitisation

David Burkett at the web page Workingmouse (Burkett, 2017) defines digitisation as:

“Digitisation is the process of converting information from a physical format into a digital one. “

Regarding digitalisation, the web page Workingmouse (Burkett, 2017) defines digitalisation as:

“Digitalisation is the process of leveraging digitisation to improve business processes.”

Relocating data and processes to cloud storage makes it easier for the workers to access information on their projects, and it also makes it easier for customers to access information

about their products or services (Burkett, 2017). But it is necessary with a reliable cloud storage provider, and a good Wi-Fi system (Burkett, 2017).

3.4.3.1 Mobile technology

In the last years the mobile devices have become more than communication tools, the use of Internet makes it possible to receive, process and send large amounts of information and data (Ustundag and Cevikcan, 2018). High quality cameras and microphones make it possible to record and transmit information. In the implementation of technologies in Industry 4.0 communication and networking is a huge part of this, where connectivity to non-living objects makes it possible for the companies to communicate with them, and issues can be detected and dealt with much earlier (Ustundag and Cevikcan, 2018).

3.4.3.2 Smart devices

Techopedia (Techopedia) defines smart devices as “*an electronic device that is able to connect, share and interact with its user and other smart devices.*” Making all devices that are interactive and understand simple commands smart devices. Some of the most common devices are smartphones, tablets, smart watches, smart glasses and other personal devices, but today also TV and refrigerators are connected to a network for sharing and interacting and are therefore smart devices (Techopedia).

3.4.3.3 Big Data

The capacity of computers has increased and resulted in the possibility to gather, storage and analyse a large amount of data, which provides large amounts of information leading to interconnectivity with the usage of computing methods and databases (Emrouznejad, 2016). According to Emrouznejad (Emrouznejad, 2016) the term Big Data appeared for the first time in a paper by Cox and Ellsworth describing the challenges facing computer systems when the data is too large to store in the local memory or remote disks. Google is a company working a lot with big data, and they and other companies have made available open-source tools like Hadoop, Bigtable and MapReduce (Emrouznejad, 2016).

Mark van Rijmenam (Van Rijmenam, 2014) explains Big Data using the 7Vs, which are:

- **Velocity:** the speed, of which the data is created, stored, analysed and visualized.

Today the data is created in real time or near real time, and with the use of Internet

connected devices and wireless or wired machines can share this data the same time it is created.

- **Variety:** most of the data today is unstructured, and it can come in many different formats like structured, semi structured, unstructured and complex structured, and each type of data requires a different type of analysis and tools to interpret.
- **Volume:** with the creation rate of data today the amount will double every two years, and all this data contributes to the expanding digital universe, the Internet of Things.
- **Veracity:** the generation and collection of data at a high speed needs to be used correct for it to be valuable, incorrect data can result in problems for the organisation and the consumers.
- **Variability:** means that the definition is changing (rapidly), and to perform proper analysis algorithms to decipher the exact meaning of the data in the context is needed, which is very difficult.
- **Visualization:** making the vast amount of data comprehensible in a way that is easy to read and understand, and with the right visualisation this raw data can be used properly.
- **Value:** all the available data will create value for the organisations, societies and consumers, but it is not the data itself that creates the value but the analyses and how the data is turned into information, knowledge and wisdom.

3.4.3.4 Cloud technology

Cloud storage is an important part of the digitisation, where it is possible to store digital data in a “storage space” in the “sky”. Techopedia (Techopedia) defines cloud storage as:

“Cloud storage is a cloud-computing model in which data is stored on remote servers accessed from the Internet, or “cloud.” It is maintained, operated and managed by a cloud storage service provider on a storage server that is built on virtualization techniques.”

Cloud storage is a virtual storage that can be delivered through a public service provider, then the cloud storage is known as utility storage, or through a private storage provider which provides the same as a public provider, but with restricted or non-public access (Techopedia). Since the cloud technologies has been more advanced lately it has resulted in a decreasing amount of reaction times, making the manufacturing data easier to used to provide a data-

driven decision making for both service and production systems (Ustundag and Cevikcan, 2018).

According to Ustundag and Cevikcan in the book Industry 4.0: Managing the digital transformation (Ustundag and Cevikcan, 2018) the requirements of cloud based processing is:

- Data driven applications are worked on cloud-based infrastructure, and every supply chain element and user is connected through the cloud system.
- Real time data analytics for notifications and abnormalities using independent cloud database function.
- Take full advantage of big data to optimize system performance according to external and sudden changes.
- Users need a connected device to see the necessary information on cloud, and to have authorized access to available applications and data worldwide.
- Proactive application function as an automatic shift log or tool change log, perform adaptive feed control, detect collisions, monitor process, and much more besides.

3.4.4 Sensorization

Techopedia (Techopedia) defines Sensorization as ” *a buzzword to define the extent or the trend of embedding as many sensors as possible with a device or appliance.*”

3.4.4.1 Sensors

In the book Smart Sensor Systems, Meijer (Meijer, 2008) explains sensors as a device that transform signals from different energy domains to the electrical domain. The different signals can be classified in six signal domains: magnetic, chemical, radiant, mechanical, thermal and electrical, as shown in *Figure 3*.

Further there are two types of sensors, passive (self-generating) and active (modulating) (Meijer, 2008). The passive sensors get their output energy from the input signal, while active sensors have internal power source.

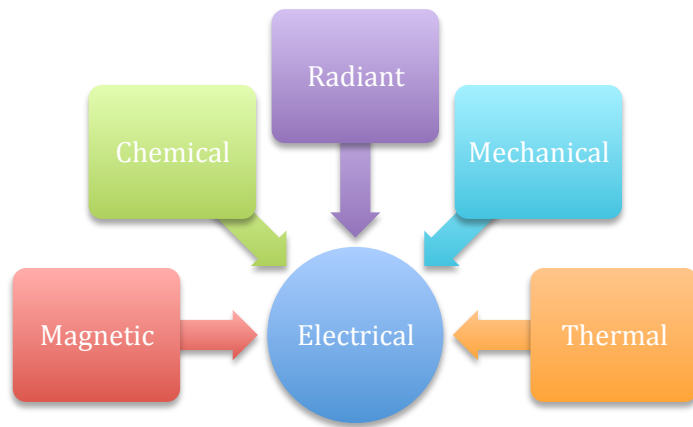


Figure 3 Signals a sensor receive, illustration from the book Smart Sensor Systems (Meijer, 2008)

Sensors and actuators are the basic technology for CPS, and control units for the systems are necessary. Since there now are smart sensors these sensors handle the processing of the signals and the actuators check the status of the production and adjust it if needed (Ustundag and Cevikcan, 2018). It is the sensors that enables real-time tracking of the production or service system, gathers documentation and data for big data analysis, deep learning and knowledge, and it increases availability of the systems by condition monitoring it.

