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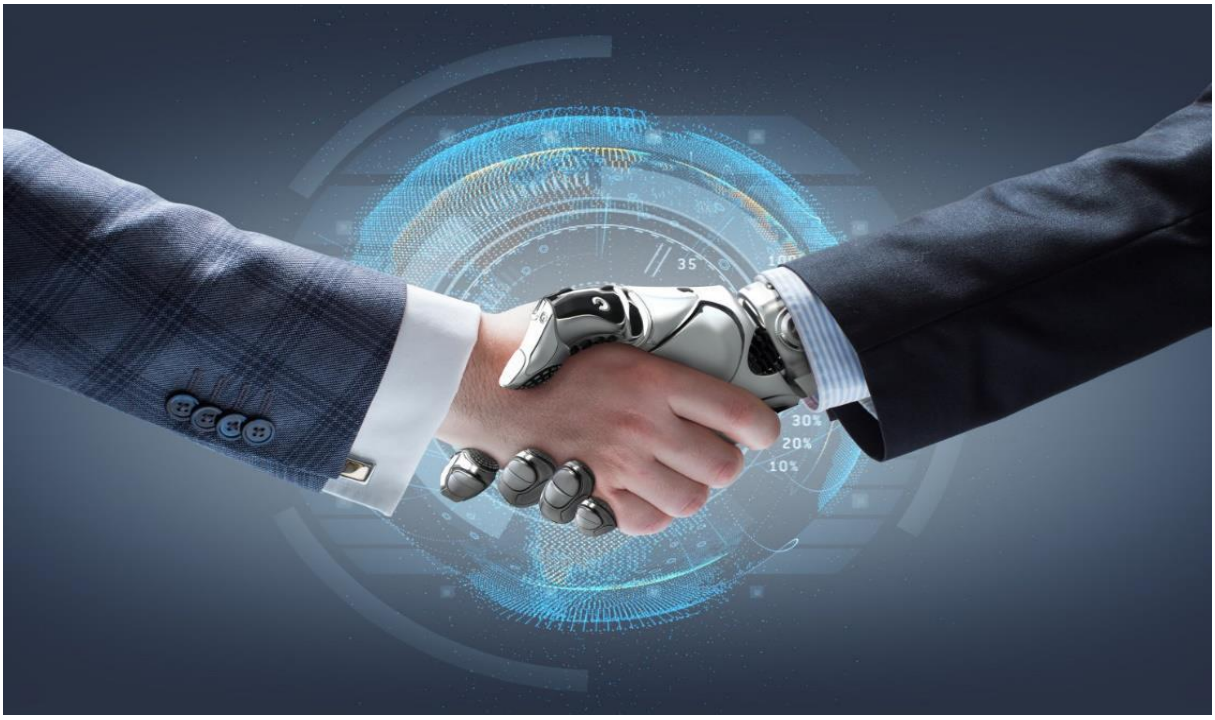
Technology Trends and Opportunities for Construction Industry and Lifecycle Management



(Bradberry, 2017)

By

Vidar Janson

A Thesis submitted in fulfilment of

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Preface

The purpose of the report is to highlight methods that can make it easier for the construction industry and industry in general to benefit from new technology. The report is intended as a reference to technological solutions that along with some techniques, can streamline workflow for multiple tasks in planning, design, and operation and maintenance management. The problems focused on is how to:

- Simplify the procurement and tracing of documentation
- Optimize building stages, design, and Life Cycle Management (LCM)
- Provide interactions between disciplines and employees using different software

Scientific Platform are based on literature within technology trends.
Some history and trends in digital technology are presented. Definition of roles and general terms related to documentation is derived from Norsk Standard and is interpreted on this basis. The report charts the use of individual software and technical setup of digital tools within CAD-engineering (Computer Aided Design), HDS-technology (High Definition Surveying), and gaming technology. This technology combined with cloud-services to support planning, design and management of building stages. Later to support LCM of facilities and businesses' ERP-systems (Enterprise Resource Planning). Use of Robotic Process Automation (RPA) and Artificial Intelligence (AI), for document control tasks. The result of the report is that several suppliers provide services and products accessible through web. Setup and implementation will require some work and knowledge for business and organizations, but the gain largely seems to justify the use of resources for this purpose. Particularly through IOT-interactions (Internet of Things), cloud-services and free downloadable applications that may be considered as a paradigm shift related to the issues in the report.
Also, presenting new platforms for engineering phases to support Building Information Modeling processes (BIM). With the use of Algorithmic Editors for encoding between computer programs without the need of data programmer expertise. To streamline workflows, reduce recreation of data, interactions between different software of various user level, and support of AI to optimize designing by adds-on for CAD-engineering (Computer Aided Design).
Mobile devices like phones and tablets to support several of solutions and products presented is very accessible. It seems naturally to assume that the vast majority of people are familiar with technology related to smartphone applications for daily use.
The use of resources for implementing the presented solutions have not been considered in this report. Some of the equipment presented can be interpreted as relatively expensive. Investment analysis would be sensible. The trend however, shows continues price drops and increased availability. At the same time as the user interface is being improved for both software and digital equipment.
The conclusion, is that the construction industry, as well as Facility Management (FM). Within both, public, and private sector, can have much to gain using the technology and techniques presented in the report.

Table of Contents

Figure List

Symbols and Abbreviations

3D: Three Dimensional

AI: Artificial Intelligence

App/Apps: Applications

Arithmetic tasks: Branch of mathematics consisting of the study of numbers

Back-Office Work: Administration and support personnel who are not client-facing[1]

BIM: Building Information Model

CAD: Computer Aided Design

CMMS: Computerized Maintenance Management System

DCC: Document Control Center

EPCIC: Engineering, Procurement, Construction, Installation & Commissioning

ERP: Enterprise Resource Planning

FM: Facility Management

HDS: High Definition Surveying

HR: Human Resources

ICT: Information and Communication Technology

IT: Information Technology

JIT: Just in Time (Production)

LCI: Life Cycle Information

LCM: Life Cycle Management

M2M: Machine to Machine (Communication)

MMO: Maintenance, Modifications and Operations

PLM: Product Lifecycle Management

RPA: Robot Process Automation

TQC: Total Quality Control

VDC: Virtual Design Construction

VR: Virtual Reality

WBS: Work Breakdown Structure

[1] Description on website: http://www.investopedia.com/terms/b/backoffice.asp

QA: Quality assurance, the process or set of processes used to measure and assure the quality of a product.

QC: Quality Control, the process of ensuring products and services meet consumer expectations.

QA/QC: the combination Quality assurance (QA) and Quality Control (QC).

Acknowledgments

The Master's thesis is the final submission report for the 2-year Master study; "Offshore Technology - Industrial Asset Management" at The University of Stavanger, years 2015-2017.

I would like to thank my supervisor Assoc. Prof. Knut Erik Bang for inspiration and support, and the University of Stavanger for the opportunity to carry out this program that has enriched me with knowledge and expanded my horizons. While working on this report, I gained insight into several applications that I eventually started actively implementing during the master thesis. They are very useful and I could feel how much faster I managed to work, in addition to being good they are also free. I would recommend anyone looking at the task of examining available applications, especially those from Google, their AI engines are incredible. Personally, I will benefit from these digital tools and continue to explore new technological trends and opportunities for the rest of my life.

“What is now proved was once only imagined.”

William Blake

1 Introduction

1.1 Background

Background for the task is technological development that enables automation of several work processes. Trends in technology are sustained from the book “The Second Machine age” by Erik Brynjolfsson and Andrew McAfee, with reflections on how these new types of engines effects our jobs, and how they expand in development. The McKinsey & Company report Ideas to Disrupt Construction 2016, forms the basis for the potentials presented in the report.

According to McKinsey Global Institute (MGI) in a survey done by James Manyika considering automation potential in the world economy, focusing on 46 countries representing around 80 percent of the global workforce. *“We find that about 60 percent of all occupations have at least 30 percent of activities that are technically automatable, based on currently demonstrated technologies”* (Manyika, 2017).

In MGI's report “Technology, Jobs, and the Future of Work”, more than 2000 different work activities have been investigated and quantified the technical ability to automate each of them. MGI claims that the proportion of professions that can be fully automated using today's demonstrated technology is actually less than 5 percent, but a further important conclusion is that *"even if whole occupations are not automated, partial automation (where only some activities that make up an occupation are automated) will affect almost all occupations to a greater or lesser degree. The impact will be felt not just by factory workers and clerks but also by landscape gardeners and dental lab technicians, fashion designers, insurance sales representatives, and even CEOs”* (Manyika, 2017).

1.2 Objective

1.2.1 The purpose of the assignment

Contribute with research-based knowledge to:

Shorter execution time, Reduce costs and Increase quality:

- Support automation of Document Control Center (DCC) and Life Cycle Information (LCI) for construction projects and Life Cycle Management (LCM).
- Automate control checking and approval to reduce rework and errors in construction projects and LCM.
- Optimize design.
- Lower interface design to Computer Aided Design tasks (CAD).
- Interaction to support workflow in projects.

This report aims to: provide a fact-base for considering automation, including technical potentials and trends that can benefit construction projects and LCM within the public and the

private sector. Inform and inspire by recommendations and referrals. Supporting opportunities to improve productivity, enabling businesses to do more in less time with reduced costs and to lower risk.

The considered potential is use of digital technology, and systematic methodology for optimization of construction stages, and operation and maintenance management LCM.

1.3 Research questions and Delimitation

In this report, research questions are concentrated on the design and LCM disciplines. The listed questions define the areas in which the survey will look for potentials.

Delimitations are set to consider these disciplines even if some of the considered products have potentials to preform activities for other disciplines if implemented.

1.3.1 Research questions:

1. *Can digital tools reduce the amount of documentation and streamline tasks related to Documentation work, Document Control Center (DCC) and Life Cycle Information (LCI)?*
2. *Can digital tools optimize design and engineering phases?*
3. *How can digital tools reduce risk?*

The research questions are interesting because no concrete investigations have been made to confirm or declare whether these digital solutions lead to improved or faster design or documentation processes in the construction industry. At the same time, the research questions have a theoretical approach, and the studies will therefore provide the basis for testing and developing digital concepts further.

1.3.2 Delimitation:

Use within Computer Aided Design (CAD) and Life Cycle Management (LCM).

The report is a student assignment that is limited in both time and extent, and therefore has several limitations. The digital solutions and technological trends are introduced in this report as theoretical concepts that encompass processes within CAD and LCM with some features of other applications such as HR tasks. All the issues are interesting, but the surveys nevertheless take the most focus these trends in design, engineering and LCM processes. A deductive approach to the topic is chosen because the purpose of the report is to set theory and concepts against practical use.

1.4 Structure of the Report

The report consists of the following chapters:

- *Chapter 1 - Introduction*

  Here is the background and motivation for the report described. The chapter explains the report's purpose and problem, research questions as well as scope and delimitations.

- *Chapter 2 - Scientific Platform*

  Initially, the chapter gives a brief overview of scientific methods. Furthermore, the chapter explains how existing literature and background are identified and chosen. Justification for the choice of method. Finally, the chapter summarizes the results of its credibility based on the concepts of reliability and validity.

- *Chapter 3 - Theory*

  History and developments in digital technology. A review and description of digital tools and solutions are presented, followed by explanations and some illustrations to technological concepts. The link between the themes is anchored theoretically. Reflections of the potentials that are being considered continually. The theory is relevant as a basis for the researches on products to support the research questions and for discussing results and conclusion.

- *Chapter 4 – Technology to Support Engineering, Construction and LCM*

  Chapter presents new trends and products available. Way to organize work procedures for faster and more assessable information and making bridges over different software for optimizing interactions. Establishing new platforms for innovation.

- *Chapter 5 - Results and Conclusion*

  Theory and results provide a basis for discussion in relation to digital tools. This new technology involves changes that can bring many benefits, but also some challenges. The discussion is shaped to also shed light on this issue. The report's theory and results provide the basis for the conclusion of the survey.

- *Chapter 6 - Further development of Task*

  The report's findings and conclusions provide the basis for recommendations for further academic work and business ideas.

- *Chapter 7 - References*

  Contains a complete list of references used in the report.

2 Scientific Platform

The chapter has five main parts. Scientific methods are briefly described. As a starting point for the thesis it was natural to map related work that has been done in this sector. This mapping revealed the work done by Abu – Shagfa and Menyar Deyab in their master thesis from 2014. Laws and legislation are obtained from Norsk Standard, NORSOK.
Explanation of how searches have been completed and background for literature. The choice of method. This part also contains a justification for the choice of method. Description of how the research approach. Furthermore, a summary to potential sources of error will be identified and the results of their credibility discussed in the context of the terms of reliability and validity. Chapter ends with a summary of method.

2.1 Scientific Method in General

A research method is a procedure for approaching a new theme. A distinction is mainly between qualitative and quantitative research methods.

Qualitative methods are research methods which emphasize understanding and analysis of contexts. Its purpose is to illuminate opinions and experiences that cannot be quantified or measured. A qualitative approach goes into depth and intends to establish context and comprehension through the dissemination of understanding. When you want a lot of information about a topic from different references, it is considered beneficial to use a qualitative method. (Dahlum, 2015).

Quantitative method aims to convert a lot of information into measurable units. Statistical results and breadth are important, and often part of the conclusion. A quantitative method is used as a structured approach to a topic that you do not have sufficient knowledge of, or will continue to research. Furthermore, a quantitative method will provide an opportunity to map trends. The data generated in such an investigation will be in numerical form, which may be analyzed using statistical or econometric methods. One usually uses data tools to draw conclusions. (Dahlum, 2014).

2.1.1 Scientific Approach

Inductive research means that *theory is developed from data.* Inductive approaches in the research are observation and analysis of phenomena that form the basis for making issues or theory. Trends and contexts can be emphasized by supplementing existing data with new surveys. One operates with the so-called working hypotheses way, and these forms the basis of that one develops a theory of direct interaction with the empirical data. This creates the basis for some hypothesis testing and hypothesis formulations along the way in the process.

Example of inductive research:
A statement says; "All swans are white."
Based on “x” number of observations, we can conclude that all swans are white, but we can never know if there is a black swan before we have seen one.

The starting point is usually an experienced problem or a phenomenon that we want to consider.
Deductive research tests *theory in relation to data*, and is the opposite of inductive research. Deductive research refers to what we call hypothetically deductive research. The starting point is theory, and issues (called hypotheses) are derived from the theory and these govern most of the research process by selecting methodical arrangements, data scope and analysis. Research has a basis in these approaches and is separated from each other depending on theoretical anchoring. Inductive research seeks to develop new theory, while deductive research seeks to further develop the theory.

In summary:

- Deductive - Theory is checked against practice.
- Inductive - Practice forms the starting point for theory building.

Source: (Tranøy, 2014)

2.1.2 Reliability and Validity

The statements regarding *Reliability* and *Validity* are based on Tove Thagaard interpretations and are obtained from her book about qualitative methodology (Thagaard, 2003).

Reliability:

This deals with the research's credibility of the reliability. The reliability of the research assumes that researchers using similar methods will achieve the same result. Openness makes it easier to convince critics about the reliability of research, and thus the quality of the results.

There is a distinction between external and internal reliability. External reliability is linked to research carried out in a way that can be repeated by other researchers in another situation. Generally, it is difficult to achieve external reliability in qualitative studies. Internal reliability is linked to the extent to which there is consistency between retrieving data for researchers in the same situation. High degree of internal reliability is achieved by presenting a detailed description of research strategy and analytical methods to create transparency around the research process.

Validity:

Validity is related to the interpretation of data and is about the validity of interpretations the researcher does. An interpretation is valid if the correct method is used at the right time, in the correct environment and results in the correct reviews. The concept of validity is composed of internal and external validity. Internal validity is related to causality within a particular survey, while external validity is related to how interpretations from an investigation are also valid in other contexts. External validity is attributable to transferability. In general, investigations' validity is enhanced with transparency. Transparency implies that the researcher clearly explains the basis of interpretation and further how an analysis provides coverage for the conclusions the researcher presents.

2.2 Background

2.2.1 Starting point (work that has been done in this sector)

Abu – Shagfa and Menyar Deyab Master's Thesis from 2014 “Challenges and opportunities in tags and tag-related technical information management” (Abu - Shagfa, 2014) cover the relevant standards and regulatory requirements for Life Cycle Information (LCI), documents, and Document Control Center (DCC). Based on NORSOK by Norsk Standard legislation. NORSOK Standard defines LCI as:

> *"The information required by the company for engineering, preparation for operations, start-up, operation, maintenance, repair, modification and decommissioning of a plant. LCI includes both information submitted to the company and retained by the supplier on behalf of the Company. LCI includes what has previously been termed Documentation for Operations (DFO)."*
>
> NORSOK (Z-018:2013), 2013).

Their aim of their thesis was to: *“Study tags and tag-related technical information challenges in small and large scale EPCIC and MMO projects as well in order to understand the current situation and best practices used to handle tags and tag-related technical information.”* (Abu - Shagfa, 2014). Tag number is letters and numbers that identify the type and function of instrument and equipment.

Asset integrity Department at Apply Sørco had developed a tool to administrate tags and tag-related information, “Tag Manager.” The tool was developed to support MMO (Maintenance, Modifications and Operations), and EPCIC projects (Engineering, Procurement, Construction, Installation & Commissioning). When the authors started their thesis, Tag Manager had been in active use by a drilling company for more than one year. Their work mapped Tag Manager’s performance and identified challenges and potential improvement areas that could enhance Tag Manager performance and capabilities. Through their survey, it was clear that Tag Manager had benefited the drilling company in many areas. *“Improvements on tag’s and tag-related technical information quality and availability have been achieved. Implementing Tag manager has benefited the company to align with information and data sharing regulations as well”* (Abu - Shagfa, 2014). This survey map incites how companies can benefit from applications like Tag Manager. One of the thesis research area was to “Identifying potential improvement areas to bring Tag Manager to its second phase if possible and in case the drilling company requested this” (Abu - Shagfa, 2014). The authors covered that Tag Manager could benefit from integration with other software or systems e.g. ERP-systems (Enterprise Resource Planning) like SAP, a software developed for managing ERP (SAP, 2017). This type of integration could be supporting automation for task related to logistics cost control.

> *“In the long run, Drilling Company can improve features to a bi-directional interface, and that will allow Tag manager users to access SAP and CMMS (Computerized Maintenance Management System) data directly. For example, a SAP user who requires direct access to tags master register in Tag manager or technical information for tags or equipment identified in the SAP material master will be able to use Tag manager from SAP and find data for the required item. Similarly, an engineer who is a Tag manager user can have access to details of the repairs and maintenance programs held in SAP and CMMS for a tag or equipment serial number.”*

(Abu - Shagfa, 2014).