3.4.4.2 RTLS and RFID technologies

Radio-frequency identification (RFID) and real-time location systems (RTLS) are technologies that helps with location detection, condition monitoring and identification in systems with smart logistic, transportation and storage to satisfy an efficient coordination of embedded systems and information logistics (Ustundag and Cevikcan, 2018). This gathering of information and real-time data is necessary for self-decision making for machines and smart devices. According to the book Industry 4.0: Managing the Digital Transformation (Ustundag and Cevikcan, 2018) the outcomes of RTLS and RFID based systems are appeared as follow:

- Process-optimized production of a product in a large number of versions
- Enhanced functionality and flexibility of the assembly line
- A high degree of data transparency
- Real time data flow to enable rapid support for workers.

3.4.4.3 Digital twin

Digital twin is a new and fast growing technology. According to the article Digital twin-driven product design framework (Tao et al., 2018), Digital Twin is:

“a new emerging and fast growing technology which connects the physical and virtual world. In the virtual world, products are created in laboratories to visualise product structure, simulate product behaviour and optimise product performance. In the physical world, when products are utilised by end users, their performance, behaviour and interaction with the users are captured by sensors and controlled by actuators.”

3.4.5 Autonomization

Wiktionary (Wiktionary) defines Autonomization as *“the process of making something autonomous.”*

3.4.5.1 Robotics

An important area where a digital improvement have been seen is with robotics, building machines that can navigate through and interact with the physical world in factories, warehouses, battlefields and offices (Brynjolfsson and McAfee, 2014). According to Brynjolfsson and McAfee (Brynjolfsson and McAfee, 2014) the word robot first entered the English language in 1921 via the Czech play, R.U.R. (Rossum`s Universal Robots) by Karel Capek. Automation and use of robots have fascinated humans ever since, but there are still some challenges when it comes to the robots functioning in the real world (Brynjolfsson and McAfee, 2014).

Automating a single activity is easy, but the task must remain constant over time and take place in the “regular” environment (Brynjolfsson and McAfee, 2014). The book *The Second Machine Age: work, progress, and prosperity in a time of brilliant technologies* (Brynjolfsson and McAfee, 2014) explains that companies buys specialized machines for simple, repetitive tasks, and have their engineers program and test them, and adds them to the assembly line. Each time the task changes, engineers has to reprogram the machines.

But there has been progress. Rodney Brooks, the founder of iRobot, have made robots that can handle countless of imprecise tasks done by people today in factories, and the robots does

not need to be programmed by engineers, but can be taught to do tasks (Brynjolfsson and McAfee, 2014).

With sensors, CPS and AI the machines, products and services becomes smarter, they do not only have abilities of computing, communication and control but also autonomy and sociality (Ustundag and Cevikcan, 2018). Combining robots with AI gives easier manufacturing process with decreased production costs, reducing production time and reduce waiting time.

Robotic Welding:

Robotic welding systems can be beneficial for the companies; it provides precision and productivity, as well as eliminates the risk by removing the need for human welders and operators in a hazardous environment (Tarn et al., 2011). The robotic welding systems normally comprises measuring and identifying the object being welded, welding it, controlling the welding parameters and documenting the welds, but intelligent robotic welding systems can also accomplish tasks without any human interference (Tarn et al., 2011). For this to be possible the robots need to be capable of functioning in unstructured environments with large uncertainties, and be able to determine the possible actions and choose the right one (Tarn et al., 2011). According to Tarn, Chen and Fang this is done by gathering information from various sensors, such as computer visions, tactile sensing, ultrasonic and sonar sensors, lasers and other smart sensors.

K-TIG:

Keyhole TIG welding is according to Welmax (Welmax), an automated, full penetration process, as shown in *Figure 4*, completing the weld without a need for filling material. This is because the high current arc opens up a full-penetration keyhole in-between the two surfaces, which gives a finished welded product with 100% of the object material, and there is no need for edge preparation.

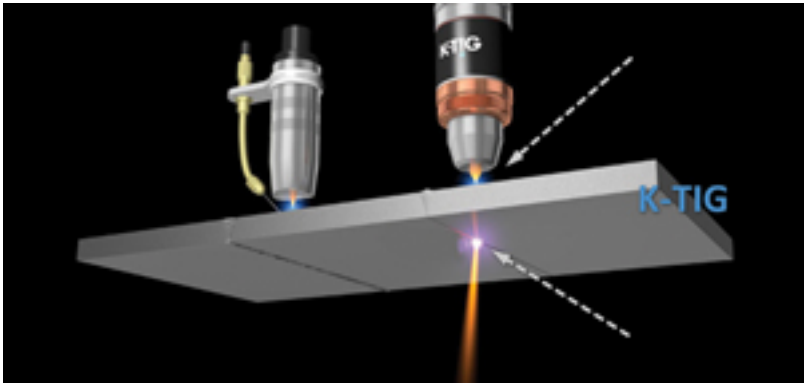


Figure 4 Illustration of K-TIG, from Welmax’s homepage (Welmax)

The controller monitors every aspect of the welding procedure, making flawless welds at up to a hundred times faster than traditional TIG, and this without the need for experienced operators (Welmax). The method can be used on a wide range of materials (Welmax).

3.4.5.2 AI (Artificial Intelligence)

The book *Machine, Platform, Crowd: Harnessing Our Digital Future* (Brynjolfsson and McAfee, 2017) explains that John McCarthy, a math professor at Dartmouth, defined artificial intelligence as the “*science and engineering of making intelligent machines.*” As a result of the advanced information and knowledge technologies to facilitate information, the amount of real-time data has increased significantly (Ustundag and Cevikcan, 2018). According to Brynjolfsson and McAfee (Brynjolfsson and McAfee, 2017), Hinton showed in his paper “A Fast Learning Algorithm for Deep Belief Nets” co-authored with Simon Osindero and Yee-Whye The, that with the right amount of data and a sufficient power and configuration, the neural network could learn on its own, with no human training.

Now that the machines can be interconnected the amount of historical information and new data increases, resulting in an increased need to process data. This is needed to evaluate the state of machines and configuration of machinery, bringing a competitive advantage to companies by evaluating the entire processes (Ustundag and Cevikcan, 2018).

3.4.5.3 3D printing

3D printing, also called additive manufacturing, is a technology to produce three-dimensional objects directly from digital models (Ustundag and Cevikcan, 2018). This can be done with polymers, ceramics or metals being added in thin layers, and the objects are designed on

computers where the details and features of the products are submitted (Ustundag and Cevikcan, 2018). The technologies with 3D printing offers a customization and democratization of the production, reduces the transport cost by increasing the possibilities for value creations process and on-site manufacturing (Ferdinand et al., 2016). The visions of 3D printing as a fusion of the traditional producer and consumer roles will change the industrial processes and infrastructure, eliminating for example the need for spare part storage and the need for mass production.