2.2.2 Literature

Theories, methods and models relevant to the assignment are originating from sciences literature within different subjects and are listed and referred to continually in the text:

Technological Trends:

- The book "The second Machine Age" by Erick Brynjulfson and Andrew McAfee, 2014.[2]
- McKinsey&Company Article "Imagining Constructions Digital Future" by Rajat Agarwal, Shankar Chandrasekaran and Mukund Sridhar, 2016.[3]

Industrial Services and Strategies:

- The book "Service management and marketing: a customer relationship management approach" by Christian Grönroos, 2000.[4]
- Journal of Quality in Maintenance Engineering "Design and development of product support and maintenance concepts for industrial systems" by Tore Markeset and Uday Kumar, 2003.[5]
- Journal of Business & Industrial Marketing "A conceptual framework for the development of a service delivery strategy for industrial systems and products" by Rajesh Kumar and Uday Kumar, 2004.[6]

Decision engineering and Performance management:

- The book "Quality Decision Management: The Heart of Effective Futures-Oriented Management" by E.G. Frankel and SpringerLink, 2008.[7]
- The book "Performance measurement for world class manufacturing: a model for American companies" by Brian H. Maskell, 1991.[8]
- The book "Handbook for productivity measurement and improvement" by William F. Christopher and Carl G. Thor, 1993.[9]

Project Management:

- The book "Pinto: Project Management, Achieving Competitive Advantage Global Edition" by Jeffery K. Pinto, 2012.[10]

Risk Management:

- The book "Risk analysis" by Terje Aven, 2015.[11]

[2] (Brynjolfsson & McAfee, 2014b)
[3] (Agarwal et al., 2016)
[4] (Grönroos, 2000)
[5] (Markeset & Kumar, 2003)
[6] (Kumar & Kumar, 2004)
[7] (E. G. Frankel & SpringerLink, 2008)
[8] (Maskell, 1991)
[9] (Christopher & Thor, 1993)
[10] (Pinto, 2012)
[11] (Aven, 2015)

Laws and regulations are obtained from Norsk Standard, NORSOK.

2.3 Choice of Method

The report uses *qualitative methodology* to illustrate the burst of technological concepts against reality issues about the construction industry and LCM. The research provides a basis for a deeper understanding of how theoretical concepts can be used in practice.

The report deals with a topic with a little documented practical experience. Several of the concepts are relatively familiar in personal use of mobile applications and are constantly evolving, but use within industrial tasks is relatively new. Research therefore has a *deductive approach*.

The goal of qualitative research is to highlight the importance of how new technology trends can have a positive impact on the construction industry and LCM.

2.3.1 Justification for the Choice of Method

Methodology has been chosen in terms of suitability in relation to answering the research questions. Research questions seek to map the main features of concepts of digital tools and how they can be used to optimize or automate tasks within the building industry and LCM. To elucidate the research questions, the report maps products and methods with views on technological development and trends from specialist literature.

The report is an in-depth study that includes:

- historical development of technology.
- Detection of areas where new technology can be used in relation to the construction industry and LCM.
- Search for products and solutions that can be used in these areas.

An in-depth study is most appropriate in order to get a comprehensive picture within the given framework for the report. Themes can be treated broader and more comprehensive in an in-depth study versus quantitative surveys. Depth studies should provide insight and understanding. The ambition is not that research necessarily has to be representative or generalizable. The research framework is determined by the theme and the time frame for the thesis.

For this report, in assessing alternative methods/solutions of components or equipment, the survey is directed form a more consumer kind of view than in Abu – Shagfa and Menyar Deyabs' thesis. This survey is related to what can be seen as mapping opportunities based on new technology and trends. It's not a survey particularly for supporting development or testing strength to one specific product, but to argue for the potential solutions, especially where the source is open and accessible for everyone. Solutions that can drive the construction industry and LCM into an era of digitalization to ease and optimize their operations. Like direct interactions between applications, as the students suggested for Apply Sørcos' Tag Manager. Virtual Design Construction (VDC) to support operations and

decisions in field through a digitized cloud based document and LCI-system assessible for all workers trough access control and permission level. Where CAD-software interacts on Building Information Model (BIM), document system, and ERP systems. To automate and streamline processes. Survey for products are done on web e.g. Google play store.

2.3.2 Research approach

The survey is to find information about how, and what kind of digital solutions that can be used to interact, optimize, and streamline processes within construction and LCM. Literature search and product search for cloud-services, Robot automation, AI, HDS-Technology, VR-simulation, digital setup and procedures are largely done through the web. Model development is based on the concept where the purpose is to use different digital solutions and tools, combining them to optimize documentation and documentation processes, workflow efficiency, improv design and lower the risk. Emphasis is placed on opportunities for free downloadable and open source applications, for example. Google Sketchup[12], Google Flux[13], and Autodesk BIM 360 Docs[14].

The report will go through literature review of digital technology and the pace of this development. LCI management based on Norsk Standard and some reflections to the concepts are also considered in this chapter. Following chapters will take a comprehensive survey to map digital equipment, computer software applications, and applications for mobile devices. As the digital solutions are presented, reflections for use in engineering, planning, and LCM are assessed continuously. The most emphasized areas to assess in this survey are accessibility, automation capabilities, optimization and user interfaces. The use of resources for implementing the presented solutions has not been considered.

2.4 Reliability and Validity of the Survey

The input used in this survey are based on literature review and research on the web for solutions to support issues described. LCI coordinators, project managers, CAD-engineers, and experienced executing carriers within mechanical industry and petroleum related projects have shared their experience and issues to support the survey.

2.4.1 Possible sources of error

For the presentation of various digital solutions and software it is important to emphasize that these may be of a subjective nature as these are based on manufacturers' descriptions of performances. The concepts are nevertheless based on trends in digitization and automation. The manufacturer references are therefore largely intended as a reflection of concepts and potentials for optimizing processes. As the thesis title says, “Technology Trends and Opportunities for Construction Industry and Lifecycle Management.”

[12] Downloadable at: https://www.sketchup.com/download
[13] Get Account at: https://flux.io/signup/
[14] Downloadable at: https://play.google.com/store/apps/details?id=com.autodesk.bim360.docs&hl=no

2.5 Summary of Method

The research uses a qualitative method with a deductive approach. The results and conclusions in the report are that technology trends and opportunities for innovation can help to optimize processes and quality for the industry. Data is obtained from web and literacy search. The report delves deeper through the dissemination of context and understanding of the digital concepts and development speed of technology. Where tasks within the report's demarcation can be supported. The report seeks first and foremost to see theoretical concepts in terms of practical utilization.

3 Theory

The chapter digs deeper into the history of digital technology. Starting with reflections of this accelerating development. The inspiration is largely sourced from Erik Brynjolfsson and Andrew McAfee's book from 2014, "The Second Machine Age" with reflections towards technological development after the book's publication. A review and description of digital tools and solutions are presented, followed by explanations and some illustrations to technological concepts. The purpose is to form a foundation for the potentials that are being considered later in the chapter. General definitions within documentation and Life Cycle Information are obtained from Norwegian Standard (Norsk Standard).

3.1 Development in Automation (the second machine age)

Can it be automated? - The second machine age raises exponentially in a growth way faster than our first machine age - the industrial revolution that was kickstarted by James Watt's improvements to the steam engine combined with vastly developments in mechanical engineering. The second machine age is a reaction from the impact of what computers and all kinds of digital advances are doing for mental power – the ability to use our brains to understand and shape environments – such as the steam engine and its accompanying equipment did for muscle power. This progression makes us blow past previous limitations, and takes us into completely new territories. We now live in a time of astonishing progress in digital technologies.

"Advances in technology suggest the world of work is on the brink of a new automation age, in which machines, robots and artificial intelligence graduate from routine tasks on the factory floor to activities across industries, skill sets and pay scales" (McKinsey & Company, 2017).

3.1.1 The Magnitude of Exponentially Growth

Computers hardware, software and networks have been used by businesses and pioneering research and development for more than half a century. But just as it took generations to improve the steam engine to a point that it could power the industrial revolution (James Watt steam engine improvements 1765–1776), it also took time to refine our digital engines to; automate, communicate and share information in real time and do researches and predictions for us - this among many other advances.

As for the first machine age the growth is exponentially. Experienced as very slow and gradually, then suddenly, for then to explode into numbers far beyond our comprehension. From the doubling of one to two - to trillions, quadrillions and quintillions. The power of exponential growth has been a challenge for humans to understand, as Albert A. Bartlett puts it – "*The greatest shortcomings of the human race is our inability to understand the exponential function."* (Bartlett, 1976)

The power of constant doubling is enormous! To picture the magnitude of this phenomenon a distinction could be helpful. A story retailed by the inventor and futurist Ray Kurtzweil, the story of how an empire was tricked by the inventor of the chess game, when the emperor invited the inventor to name his reward (Kurzweil, Richter, Kurzweil, & Schneider, 1990). The inventor suggested he should be paid in rice, and use the chessboard to determine the amount of rice he would be given in reward for inventing the game. *"Place one single grain of rice on the first square of the board, two on the second, four on the third and so on, so that each square receives twice as many grains as the previous."* Like common human behavior the emperor also had this inability to understand the magnitude of the exponential function. Gaining into 63 instances of doubling, mathematically expressed as; 2^{64-1} , this is more than eighteen quintillion grains of rice, a fantastically big number. To picture it, it would make a pile of rice larger than Mount Everest, this is more rice than what's produced in the entire history.[15]

Figure 1: Picture to illustrate the exponential growth, "The chess inventor and rice story."