3.4.5.4 Virtualization technologies

Virtualization technologies is the use of Virtual Reality and Augmented Reality tools which have a integration of computer-supported reflection of a real-world environment with additional and valuable information (Ustundag and Cevikcan, 2018). According to the book Industry 4.0: Managing The Digital Transformation (Ustundag and Cevikcan, 2018), visualisation technologies have four functional requirements: scene capturing, scene identification, scene processing and scene visualization. Approaches for the displays for the visualisation tools are based on three focuses: video-based adaption supported by the camera that assists augmented information, optical adaption that users give information by wearing a special display and projection of stated objects (Ustundag and Cevikcan, 2018).

3.4.6 Connectivity

The webpage Business Dictionary (Businessdictionary) defines Connectivity as the “*measure of the extent to which the components (nodes) of a network are connected to one another, and the ease (speed) with which they can `converse`*”. “

3.4.6.1 Cyber Physical Systems/ Embedded Systems

Embedded systems, also named Cyber-Physical Systems, is a supportive technology for coordinating and organising networking systems between physical infrastructure and computational capabilities, which is required to connect devices and tools together, and achieve decentralized actions (Ustundag and Cevikcan, 2018). Lee, Bagheri and Kao (Lee et al., 2015) defines Cyber-Physical Systems as transformative technologies for managing interconnected systems between its physical assets and computational capabilities. And with the industry using more high technological methods to stay competitive, the increasing use of sensors and networked machines results in a high volume of digital data, also known as Big

Data (Lee et al., 2015). When the data volume increases and a Big Data environment is the case CPS can be further developed for managing the data and leveraging the interconnectivity of machines to get intelligent, flexible and self-adaptable machines (Lee et al., 2015).

An embedded system needs to fulfil two functions according to Ustundag and Cevikcan in the book Industry 4.0: Managing the Digital Transformation (Ustundag and Cevikcan, 2018):

1. An advanced level of networking to provide both real-time data from the physical infrastructure and information feedback from the digital structure.
2. An intelligent data processing, decision-making and computational capability that support the physical infrastructure.

According to Lee, Bagheri and Kao (Lee et al., 2015) integrating CPS with production, logistics and services in the industry today would transform them into Industry 4.0 companies with significant economic potential. They have also developed a 5-level CPS structure as a step-by-step guideline for developing and applying CPS in manufacturing named the 5C.

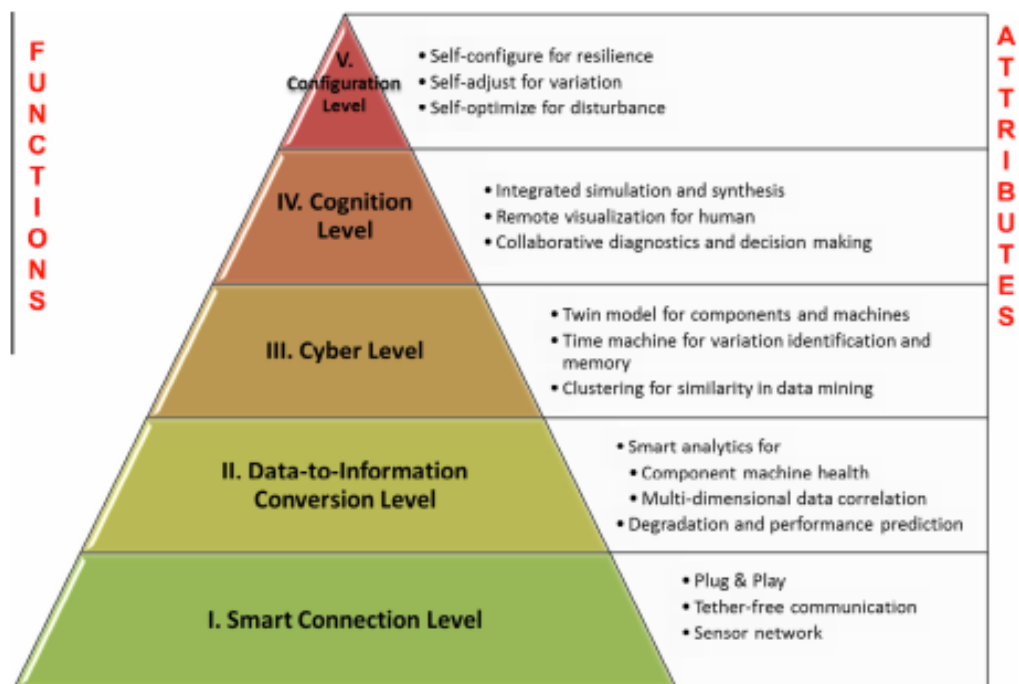


Figure 5 The 5C architecture for implementation, developed by Lee, Bagheri and Kao (Lee et al., 2015)

The 5C architecture is, as shown in *Figure 5* and *Figure 6* developed by Lee, Bagheri and Kao (Lee et al., 2015):

- **Smart Connection-** gathering accurate and reliable data from machines and their components is the first step in the development of a CPS application. This data can be measured by sensors or from controller or enterprise manufacturing systems. There are two factors that must be considered, first the various types of data and how to gather and transfer them to central server, and second to select the proper sensors.
- **Data-to-information conversion-** the necessary information must be retrieved from the data, and there are several methods available for the data to information conversion.
- **Cyber-** is the central information hub in this architecture, where information is entering from the machines to form the machine network. To process this amount of data specific analytics have to be used to find the necessary information that provides insight over the status of the machines. With these analysis the machines gets self-comparison abilities and machines compares their performances with the machines in the same network. The similarities and historical information can also be measured and to predict the future behaviour of the machines.
- **Cognition-** implementation of CPS like this generates a detailed knowledge of the monitored system, and the gathered knowledge needs to be presented well to the experts to support the right decisions to be made. Since comparative information and individual information for the machines are available the decision on priority of tasks to optimising the process can be made, and proper info-graphics are needed to transfer the knowledge to the users.
- **Configuration-** feedback from cyber space to physical space as a supervisory control to make machines self-configure and self-adaptive. The stage acts as resilience control system (RCS) to apply the correct and preventive decision, which the cognition level has made for the monitored system.

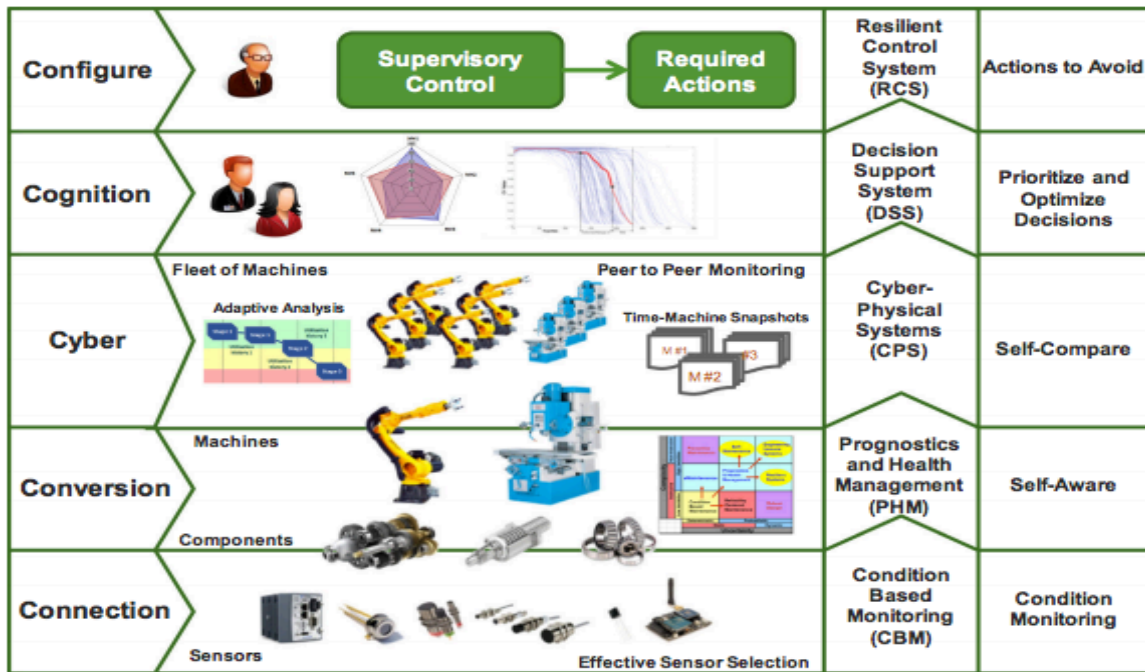


Figure 6 Applications and Techniques associated with each level of the 5C, developed by Lee, Bagheri and Kao (Lee et al., 2015)

By having PHM based CPS systems one get a interconnection between machine health analytics through a machine-cyber interface (CPI), which is similar to social network (Lee et al., 2015). The machines can register to the network and exchange information, as illustrated in *Figure 7*, when the cyber-level infrastructure and the 5C architecture is in place.

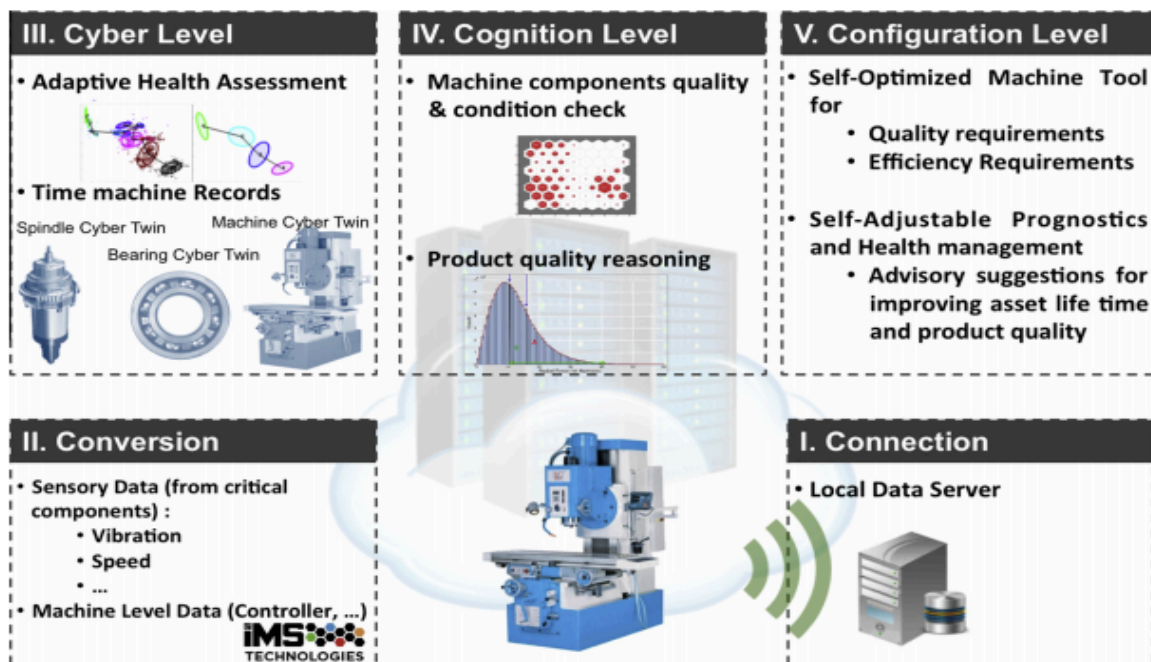


Figure 7 Illustration of the flow of data and information in a CPS enable factory with machine tools in the production line based on 5C CPS architecture, made by Lee, Bagheri and Kao (Lee et al., 2015)

3.4.6.2 Cyber Security

Cyber Security is the security of the data storage and data process in the companies (Ustundag and Cevikcan, 2018). It is important to provide security to all machines, robots, automated systems and cloud technologies according to Ustundag and Cevikhcan (Ustundag and Cevikcan, 2018) regarding:

- Data exportation technologies' security.
- Privacy regulations and standardization of communication protocols.
- Personal authorization level for information sharing.
- Detection and reaction to unexpected changes and unauthorized access by standardized algorithms.

4. Technology Analysis and Opportunities

In this section the different technology opportunities emerging from Industry 4.0 are mapped to get an overview of what the possibilities are, and how they can affect the production. The opportunities are further analysed to give an understanding of how the technology potentially can benefit the companies.

4.1 Mapping of opportunities

Industrial segment: Pre-Fabrication		Digitization	Sensorization	Autonomization	Connectivity
Value creation flow	Changes to process flow – Are there possible improvements from this technology trend to the process flow?	<ul style="list-style-type: none"> -Digital data records, eliminates the need for paper and physical storage place for documents. -Cloud storage, making all data easy to access at all time. -Sensors to digitise data, and digital analysis from this data, makes the data more accessible and the customers get the full information about their products. -Digital signatures and user identification, to make it easier to 	<ul style="list-style-type: none"> -Location awareness in the production. -Embedded sensors have control on all factors. - Communication between the machines. -Smart devices gather information and data for analysis. - Digital twin of crucial equipment can help predict and plan the maintenance. 	<ul style="list-style-type: none"> - Use robotics to automate the production, which gives higher and more stable quality and replaces human work hours. - AI (artificial intelligence), with use of robots, making the robots able to make their own decisions. - With cloud storage and AI the robots can perform tasks they are programmed to. - Modulation and designing programs that can be used by the robots. 	<ul style="list-style-type: none"> - Wireless connection between the automated parts of the process, so that an optimal production can be obtained. - Mobility - Global connectivity can make it possible for the companies to have parts of the fabrication process in other countries, and monitor the process. - Everything that has computational power records data, and can be connected together, which makes it possible for all the smart