[15] Picture is obtained from website: http://www.33rdsquare.com/2015/01/andrew-mcafee-on-second-half-of.html

This distinction was intended as a metaphorical reflection to the power of constant doubling. In 1965, Gordon Moore wrote an article published in "*Electronic Magazine"* with the title *"Cramming more components into integrated circuits*" (G. Moore, 1965). Intel's co-founder Gordon Moore is best known for the prediction he made in this article, which later have been referred to as "Moore's Law." The original statement of Moore's Law:

"The complexity for minimum component cost has increased at a rate of roughly a factor of two per year…. Certainly, over the short term this rate can be expected to continue, if not to increase. Over the longer term, the rate of increase is a bit more uncertain, although there is no reason to believe it will not remain nearly constant for at least ten years."

What Moore had noticed was that the number of transistors per square inch on integrated circuits had doubled every year since their invention, and the integrated computing power you could buy for one dollar had doubled each year (Investopedia, 2017).

Moore's law predicts that this trend will continue into the foreseeable future. As it turned out his "law" has held up for digital progress for over four decades. Although the pace has slowed down incrementally. First to a doubling approximately every 18 months 7 years after the first integrated circuit was produced, then in 1975 to every 24-month (G. E. Moore, 1998).

As presented in Investopedia (Investopedia, 2017) the extension of Moore's law is that computers, machines that is run on computers, and computing power. They all become smaller and faster with time, as transistors on integrated circuits become more efficient. Transistors are simple electronic on/off switches embedded in microchips, processors and tiny electrical circuits. The faster microchips process electrical signals, the more efficient a computer becomes. When designers increased the performance of computers with better integrated circuits, manufacturers could create better machines that automates certain processes. This automation created lower-priced products for consumers, as the hardware created lower labor costs, and more and more circuits on a square inch makes this doubling effect on computer power when it comes down to space and value for the money. As for the old story of rice and the chess game, the numbers do get large in the first half of the chessboard, but as we enter the second half, the numbers get beyond our sense. By the year of 2006 the business world had gone through 32 of these doublings, this was when digitalization entered the second half of the chessboard. Half a century after Moore's law, contemporary society sees the reality from his vision as smartphones and tablet computers. These devices would not work without very small processors. Smaller and faster computers improve transportation, health care, education and energy production. *"Just about every facet of a high-tech society benefits from the concept of Moore's law put into practice."*

Comparing the speed of the exponential growth in digitalization to innovation based on Watt's steam engine, it would take a millennium for that technology to reach 32 doublings.

3.1.1.1 Moore's Law and a few doubling periods from the real world

In 1996, the world's fastest supercomputer was introduced "The ASCI Red" produced by Intel (also known as the Intel TFLOPS supercomputer). The U.S. Department of Energy needed the machine for computer simulations (Mattson & Henry, 1998). This was the first product of the U.S government's accelerated strategic computing initiative. The cost of developing this machine was $55 million, and all its cabinets occupied an area equivalent to 80% of a tennis court. With the energy use of 800 homes it was the first computer to reach a

speed above one teraflop (one trillion floating operations per second). One year later, 1997, it had reached 1,8 teraflops. In 2006, nine years later, Sony's gaming machines PS3 entered the market. This machine also hit 1.8 teraflops, but could be stored next to the channel decoder on the TV bench using the same amount of power as a DVD-player. All this for the cost of approximately $500.

The spread of Moore's Law is beyond just computing power, it also contributes to all other sorts of digital devices. Apples Ipad2 tablet introduced in 2011 for a cost less than $1000 nearly matched the peak calculation speed of the supercomputer "Crazy-2", a $35 million supercomputer introduced in 1985. Compared to the Crazy-2, the Ipad2 was equipped with; speaker, microphone, and headphone jack. It also had two cameras, one in the front and one in the back, taking still pictures and video recording. Receivers allowed it to participate in booth wireless telephone and Wi-Fi networks. Other specs Listed:

- GPS receiver
- Digital compass
- Accelerometer
- Gyroscope
- Light sensor
- Touch screen (functioning as keyboard)

Apple fitted all this capability into a device smaller, thinner and lighter than many magazines.

3.2 Today and Forward

Investopedia, one of the largest financial education website in the world. Driven by a team of data researchers and financial experts, states that the progress in achieving doubling of the number of circuits has slowed, and that integrated circuits cannot get much smaller as transistors approach the size of an atom.

"Thanks to nanotechnology, some transistors are smaller than a virus. These microscopic structures contain carbon and silicon molecules aligned in perfect fashion that help move electricity along the circuit faster. Eventually, the temperature of the transistors makes it impossible to create smaller circuits, because cooling the transistors takes more energy than what passes through the transistors. Experts show that computers should reach physical limits of Moore's law sometime in the 2020s. When that happens, computer scientists can examine entirely new ways of creating computers"

(Investopedia, 2017).

The website states that "*many designers, engineers and computer scientists agreed in early 2016 that Moore's law may run its course within 10 years."*

> *"Sometime in the future, software or hardware breakthroughs may keep the dream of Moore's law alive. However, the computer industry seems ready to veer to another course moving forward from 2016."*

New course as applications and software that can improve the speed and efficiency of computers in the future, rather than physical processes are examples of this.

"Cloud computing, wireless communication, the Internet of Things and quantum physics may all play a role in innovating computer technology."

Source: Investopedia[16]

3.2.1 Cloud Computing

Today internet can provide us access to computing power. This is called cloud computing or working through cloud. Like the mains which gives us electricity, internet can provide us computing power from remote servers. This means we're not as dependent on owning or occupy space for powerful data processors. We can rent this as a service via the Internet connection and pairing our various devices to a cloud service. Information and data from many sources such as sensors or robots can be sent to personal devices, like smartphones or tablet after being processed in a cloud service. With this technology computing power is an available resource. At any given time, one can purchase the amount needed. The demand of powerful processors and large software programs on computer equipment and devices are no longer a restriction when it comes to plain computer power, and your data is accessible anytime anywhere (Microsoft, 2017). Telephone companies and Google are operators that offer cloud services across the network continuously. Taking a picture with your cellphone, these operators gives you an offer to save it in their cloud. The picture will be saved and accessible from the web and doesn't need to occupy digital space on the phone or other devices. The Google Chromebook computer is based solely on Google's applications through cloud services. The computer has a simple hardware and is therefore to be interpreted as cheap in today's market. The product has no operating system or software, only cloud services. Google says that virus attacks is their problem.[17]

3.2.2 Automation Starts

In addition to being faster, smaller and lighter, and affordable for common people. All this hardware development of processors, memory chips and sensors etc., do things that previously seemed far beyond our reach. To get machines to do human tasks, such as; orient themselves, or make contemplated choices have previously been dejected of several scientists. As late as in 2004, Frank Levy and Richard Murnane presented their book "The New Division of Labor" (Levy & Murnane, 2004). They focused on the division between people and computers. The authors stated that since computers are really good at following rules, they should do arithmetic work and similar tasks. *"In any sensible economic system, people should focus on the tasks and jobs where they have a comparative advantage over computers, leaving computers of the work of which they are better suited" (Frank Levy).*

Hundred years ago, some people spent all their workday on arithmetic tasks, which is a branch of mathematics that consists of the study of numbers, for then two tabulate results. They were doing todays computer work, but computers are way faster, cheaper, and more correct than these workers. The computers aren't just excellent number crunchers, they're symbol processors. The processors circuity is interpreted in the binary language of ones and zeros, and can be set up for rules to follow; true or false, yes or no, or any other symbolic

[16] Website: http://www.investopedia.com/terms/m/mooreslaw.asp
[17] Computer only operating through cloud website: https://www.google.com/chromebook/about/

systems. This means that the computers can do all manners of symbolic work for us, from math, logic to language. What Levy an Murnane questioned was computerization of other tasks, like the kind of work listed:

- Entrepreneurs
- CEO's
- Scientists
- Nurses
- Waiters

"What is it about their work that makes it harder to computerize?"

Getting to the root of this they divided and distributed information processing tasks into arithmetic work that required the application of well-understood rules.

Setting up a computer processor to do information processes is what's expressed as a computer code, and this is what we call an "Algorithm."

With the use of algorithms, banks all over the world have started to use computers instead of humans for mortgage approvals. Here follows an example of how an algorithm can be set up by rules to process this task gathered from the book *"The Second Machine Age"* (Brynjolfsson & McAfee, 2014b).

3.2.2.1 Illustration of an Algorithm

Expressed in words a mortgage rule might say, "If a person is requesting a mortgage of amount ***M*** and they have a credit score of ***V*** or higher, annual income greater than ***I*** or total wealth greater than ***W***, and total debt no greater than ***D***, then approve the request."

When expressed in computer code, we call mortgage rules like this an algorithm.

(Brynjolfsson & McAfee, 2014b)

3.2.3 Robotic Process Automation (RPA)

Algorithms are simplifications that only abbeys the rules they're set up to deal with. They will usually be set up to includes the most common and important things, and work quite well at tasks like predicting payback rates. *"Robotic process automation (RPA) is the automation of handling structured data using robot software. This is process automation of manual, rule-based and repetitive tasks"* (Deloitte, 2016). The company UIPath is a vendor of RPA software. Their preferred labeling mission is to eradicate mundane, redundant tasks and let software robots do the grunt work. UIPaths' statement: *"We enable companies and organizations to develop a flexible robotic workforce by providing a state-of-the-art platform for software robots orchestration"* (UiPath, 2005-2017). UIPath delivers a software that doesn't need the skills of a computer programing expert to be setup for the intended tasks. The software contains several standard "building blocks" adaptable to fit the users' needs.[18] The technology company Deloitte has implemented an RPA software for the Norwegian Government's Directorate of Financial Management, this so-called robot was put into

[18] Webpage illustrating RPA use in HR-tasks, and downloading for free trail to software: https://www.uipath.com/blog/how-rpa-can-help-companies-rethink-hr-tasks

operation autumn 2016 ("Teknologien som forandrer oss [video clips] ", 2016). The RPA opens folders, gather information/data, matches the data to check financial statements using steps of logic mathematic between stages. It notifies personnel if something is needed or missing.[19] It is possible for the RPA to bridge gaps between different systems and software. This means it can work in an excel spreadsheet with data gathered from other systems, then opens a new software, implant spreadsheet data and run a new process.