		<p>track down who performed the work.</p> <ul style="list-style-type: none"> -Digital displays and headgears to communicate and activate equipment and/or processes. -Smart devices, like tablets and iPads to monitor and control the process and equipment, making the process more efficient. - Possibilities to use AI for the process of ordering, planning and delegating the work. 			<p>devices, equipment and machines to communicate when they have programs that can work together.</p>
	<p>Changes to required skills – Are there possible changes to the required skills from this technology trend?</p>	<ul style="list-style-type: none"> -Required knowledge and training with the digital equipment and smart devices. - Learning how to search and find and use the data correctly. - Learn about the digital programs 	<ul style="list-style-type: none"> -Installation and programming skills for the systems and robots. -Knowledge on correct usage of the sensors. -Being able to connect the sensors with smart devices. 	<ul style="list-style-type: none"> - Knowledge about robotics and the automated process. - Programming skills for the programs and systems. - Knowledge about programs for algorithms and analysis with AI. 	<ul style="list-style-type: none"> -Needs a good wireless internet.

		and procedures.			
	<p>Changes to costs</p> <p>– Are the process flow costs changing from this technology trend?</p>	<p>-The data and information will be easier to access, and therefore it will save time.</p>	<p>-Easier to monitor the process flow, less human monitoring.</p> <p>-Time saving, when data is easier accessed.</p>	<p>- The automated processes will reduce the work time, and therefore reduce the costs.</p> <p>- Makes the companies more competitive with other similar companies on price and time.</p> <p>-Robots can work 24 hours every day the whole year.</p>	<p>- When the machines are connected decisions can be made that is most optimal for the whole production line, taking historical and real-time data into consideration.</p> <p>- A fully connected and automated system working optimal will be more efficient and saving time.</p>
Market	<p>New needs covered</p> <p>– Can this technology trend contribute to covering potential new needs?</p>			<p>- Can potentially expand the portfolio of the process, and make it possible for the companies to expand their market.</p>	<p>- Can make the company more Global by making it possible for yards at different locations to be connected.</p>
	<p>New customer groups</p> <p>– Can this technology trend help attract other customer groups?</p>			<p>- Can result in cheaper products, and therefore attract smaller companies and other industries.</p>	<p>-With a more global company there is potential for new customer groups from other countries.</p>

Key	Solving key challenges - Can the technology trend help solve one of the key challenges ?	- Makes it easier to monitor and control the amount of time and workforce spent on each job.	-Makes it easier to monitor each part of the process. -Possible to access data from the process during and after. - Can help avoid overheating, tearing and bad quality on the welded objects.	-Makes the companies more competitive in the global market. - Higher production capacity. -Eliminated human workers from hazardous environments. - Less wastage.	
	Increased intangibility – Can the technology trend contribute to making the value creation process less tangible/more of a service?			- With AI the fabrication process can be more like a service.	
Other	Other factors	-Cloud storage and smart devices, making it possible to manage the production from all over the world. - By digitizing the data and	-Sensors make it possible to convert the data to digital data, enabling the use of CPS and AI.	- Robots make it possible to use new welding methods, like K-TIG, which have higher quality and uses less time than traditional welding methods.	

		mapping the process it makes it easier for the customers to follow their project and see if it is on schedule.			
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Table 5 Mapping of the opportunities with new technology (table provided by supervisor and his assistant)

4.2 The ideas

From the *Table 5* used to map the potential in using new technologies the ideas must be further explained. For all of these ideas it must be assumed that the operations and process is or have been standardised.

4.2.1 Digitisation

Digitising all the data in the production line opens up opportunities to use the data in ways that can benefit the companies. It eliminates the need for shelves and binders with documents and data, which is not the most efficient way to store important data and documents.

The digital data is easy to access at all times. With cloud storage the data it is safely stored in the “sky”, available for the employees and customers with access. When all the data is stored in the “sky” over time it generates archives.

Implementation of digital signatures from the operators conducting the work helps to keep track on the work and workers. User-identification keeps track on who performed the work, and can be used to monitor and control the amount of time and workforce spent on each job.

Another opportunity is to digitise the machines and equipment by installing digital displays, also making them more adaptable to the fully automation process. Use of headgears to communicate and activate equipment and/or processes makes the production line “hands-free”.

Using smart devices, like tablets, in the workshop provides monitoring and controlling of the process, keeping track on the status of work and projects. It also allows workers to see who is performing the work task, and the remaining work. Smart devices potentially can be used to control the machines and equipment, starting and stopping them, keeping track on the work and status.

Implementing new digital features in the workshop requires new knowledge, and it is therefore necessary for the workers and leaders to learn about the digital programs and procedures. Learning how to search, find and use the data correctly, how to use smart devices properly and in the most efficient way.

Cloud storage and smart devices opens up the possibility for the companies to share their data, knowledge and experience with yards or other companies all over the world in real-time.

4.2.2 Sensorization

Sensors can make the whole pre-fabrication process easier to monitor and control. Installing sensors at every part of the production makes it possible to keep track on all the products and where it is located in the production line. Today, sensors are smart and they can measure not just where the products are in the production, but also if it is moving, the temperature, the chemical structure, etc.

Using sensors also makes it possible for the employees to monitor their projects, and helps to control that the product has not been overheated or bent too much according to material specifications. The customers can also monitor their products to see if the projects are on schedule, and calculate remaining time.

Monitoring the temperature during welding processes is possible with todays sensors, the sensors gathers all the data on the temperature changes and map the conditions and standards of the welding. This ensures a high quality in all the finished products.

With usage of sensors on machines and equipment a digital twin can be made gathering and analysing data, monitoring the condition, as well as predicting and planning the maintenance.

If smart devices are being used, it is possible to connect the devices to the smart sensors, resulting a very detailed and real-time monitoring device for the production and its machines. The use of smart sensors can be combined with technologies like AI and CPS.

4.2.3 Autonomization

There are many possibilities to use robotics to automate the production. The storage of pipes is an example of what can be automated. The workers plots in to a display which material, dimension and specifications the desired pipes have, and the automated storage systems locates, picks it from the self and delivers it on a production tie. Further in the production line the welding and bending begins. Bending machines are automated in the form that operators plot in the desired angle for the bending. The welding process is also something that can be automated, with new and improved welding methods.

With a successful use of robots to assemble the objects being welded, and welding robots performing the welding process, there is a potential in fully automating the whole production, from storage to performing of NDT and surface treatment.

Automated robots open up to use AI in both the machines and control units. By using AI and machine learning the robots and machines are able to take their own decisions based on the gathered data, cloud computing and real-time analysis, eliminating the need for human interference, and reducing the risk of human workers getting hurt. This reduces the need for welding operators, but it opens up for new jobs with further development and keeping track on new opportunities for the production.

When the machines and robots are connected to a CPS the use of modulation and designing programs can be directly connected with the machines and robots, making it possible to send the file with the model to the machines, which will process it and decide what must be done before eventually perform the needed work.

To invest and implement use of robots and automated systems it requires knowledge about robotics and the automated process. It also requires knowledge and experience about programming and algorithms for analysis.

Using welding robots opens up for the possibility to use new and more efficient welding methods, like K-TIG, which have higher quality on the welding, adds no additional materials

in the weld and uses less time than traditional welding methods. With robots performing the welding operations there will also be less wastage. The welding robot is more accurate, and does not weld wrong or poorly.

The use of 3D printing is an opportunity for creating spare parts, and in the future eliminates the need for spare part storage.

4.2.4 Connectivity

Everything that has computational power records data, and can be connected together, which makes it possible for all the smart devices, equipment and machines to communicate when they have programs that can work together. With smart sensors and smart machines a wireless connection between the automated parts of the process is possible. With a wireless system like CPS the data is collected in real-time, and the historical data and real-time data is analysed for making the best possible decisions.

Global connectivity can open up for the possibility that companies can have parts of the fabrication process in other countries, and still monitor the process from their current location. Making the companies more mobile. And it makes the industry more open for sharing experience and research on innovative solutions.

4.3 Challenges and constraints regarding the ideas

With new technology, challenges and constraints follow, and there are several factors to consider.

4.3.1 Digitisation

Implementing all digital data and use of smart devices can make the workers hesitant and dismissive of the changes. It also adds new routines and programs, requiring the workers to gain new knowledge and changing their existing routines.

Another factor that comes with the digitization is the security, preventing the company from being hacked, and misuse information.

4.3.2 Sensorization

In a system with several sensors that has to be connected together the sensors are dependent on a network to properly function. The accuracy and reliability of the sensors is an important factor.

4.3.3 Automization

If parts of the production, or the whole production are being automated there can potentially be some resistance from workers. Some workers will lose their jobs, and others will get other work tasks than before, giving them no choice but to change.

In the starting face of the automating process there will be a deployment time, with potential wrong production.

Another important factor is that investing in automated machines and systems are costly, and it requires new knowledge.

4.3.4 Connectivity

A requirement for the connectivity between companies, workshops, machines and robots is good wireless Internet. All the communication, converting of data, sharing data and analysing the data is done through the Internet.

Also the need for good cyber security increases when the amount of data and work done through the Internet increases.

4.4 SWOT analysis

To look at the differences between a fictional company today with no or few automated processes, and a fictional company with fully automated production with robots, AI and CPS, SWOT analysis of the two situations have been conducted.

4.4.1 SWOT analysis of situation without new technology



Figure 8 SWOT analysis of the situation without new technology

INTERNAL

Strengths: The strengths in this company are the knowledge and experience build up after many years in the industry. This also means that the company has well-established customers and suppliers.

Weaknesses: The weaknesses in this company is that the processes are time consuming, there is also a risk for human errors, and the process has a limited amount of capable work load.

EXTERNAL

Opportunities: Expanding the company to other parts of the world in an opportunity to expand the existing market, and continuously searching and implement innovative improvements.

Threats: The threats against the company is that other similar companies start using new technology, making the company look "old fashioned" by not producing and offering the same. Another threat for the company is not being able to compete with other companies on prices, making them loose customers. The unsecure market is also a threat.

4.4.2 SWOT analysis of situation with new technology

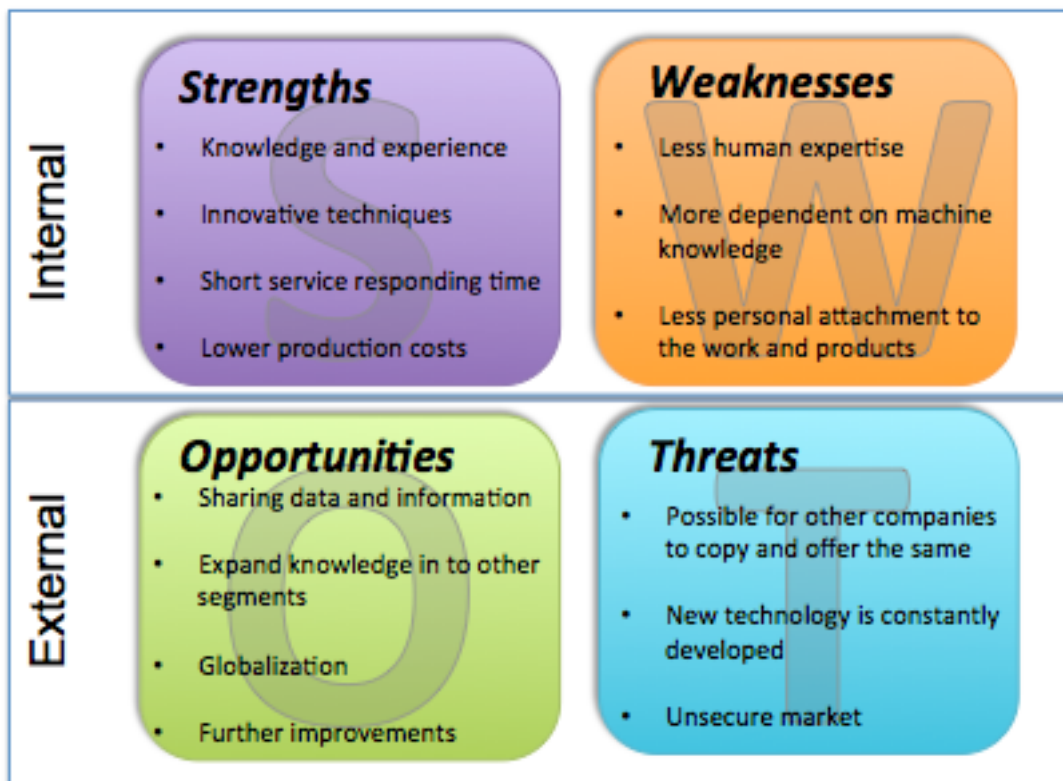


Figure 9 SWOT analysis of the situation with new technology

INTERNAL

Strengths: Strengths for a company with new technology is its knowledge and experience, use of innovative techniques and constantly developing and improving, making the company new thinking. The service time becomes much shorter with a fully automated and networked process, and the production costs will be reduced with fewer operators, less wrong welding and more stabile production.

Weaknesses: The weakness with the new technology is less human expertise regarding welding and the work process now being done by robots, and the production becomes more dependent on machine knowledge. The workers also lose the attachment to their work and products, taking away the feeling of ownership to the products.

EXTERNAL

Opportunities: The opportunities with new technology is the possibility to share data and information over the Internet to all the devices and machines connected to the network, which makes real-time decisions possible. It is also possible to be connected with companies or other locations, sharing data and managing the processes there, making it much easier to globalize and expand the market. The new technology in one part of the company also enables

expanding the use of technology to other parts of the company, using the already acquired experience, and to make further improvements on the technology already existing.