RPA enables simple automation by a robot using the applications in the same way as a human being; With username and password, and open and close programs, read, press, and type. Routine tasks that do not really require human creativity to be implemented can be automated, which in practice means that you can free up time for employees. Time that most people can spend on more exciting and value-creating tasks. Unlike a regular employee, the robot can work 24/7. Additionally, a robot cost as little as one fifth of the employment of a "onshore" resource (Institute For Robotic Process Automation, 2014).

Implementation of an RPA is by Capgemini Consulting stated to be relatively fast and it is not uncommon to realize an automated process in just a few weeks. Compared to many other IT systems, the RPA software does not require any integration with other IT systems. It's possible to implement it without affecting any existing IT infrastructure which often is a big issue when implementing new systems in an organization (Consulting, 2016). The robot relies on the rules and procedures that are programmed and do not enter incorrect information in systems. In one of ten cases, something goes wrong when people make "redundant" manual tasks, such as calculation error or input error. This can be avoided by using RPA and increased the quality of work (Institute For Robotic Process Automation, 2014).

[19] Videoclip RPA, link: https://tv.nrk.no/serie/teknologien-som-forandrer-oss#t=23m49s

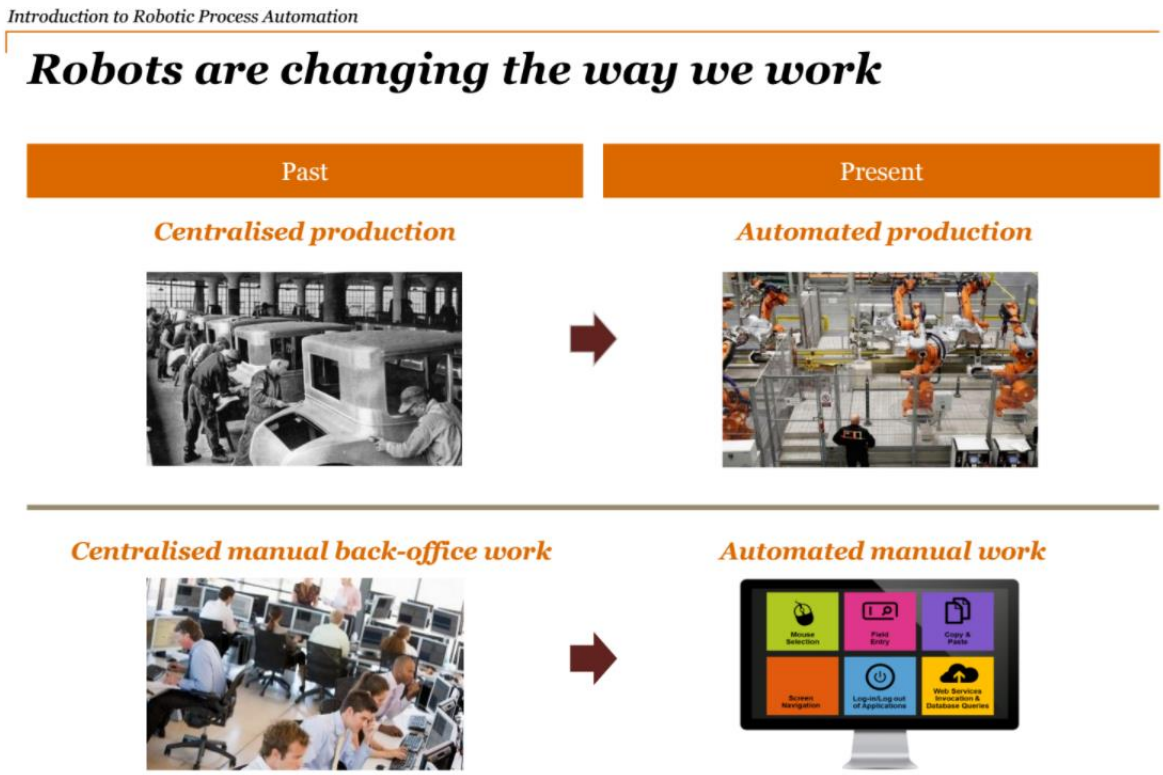

Figure 2: How Robots change work[20]

An RPA system has great flexibility and scalability. As volume increases or automation of multiple processes becomes necessary, capacity can easily be increased by adding more robots. There is no need for new implementation. Each extra robot does not need training time, and have the same "expertise" that first robot. This leads to increased flexibility; the organization can easily increase staffing in the short or long term. In addition, a robot can work across different departments and perform processes that are not related to each other, for example, one and the same robot can work with processes from the HR, Finance and Customer Services department *(Tronstad, 2017)*[21]. Not only back-office work, but also toward customers. The RPA can also be scaled up with cognitive intelligence (Artificial Intelligence) and digital assistants (Virtual assistants). The RPA works on top of the digital system and can work different software.

A small digression in the context of the research questions; payroll is rule based, a typical area for implementation of RPA.

[20] Webpage RPA changes work: https://www.pwc.dk/da/arrangementer/2017/cxo-konf-2017-rpa.pdf
[21] Webpage Implementing RPA: https://www.no.capgemini.com/blog/capgemini-bloggen/2017/01/robotic-process-automation-hvordan-starte-opp-en-proof-of-concept-pa

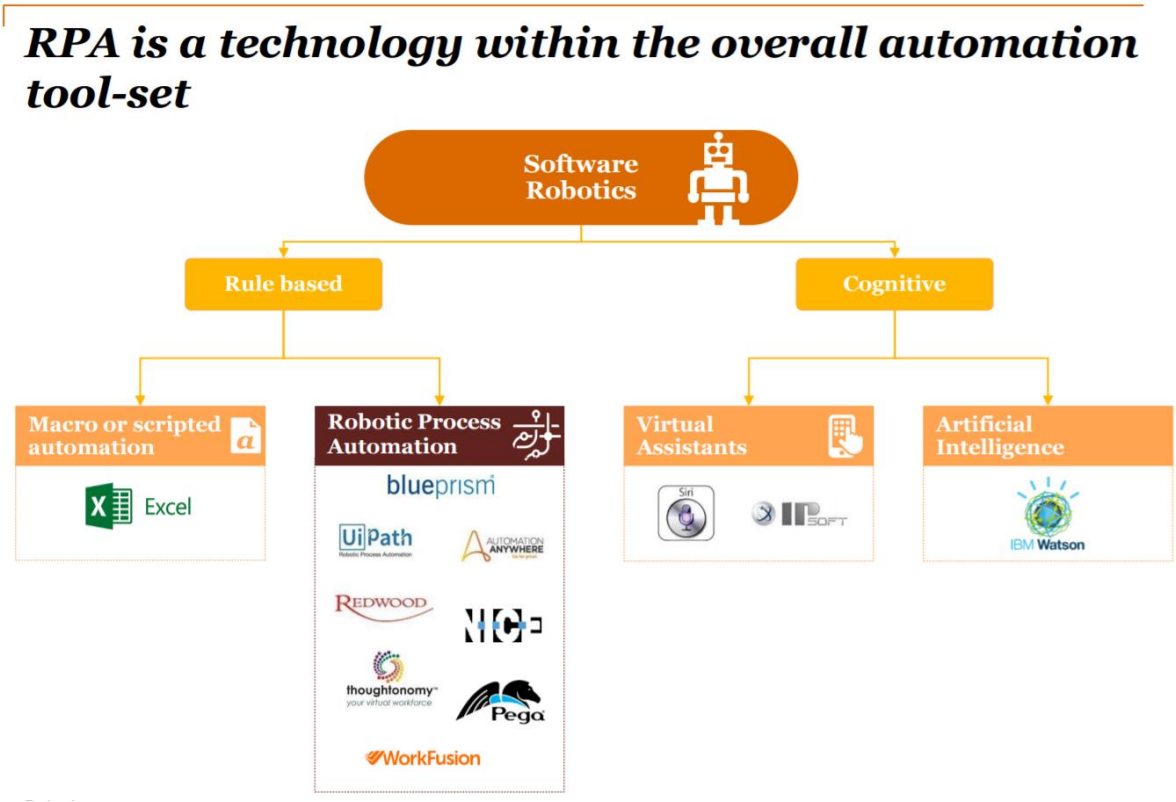

Figure 3: Illustrating RPA-software working on top of the digital system[22]

3.2.4 IOT and Big Data

Internet of Things (IOT) is a term used for physical objects communicate with the outside world via sensors connected to internet. The era when only computers, mobiles and tablets were connected to the web is passed. Now everyday things that surround us become "smart" and can talk with us and each other online, here reveals opportunities limited only by imagination. Machines and gadgets may collect, record, analyze and present data through the web by cloud computing. Giving us feedback and notifications. We can carry out status check, perform actions on digital sensors for services and equipment, and receive predictions along with recommendations for actions. For industrial use collecting information from IOT is used to support decision management. It's about gathering information and use it to feed the computers or specialists to make a forecasting that should be the basis for decision makers. Analyzing the data to make optimal suggestion. These mountain of data is what we define as *Big Data*, and make use of them is like a refining method with the use of computer power to find something valuable related to one specific purpose.