Threats: The threats are the possibility for other companies to copy the procedures and technology, providing the same products and services. Also the technology is constantly being developed, making the risk for new and better technology to be made. A threat is also the market, which is unstable.

5. Evaluation, Results and Discussion

In this chapter there will be conducted an evaluation of the different ideas, a discussion on the results from the SWOT analysis, and further discussion to answer the objective in the thesis. Some examples of successful use of new technology will be presented to create credibility.

5.1 Evaluation of ideas

5.1.1 Digitisation

Digitising all the information and data using cloud computing and cloud storage makes it more accessible, easier to use and it does not take up any physical storage place. Saving time and eliminating cases where documents and paper can be lost when removed from the binders. It also opens up the possibility to be more flexible to work from other locations.

Digitising the production with digital signatures, displays, headgears and smart devices makes it easier to control all the work, implement user identification and manage the machines. Regarding the potential downside that workers will feel like they are constantly being supervised, and the change of existing routines, the solution provides more positive outcomes than negative, making it a potentially good solution for the companies.

All together implementing smart devices will help make the fabrication more efficient and save time.

Cloud storage and smart devices also makes it possible for the companies to share their data, knowledge and experience, which can be a huge benefit for all similar companies being able to learn from each others experiences, and work together in the development of innovative solutions. But it can also damage the company in loosing customers to other companies that gained a competitive advantage from the information.

By digitising the data, and gathering huge amount of data, there is a potential to use AI to analyse the data. By using programs like TensorFlow (TensorFlow) it is possible to perform computations and make decisions. It also provides the possibilities to use AI for the process of ordering, planning and delegating the work.

A risk with the digitization is the security, and the potential of the company being hacked, and abusing information. This requires higher focus on cyber security.

5.1.2 Sensorization

Sensors can help make the whole pre-fabrication process easier to monitor and control. Using sensors also makes it easier to monitor projects, and helps to control that the product condition, ensuring high quality. By monitoring the operations using sensors the production becomes dependent on the sensors, making them critical factors in the production. The reliability and accuracy in the sensors is therefore an important factor to take into consideration when pursuing this idea.

A digital twin to monitor the condition and predicting the maintenance makes the fabrication line more reliable. Even though it is a new technology, not fully tested in this environment, it has a potential to reduce downtime in the production, and save time performing maintenance when it is not necessary.

With the use of smart devices it is possible to connect the devices to the smart sensors, resulting in a very detailed and real-time monitoring device for the production and its machines. Combining this with technologies like AI and CPS reduces the need for human monitoring of the production.

Also the accuracy and reliability of the sensors is an important factor, if the whole production is dependent on information from the sensors, there must be some backup or redundancy to the system.

5.1.3 Automization

There are many possibilities to use robotics to automate the production. Some of the yards have already automated the storage of pipes, bending of several dimensions and the welding process is also something that has started to become automated. Several companies have invested in welding robots, making it easier and more efficient to perform welding procedures.

An operation stated to be hard to automate and use robots on according to some companies, is the assembling and point welding. But with the recent technologies and development done where for example Google are teaching robots to predict what happens when they move objects, to make them learn about the world and to make safe and good decisions (Google). With a successful use of robots to assemble the objects being welded, and welding robots performing the welding process, there is a potential in fully automating the whole production, from storage to performing of NDT and surface treatment. As a result of this the production line gets more stabile, and the products a higher and more stabile quality. It also replaces human workers, eliminating them from a hazardous environment. With all the work tasks being automated it will only be necessary with a few operators to manage the machines.

Using welding robots opens up for the possibility to use new and more efficient welding methods, like K-TIG, which have higher quality on the welding, adds no additional materials in the weld and uses less time than traditional welding methods. This decreases the production time, making the production more efficient. With robots performing the welding operations there will also be less wastage. The welding robot is more accurate, and does not weld wrong or poorly. This increases the quality of the products.

The automated processes will reduce the work time, and therefore reduce the costs, and it makes the companies more competitive with other similar companies on price and delivery time. The robots and machines can work 24 hours every day the whole year, making the production capacity much higher. This can potentially expand the portfolio of the process, and make it possible for the companies to expand their market, and result in cheaper products, and therefore attract smaller companies and other industries. It also makes the companies more competitive in the global market.

When parts of the production, or the whole production are being automated there can be some resistance from workers, afraid to lose their jobs and not wanting to change their routines, which can create a bad work environment and affect the work quality.

If automated robots are used then it is possible to use AI in both the machines and control units. By using AI and machine learning the robots and machines are able to take their own decisions based on the gathered data, cloud computing and real-time analysis. The need for human interference is eliminated, reducing the risk of human workers getting hurt. Regarding

jobs, the amounts of welding operators are drastically reduced, but it opens up for new jobs with further development and keeping track on new opportunities for the production.

With AI the fabrication process can become more like a service. When the customers are ordering the wanted products/systems they can use their plans or designs if they are adaptable to the systems and the machines can process and analyse the project, checking standards, guidelines and specifications, then produce a plan with the price and time of the project, and the system performs the work and fabrication needed.

Investing in automated machines and systems is costly, and it requires new knowledge, making the projects of investing and upgrading the production a huge investment for the companies.

5.1.4 Connectivity

With wireless systems like CPS, the data is collected in real-time, and the historical data and real-time data is analysed for making the best possible decisions. These decisions are based on computed analysis, and lack the human factor of common sense, making it necessary with a human supervisor. Resulting in the need for human supervision, working together with the machines.

Global connectivity can open up for the possibility that companies can have parts of the fabrication process in other countries, and still monitor the process from their current location. This can result in an expansion of the current market, generating new customers.

Globalization makes the industry more open for sharing experience and research on innovative solutions, which can benefit the companies and the industry. But it also strengthens the possibility for other companies to provide the same products and specification, making the competition harder.

A fully connected and automated system working optimal will be more efficient and time saving. But it requires good wireless Internet, making the company depending entirely on a constant and sufficient wireless Internet, always. The use of cloud saving, AI and CPS also establish the need for good cyber security to secure the information and the workshops. When the risk increases the amount of money needed to protect the systems increases as well, which requires the companies to spend more money on security.

5.2 Results from the SWOT analysis

From comparing the SWOT analysis it becomes clear that in regards of strengthening the internal situation in the companies, implementation of new technology does strengthen the companies, but at the same time there are some weaknesses that follows. By comparing the strengths before technology and after technology, the strengths with technology will benefit the company more than the strengths without technology. The weaknesses are quite different; with the new technology the production time is no longer a weakness, making it a huge advantage. But there are new factors like the workers losing the feeling of attachment to the products, and depending on machine knowledge reducing the expertise from workers.

The external situation in the two analyses is more similar. The level of globalisation and the possibility to upgrade the production are present, but in different forms. Also the threats are quite similar, with the opportunity that other companies offers the products at lower costs, the constantly development of new technology, and the unstable market.