All digital movements and connectedness two web leaves trace in the internet, and data can be collected for various purposes. Netflix (net-television provider) have a menu that is customized the different users connected the subscription like family members. Netflix sees the types of programs and movies the user prefers; the user can also enhance data collection to provide ratings on programs and movies. This helps the vendor to propose programs that will

[22] Illustrating RPA working on top of digital system Webpage: https://www.pwc.dk/da/arrangementer/2017/cxo-konf-2017-rpa.pdf

delight consumers. Large amounts of data can be collected either through internet movements, apps and all types of sensors connected to the web. Optimization algorithms can collect, record, analyze and present suggestion out of big data.

The terms IOT and Big Data floats into each other. IOT is the source and Big Data is data gathered from branches out of IOT.

This means we can collect and take advantage of data that we have available. For a company, data can be collected from customers, or internally it is also possible to gather data from the web, like Google searches. If you have a cloud service where robots, sensors on components and employees share data, these can be analyzed to help optimize products, services or processes. By mathematic analytics these data can also help to predict the future.

3.2.5 Getting into Robots and Artificial Intelligence

Computers are good at following rules like a setup in an RPA application, but lousy at pattern recognition, or are they? At the other end of Levy and Murnane's spectrum of information processing technology, we find larger and more extensive tasks with pattern recognition. This was claimed to be far above what can be implemented in an algorithm, per the authors. They believed that people were reserved for advanced tasks, and unmanned autonomous vehicles are described as unimaginable in their book.

Their rationales were based on the human brain that is extraordinary good at taking in information through our senses and examine it for patterns. To figure out how we automatically do all this is hard to describe, and seemed more like impossible to implement in a "computer brain." Levy and Murncane concluded; *"When this is the case, tasks can't be computerized, and will remain in the domain of human workers."* This conclusion was proven to be even more compelling after DARPA (Defense Advanced Research Projects Agency) held its first Grand Challenge for Driverless Car in 2004. The challenge was Announced in 2002, and after two years' preparation 15 teams qualified to set their autonomous vehicles at the starting line out in the desert.
After 3 hours, the best performing car had managed to cover less than 5% of the 150mile course, for then to get stuck on an embankment after a hairpin turn. The event was satirized and was nicknamed "DARPA's Debacle in the Desert." But the world continued digitizing, the technology evolved and new products saw daylight. In 2010 Google announced that their autonomous car had been driving successfully for some time, - in traffic on American roads and highways (Brynjolfsson & McAfee, 2014b).

As pointed out in "The New Division of Label" a normal functioning human brain can process common tasks and patterns matching with only paying a minimum of consciousness. One of these processes is called Simultaneous Locating And Mapping (SLAM) and it happens naturally for us. This is the process of building up a map of an unfamiliar building as you navigate through it. Locating the doors, stairs, recondite things that one might tip over, and also keeping track of where your located, making it easy to find the way back out the front door.

Scholars in Artificial Intelligence (AI) have struggled with the SLAM issues. Teaching machines to do this has been a huge challenge. In 2008, it was stated as; "one of the

fundamental challenges of robotics." Two years later Microsoft announced the "Kinect Sensing Devise," a $150 video-game accessory to its Xbox gaming platform (Xbox Kinetic).

Figure 4: Microsoft Xbox 360 Kinect Sensing Device to overcome robotics SLAM challenge[23]

In 2011, a team from Microsoft overcome the SLAM challenge in robotics using Kinect (Brynjolfsson & McAfee, 2014b).

Kinect draws a three-dimensional map of the room and the objects in it, in real time. The gaming accessory can calculate how a ball would bounce inside the room, making it possible to simulate situations. Referring to the technology blog "Engadget": *"The Kinect took 3D-sencing to the mainstream, and moreover, allowed researchers to pick up a commodity product and go absolutely nuts."*

3.2.5.1 Machine Interface Design

Robot technology have in addition to SLAM also evolved much in usability. The demand of being specialized technician to program more of today's robotic arms are no future needed. With the use of Kinect, industrial robots copy your movements like the video-game characters when you play Xbox. It's a "dirt-cheap" way to bring depth sensing and 3D vision to robotics.

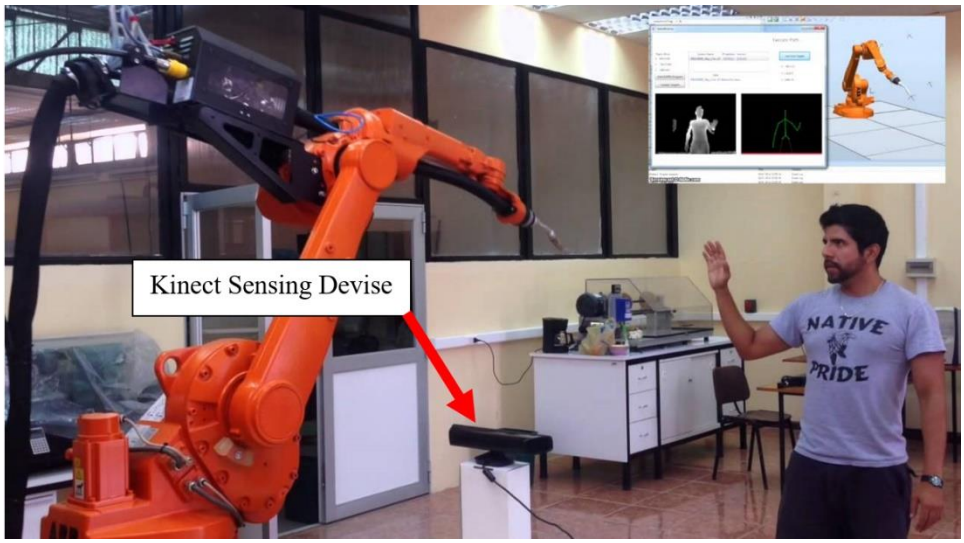

Figure 5: Illustrating Kinect-Based Trajectory Teaching for Industrial Robots.

[23] The picture is obtained from website: https://www.cnet.com/uk/products/microsoft-xbox-360-kinect/review/

Kinect helps robotics navigate, scanning 3D views, and do humanoid teleoperation. Figure 5 Illustrating Kinect-Based Trajectory Teaching for Industrial Robots.[24]

Programing a robot's movement can also be done with manually guidance. "Baxter" an industrial robot built by Rethink Robotics, can be set into a weightless mood allowing personnel to guide the robot for programming desired movements. The robot handles with ease, and make resistant when doing motions that may cause clashes or problems for the operation. [25]

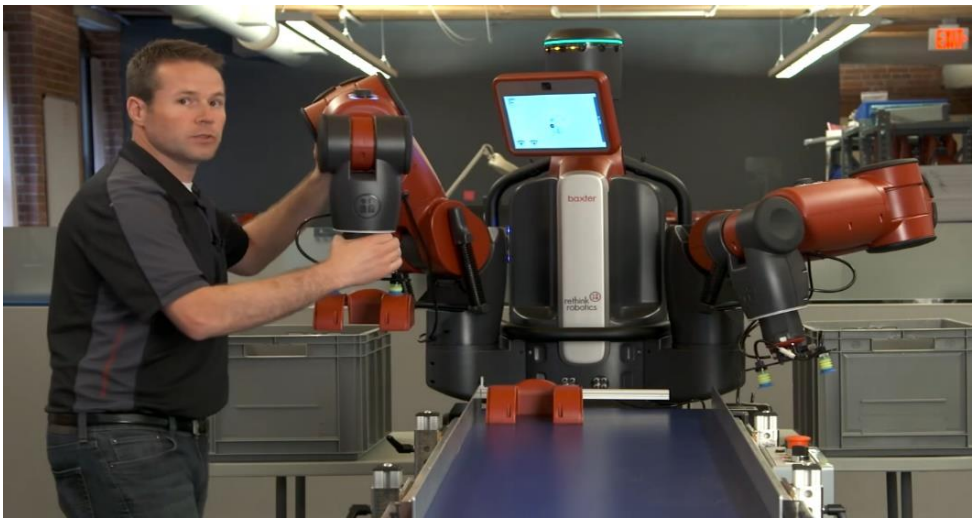

Figure 6: Programming the robot Baxter when set in a weightless mood.

Going even further, a brief look at DARPA's bionic arm illustrates how well machine interfaces are starting to become. With sensors connected to your body's nerve system it's Mind-Controlled. With it you can touch, and feel. The US government successfully developed a Luke Skywalker-like prosthetic arm (Star Wars-movie) that allowed the wearer to actually feel things (Murphy, 2015), it is a tremendous interface design between man and machine. (In a personal distinction, I would guess net-dating can be taken into a new level, but in the view of human exploration, it can be used within all sorts of robotics. This technology combined with cameras, one can control a robot with the mind, touch, feel and see things. Giving a sensory stimulus feedback. Imagine going to distant worlds in the universe, or places inhospitable for humans, experience and explore, and do physical accomplishments through a robot. Same type of sensor technology has been used in developing a full robotic suit for humans to wear, an exoskeleton suit that almost look like something pulled out of the Ironman movie. The Japanese company Cyberdyne Inc. have made this a commercial product for infirm rentals and heavy lifting workers (Cyberdyne Inc, 2017).

[24] The picture is obtained from website: https://www.youtube.com/watch?v=HA9fyHlP7gE
[25] The picture is obtained from videoclip at website: https://www.youtube.com/watch?v=4pdU2rCv91Q

Figure 7: DARPA's bionic arm controlled by thought.

Figure 7 shows DARPA's bionic arm controlled by thought, tremendous interface design between man and machine.[26]

3.2.5.2 Moores Law for Robots

Manufacturers of robotic arms like Dobot M1 offers an "industrial level robotic arm production platform," it can be 3D-printer, soldering machine or office worker putting letters into envelopes as they pop out of a printer, to picture some of its capabilities, and it is *logging everything digitally*. This machine can be outfitted with wheels so it gets mobile, it can then move around in a warehouse. With ease, it's connectable for working together with other machines, "Machine to Machine Communication" (M2M).

Kinect, multiple digital cameras and sensors, and an array of force and position detectors gives these machines eyes. Fast and accurate image recognition algorithm (pattern recognition) makes them distinguish colors and detect workpiece/object even if not appearing exactly on the same spot each time (like jelly jars on conveyer belts). For autonomous cars, a rig is mounted on top of the vehicle, the LIDAR (Light-detection-and-ranging), the most important "eye" of the car. As this device spins around the cars computer creates a 3D-image of the environments, extending 100 meters in all directions. It generates 1,3 million data points per second that is used to detect objects and avoid collisions. The computer determines if the vehicle must avoid objects, brake, accelerate or whatever's necessary. LIDAR becomes cheaper and smaller at a rapid pace. David Hall the CEO at Velodyne, a manufacturer of this rig, predicted back in 2013 that mass production would allow this product's price to "drop to the level of a camera, a few hundred dollars" (Shchetko, 2014). Back in 2013 the cost of this device was about $80.000. Researchers at the Massachusetts Institute of Technology (MIT) and DARPA have now developed a "lidar-on-a-chip." They write that the sensor can be produced at a cost of about $10 apiece. Several of these clips can be mounted around a vehicle. The clip doesn't detect in the same distance reach as the rotating device. A restriction

[26] The picture is obtained from videoclip at website: https://www.youtube.com/watch?v=sk1NkWl_W2Y

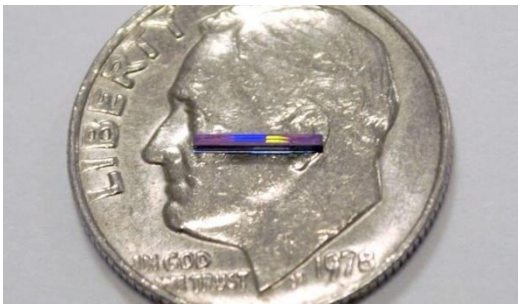

Figure 8: lidar-on-a-chip

DARPA feel confident in overcoming soon. The clip will make autonomous robots and vehicles much cheaper (Valle, 2016b).[27]

We constantly see new equipment in sensors, algorithms for pattern recognition and machine learning, and all these devices connected and sharing information digitally with M2M interactions or trough cloud computing. Autonomous cars can send information to the internet, or download information from the internet automatically, to share and receive information relative to road conditions and accidents etc. The machines learn faster than human capabilities. Once a machine has experienced something it shares it with the other machines and they learn simultaneously, as for humans, we must learn separately. Machines can receive information in a split of a second and with superfast processors they respond faster than any human, they can also do probability calculation to predict what's most likely to happen in the future and act on this basis. All this makes robotics and autonomous processes possible, and in many cases safer and more efficient than with humans.

In 2012 DARPA announced a new challenge, The DARPA Robotic Challenge (DRC). Launched in response to a humanitarian need that became glaringly clear during the nuclear disaster at Fukushima, Japan, in 2011. *The goal was to accelerate progress in robotics and hasten the day when robots have sufficient dexterity and robustness to enter areas too dangerous for humans and mitigate the impacts of natural or man-made disasters* (DARPA, 2017). Trials for the DRC was held in December 2013 and the finals in June 2015 at the Fairplex in Pomona, California. The DRCs' Finals Competition, challenged participating robotics teams and their robots to complete a difficult course of eight tasks, relevant to disaster response. Among them; driving alone, walking through rubble, tripping circuit breakers, turning valves and climbing stairs.
Taking first place and the $2 million in prize money that got with it was Team Kaist of Daejeon, Republic of Korea, and its robot DRC-Hubo.

DRC was seeking to solve problems for disaster-response operations by promoting innovation in human-supervised robotic technology. Robots with human qualities have long been an unattainable goal. They belonged to science fiction more than our reality. But now the robots are at full speed into our lives. The world's most advanced human-like robots now leave the laboratory to solve real-life real-world challenges (NOVA, February 24, 2016). This shows how robots can take over the tasks previously reserved for men, and an extensive use in harsh environments where people can be exposed to infection, toxins or other risks. Documenting and logging it's work operations digitally if implemented as for the industrial robots.

[27] Picture is obtained from Teknisk Ukeblad at website: https://www.tu.no/artikler/denne-bittelille-sensoren-kan-gi-biler-og-roboter-bedre-syn/350090

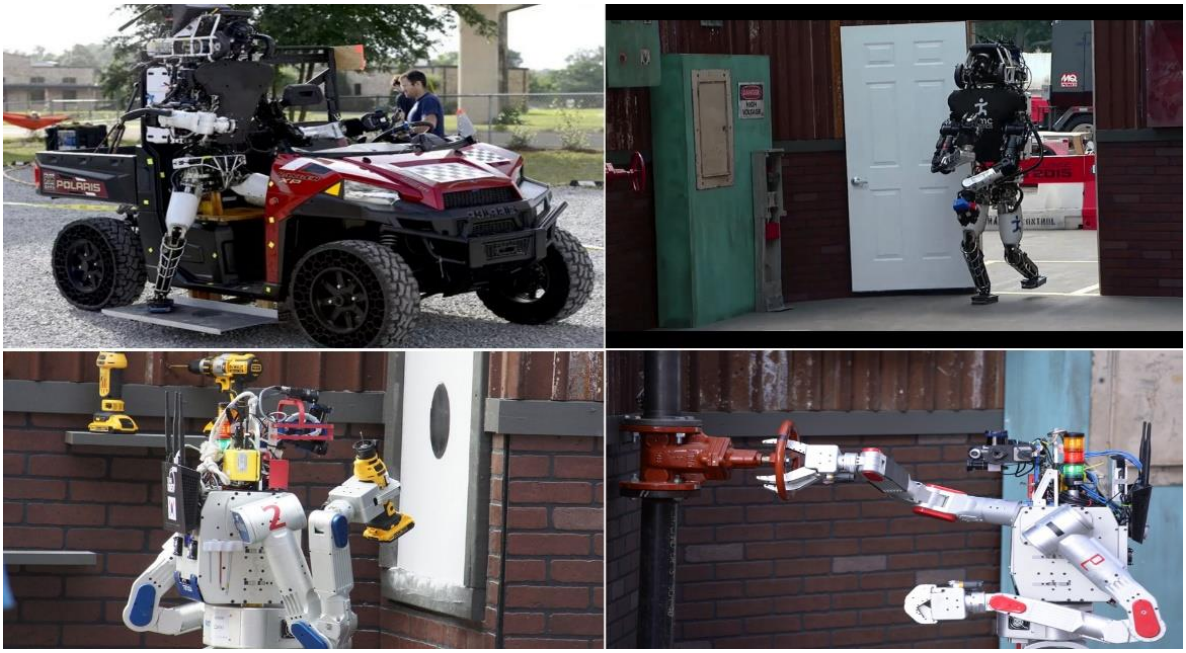

Figure 9: DARPA Robotics Challenge 2015.[28]

DRC robots are equipped with hardware containing LIDAR, cameras, sensors, accelerometer and gyroscope for sensing and keeping balance when moving. Software systems based on AI for patter matching and to optimize its actions. The robots have wireless connection to for human operators' computers for human interactions and approval of the robots' actions.

3.2.6 Virtual Assistants and Artificial Intelligence (AI)

In autumn 2011, Apple introduced "Siri" for their then-new mobile phone, Iphone 4s. "Siri" is an intelligent personal electronic assistant that works via a natural language interface. It's a digital secretary. There's been some challenges and constraints with Siri, but the application has evolved, and several other software developers have created other digital assistants. Digital-assistants are helpful tools for advices and question in frustrating environments but as they continuously grow their skills using IOT, Big Data and sharing experience trough cloud computing in the same way as robots and autonomous cars. They're becoming useful for advanced tasks. This type of software can be used in call-centers/customer service. "Amelia" is one such software provided by IPsoft, a technology company in development and delivery of autonomic and cognitive technologies. Amelia can answer "fairly" emotional, can perform thousands of calls simultaneously and remember everything that is said (IPsoft Inc, 2016). Software like these have voice recognition. Machine learning algorithms enables your software to learn each user's voice and can translate this into digital text. Voice recognition can be a shortcut from speech to text. Google offers applications to translate, transferee speech to text and reverse and combine other apps to work together. Working in Google Documents (GD) which is a cloud-service, you can take a picture with your smartphone of a document and open it in GD as a word file to work with, it can be translated and shared and a bunch of other possibilities. The pattern recognition is so strong it even translates many hand

[28] Website: http://archive.darpa.mil/roboticschallenge/

written notes, and translates languages from voice to speech in real time. Set in U.S mode Google Photo can recognize faces and environment in a fraction of a second, and are probably much reliable than any human pass port control. All these apps are free downloadable and working through cloud computing, no software to occupies digital space on your devices. They work just as well on a cheap device as an expensive one. These solutions are evolving and gets better continually as they are driven by machine learning systems. They are very useful in all types of tasks and help streamline documentation processes.