Looking at the bigger picture the situation with the new technology will more likely be able to compete with other companies, also on a fully globalised market. With better strengths and potential for expansion of customers it may be more equipped against potentially bad periods in the market.

5.3 Discussion

In today's environment with connected devices and networks, customers in the industry have or will start to demand digital precision. And in an industry like the offshore yards and the pre-fabrication segment there is a massive potential for the emerging technologies to create a new generation of fabrication and yard industry in Norway.

From writing a bachelor thesis for one of the offshore yards it became clear that there where lots of potential for innovation using new technologies. Some parts of the process were updated with more automated machines and equipment, and there were focus on innovative opportunities. But since it is an industry with high insecurity regarding the amount of projects and work in the future, the willingness to invest huge amounts of money in new machines and technology is not always present, which is understandable. But with all this new technology that is emerging today, and the development of fully automated processes, there might come a

point where this will be the normal, and those who were a part of this evolution have the potential to be the leading companies.

Speaking with companies that work with digitization and automation of different industries, like Skye and Welmax, they point out that the offshore yard industry in Norway has huge potential for implementing these kinds of technologies. The company Skye has worked with PHARMAQ, a company within aquaculture, to accelerate the innovation with a new generation of SAP (a software, commonly used in the industry) tool to optimize processes and if possible implement automation, and so far had great success (Skye).

Brynjolfsson and McAfee writes in their book *Machine, Platform, Crowd: Harnessing our Digital Future* (Brynjolfsson and McAfee, 2017) that there is an old joke about factories of the future only having two employees, a human and a dog. The human's job will be to feed the dog, and the dog's job will be to keep the human away from touching the machines. But humans have some advantages the machines don't have. Computers have difficulty gathering more or different data than what the makers of the computers programmed them to, while humans take in all the data around without a pre-selection (Brynjolfsson and McAfee, 2017). Another advantage the humans have is the common sense, making it a good idea to have humans to check the computers decisions, making sure they make sense (Brynjolfsson and McAfee, 2017). But from what Brynjolfsson and McAfee have heard they write in their book: *"We've heard this approach described as dehumanizing. Some people feel that letting computers take the lead on making decisions pushes people to the margins and diminishes them."* But they argue that even though some people feel offended by this, it doesn't make it less right if it can help the industries making better decisions.

Brynjolfsson and McAfee also shows an example of efficient use of AI in the book *Machine, Platform, Crowd: Harnessing our Digital Future* (Brynjolfsson and McAfee, 2017) when the company DeepMind wanted to see if their machine learning could be used instead of humans to monitor and control pumps, coolers, cooling towers and other equipment that keeps data centres at the right temperature. The workers monitor the thermometers, pressure gauges and other sensors collecting information, then evaluate them and make decision over time to best cool the building. DeepMind used historical data from the building, sensor readings, and environmental factors like temperature and humidity, and used all this information to train a set of neural networks to control the cooling equipment. And the results were immediate and

dramatic. The amount of energy used for cooling fell 40%, and the facility's overhead energy improved by 15%.

These examples show that there have already been performed successful implementation and use of the new technology, strengthening the ability to implement new technology in the pre-fabrication industry as well.

This thesis has evaluated and identified digitisation as the best short-term solution. Implementing smart devices, digital displays, digital signatures and cloud storage and computing is the less expensive investment, but with great potential for a more efficient and better use of data.

As the best long-term solution this thesis has evaluated and identified autonomization as the best solution. Investing in robots and automated machines is expensive, and gradually upgrade the production towards a more automated process distributes the investments over time. The gradually upgrade also allows the company to adjust its processes in time with the upgrades, making the transition better for the company and the workers.

When the short-term solution and long-term solution have been accomplished the production has the factors available for facilitating an implementation of CPS and AI.

6. Conclusion

This thesis is intended to identify and evaluate potential innovative ideas emerging from the use of new technology within the Pre-Fabrication part of Norwegian Offshore yards.

The Norwegian offshore yard industry has the potential to take advantage of and be innovative by implementing and using new technology. The technology is still new and in an initiation phase, making some of it not sufficient yet, but it definitely has the potential to strengthen and dramatically change the industry.

Examples showing that AI can monitor and control the cooling system in a building, strengthens the belief that AI one day possibly can monitor and control a pre-fabrication line, with the whole production line fully connected to a network and no human interference, only supervision. This will take time to develop, but that does not mean that companies in the mean time can take advantage of the technologies that are functional in the situation. Using robots in storage, bending and welding, and implementing new systems for handling data using cloud storage and sensors to collect the data makes the production much more efficient and time saving. And at the same time updating the processes makes the transition to a fully automated production less harsh.

Some people will most likely be hesitant and reluctantly to the implementation of more digital data and using automated robot with AI and CPS. Workers becomes afraid of losing their job by being replaced by a machine, and some will not trust a machine making the decisions. But the fact that some people are hesitant or reluctant should not keep the development from happening. If these technologies and systems can help make the production better, it will benefit the companies, and the workers will gain new jobs with further development of the processes.

The fact that all this improvements, upgrades and investments cost a lot of money is not something to forget. In an industry where the market is unstable, making large investments is a huge risk for a company, and is therefore something that must be evaluated and analysed sufficiently in advance. By not making the upgrades, a company can risk losing customers to other companies that have upgraded and offers better products, lower costs and shorter production time. Even though the second machine age does not happened over night, it is too

late for the companies to regret not investing in the new technology when other companies that did invest wins all the projects.

This thesis has evaluated and identified digitisation as the best short-term solution. Implementing smart devices, digital displays, digital signatures and cloud storage and computing, to make the production and the use of data more efficient. As the best long-term solution this thesis has evaluated and identified autonomization as the best solution. Investing in robots and automated machines, gradually upgrading the production distributing the investments over time, and allowing the company to adjust its processes in time with the upgrades. When the short-term solution and long-term solution have been accomplished the production has the factors available for facilitating an implementation of CPS and AI.

6.1 Proposed further research

For further research a deeper and more detailed analysis on the different technologies and the ideas are necessary to determine if it is profitable. This thesis only provides an overview on innovative opportunities regarding the new technologies, which requires more research and development for an optimal use.

An aspect of the production and the industry requiring more research is the safety. The technologies have the potential to remove humans from hazardous environments, but there are still safety measures that need to be taken with this new technology, and new safety situations and issues will most likely occur.

The technologies have a huge potential, not only for use in the pre-fabrication industry, but many other industries as well. The potential for development and implementation of new technology is present, and the future will most likely contain several of the technologies being frequently used and developed.

Last, an interesting and potentially revolutionary technology, with not enough time to study further in this task, with the ability to change the fabrication industry is 3D printing. Further research may lead to interesting and important findings, if there are possibilities to upscale the method, making the production of finished pipes and structure possible, resulting in minimal bending and welding operations.

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