With the application GoogleMaps, you can use speech to ask about traffic situations, or the way to an address. Internet sharing info from other users of the application (IOT), lets Google know their position. Based on this GoogleMap can give an idea of where traffic is densest and most slowly to guide the user to the fastest rout. Such applications interact between the users, sensor, and GPS etc. using the internet.

Electronic translation assistance. They have obvious weaknesses, especially on complex communication but with increased use machine learning contribute to continuous improvements. Several people do not know, or come in mind all these solutions, free of charge, helpful for their everyday work tasks.

The translation service company Lionbridge has partnered with IBM to offer GeoFluent, an online application that instantly translates chats between customers and troubleshooters who do not share a language. In an initial trail, approximately 90% of Geofluent users reported that it was good enough for business purposes. Today GeoFluent translates 95% of all languages, more than 380 languages (Lionbridge, 2017).

We now let cognitive technology learn and use our natural language. There are AI software's writing poems and journalist articles. Even AI making music or suggest flavor combinations for chefs. Their capable in writing analytic reports for top corporate executives, or customized guiding's to individual employees. Typical middle level management work. Automated Insights (Ai) is a US-based technology company that analyzes patterns in Big Data and makes them readable narratives. Their software "Wordsmith" is a natural language generation (NLG) engine that lets you turn data into text at any scale and in any format or language (Automated Insights, 2017). In an interview of Michael Osborn, a professor in Machin learning and AI at Oxford University England, done by People & Power's Bob Abeshous (Power, 2015, 27. May). In the interview, Osborn gives an insight to his profession. "We'll soon see algorithms that are as capable as men of almost everything." He points out that machine learning is driven by cheap computing and access to large data sets. "That's what makes Google Translate possible." Machines now manage writing articles and reports as well as people, "It wasn't so long ago we thought it was impossible to reproduce this type of understanding in an algorithm." What's changed is the enormous availability of data from the web which describes exactly their kinds of narratives. So, an algorithm that is equipped to scrapple this text from the web, can dig into data and identify the common structures to all this different story, and go some way to understand the kinds of "things" that comes natural to us humans.

3.2.6.1 Virtual Assistants

In a report from the magazine DN.no - Gründer, Dag Kittlaus, the man who sold "Siri" to Apple, talks about his newly developed assistant "Viv" (acquired by Samsung in 2016). "Viv" understands what you say and uses artificial intelligence to solve much more complex tasks

than current digital assistants, as "Siri". With a cell phone, he asks Viv about the weather conditions at the Golden Gate Bridge Thursday three weeks ago, the application responds. He provides Viv to send his mother flowers for her birthday. Viv shows a bouquet and his mother's address and birthday, Viv is linked to a payment account, and voila, flowers on their way. "This is just the beginning of conversation based trade and interaction. Today we have to download, sign us in and learn to use a variety of apps to do things online. By Viv it's much easier "- states Kittlaus (Bertelsen, 2016). Many similar applications to Siri and Viv are free downloadable, they can translate many languages but are mostly operated by English speech, Google got one operating by other like Norwegian. Today such free applications can support us in many ways, booth in our work and daily life. To make us do multiple tasks, help us remember and perform tasks we can't do our self in some cases.

3.2.6.2 Artificial Intelligence (AI)

Algorithms are set to optimize their answers or solutions with the use of probability and statistics combined with pattern matching based on data the algorithm are given. The program optimizes itself through learning from successes and failures (Machine learning). IBM and Google are among companies that are good at AI. Google's search engine recognizes your movements and previous searches on the web and early starts to suggest options when typing in the search field. The same type of machine learning is put into robots who perform manual tasks to help the robot to recognize objects, making choice of actions based on what the algorithm is set up to perform, and what the software has learned from optimization through successes and failures. As previously mentioned the machines also learn from each other, Tesla newest vehicles are equipped with Autopilot that share data with other cars with Autopilot, so other cars coming to a potential obstacle already know what awaits (Valle, 2016a). Robots and sensors connected digital devices share information through the cloud computing and optimize each other.

AI have become a commodity product, you can find it in videogames and toys for kids. Anki Overdrive is an $200 intelligent toy race-track delivered by The company Anki (Anki, 2017). Each car is a self-aware robot, driven by AI to optimize options for the player. The cars are counting laps, keeps track of position, give the player advice of tactics based on the competitor's strengths and weaknesses, it also informs remaining battery capacity and remaining laps. This toy-platform interacts AI, cell phone / tablet, and robotics. Phone or tablet, works as control unit which also reviles info on the display. The whole thing is like a virtual game where the action happens physically. This shows how technology, sensors and devices interact, and how accessible it is. This "cheap" technology can be used to optimize processes in everyday work processes if the situation is well understood and the standards are clear.

Google offers everyone to take advantage of their AI engine, at their website Google A.I. Experiments you can sign up and present a problem you want to solve or explore and get support and access to use their AI for free.[29]

In the period between 2006-2011 IBM developed the supercomputer Watson, specifically to play the game Jeopardy. The quest was two develop a machine learning system that could

[29] Google website for using AI: https://aiexperiments.withgoogle.com/

beat humans in their own game. Watson went from being hopeless to invincible in 5years, in January 2011, Watson defeated the two most winning contestants in the game's history. Today Watson is used for many purposes related to business, industry and healthcare. As for medical purposes to predict diagnosis and suggest treatment of cancer patients. It does this by using machine learning algorithm, IOT and access to Big Data obtained from medical records, treatments and medications overview worldwide. Use of AI is well suited in areas where there is more information than we humans can digest as individuals.

3.2.7 Blockchain Technology

Blockchain technology are based on the Bitcoin concept. As Don Tapscott, adjunct professor of management at the Rotman School of Management at the University of Toronto presents, the system secures and streamlines exchange and trading of assets and goods (money, property, music etc.) without the loop through costly and time-consuming intermediaries'. Real estate management, banks, or other institutions that have previously been essential to ensure this kind of transfers. This means fast and good control of organizations assets, and security of property. In the context of transferring securities and documents, this technology reduces time and money spent on intermediaries and having increased security issues and sovereignty over own assets jurisdiction.[30] This technology can save costings up to 10% in over boarders transactions.

Referring Gartner 2017; "*Blockchain is a type of distributed ledger in which value exchange transactions (in bitcoin or other tokens) are sequentially grouped into blocks. Each block is chained to the previous block and recorded across a peer-to-peer network, using cryptographic trust and assurance mechanisms. Blockchain and distributed-ledger concepts are gaining traction because they hold the promise to transform industry operating models. While the current hype is around the financial services industry, there are many possible applications including music distribution, identity verification, title registry and supply chain"*(Panetta, 2017).

3.2.8 Recombinant Growth

The impact of ICT on industrial processes has been translated into a series of revolutionary innovation that fall within what has been defined today as the 'Digital Manufactory' or 'Manufacturing 4.0' or 'Industry 4.0' (Brettel, Friederichsen, Keller, & Rosenberg, 2014). Industrial revolution 4.0, the digital revolution, it's the revolution of our new digital machines, sensors and gadgets, referring to all technology described so far. But the most powerful driver of this revelation is by several scientists set to be the recombinant growth.

This growth through sharing of information gathered from machines sensors, cameras etc., and humans to the internet. Access to science for everyone, different professions and technology, people of different age groups etc. who can interact and solve problems related to all kinds of questions and obstacles. As an example, NASA had no method available to predict the onset, intensity or duration of solar particle event. The challenge of predicting SPEs was posted on "Innoncentive," an online clearinghouse for scientific problems. Bruce

[30] Videoclip Blockchain Technology: https://www.ted.com/talks/don_tapscott_how_the_blockchain_is_changing_money_and_business

Cragin, a radio frequency engineer solved it (Brynjolfsson & McAfee, 2014a). Video game technology used for medical purposes, or construction work simulation. Network Intelligence as Don Tapscott puts it (TED) He reflects on how sharing and openness helps to bring about good growth, such as goldminers and geologists who presented problems in an open forum on the web where the gold was found by game innovators. A solution from a completely different range of subjects.[31]

3.3 Theory - Documentation and Life Cycle Information

This part originates from Norsk Standard, NORSOK. Statoil's open source website, "Step to the future Life Cycle Information", along with explanations obtained from Dolphin Drilling and experiences shared by LCI coordinators from Norwegian petroleum activities. Also, Abu – Shagfa and Menyar Deyab Master's Thesis from 2014 “Challenges and opportunities in tags and tag-related technical information management” cover the relevant standards and regulatory requirements for Life Cycle Information (LCI), documents, and Document Control Center (DCC).

3.3.1 DCC and LCI history

LCI = Technical Information + Information Requirements + Tools + Working Processes

The focus on LCI was strengthened in the late 1990’s after the PSA discovered a series of «bad practices» by operators/owners of offshore installations on the Norwegian Continental Shelf. These findings stated that safe maintenance/operation/modifications were in the danger of being compromised due to lack of relevant documentation, poor marking of equipment and inadequate systems in place for such work processes.

This lead to the industry working together to revise existing and produce new guidelines to the industry, such as;

- NS 5820 - Suppliers documentation of equipment
- Z-001 - Documentation for Operation
- Z-DP-002 - Design Principles CODING SYSTEM
- Z-CR-002 - Component Identification
- Z-018 - Supplier’s documentation of equipment, this standard is based on NS 5820 and will replace the standard within the petroleum industry.

Source: Norsk Standard, NORSOK

[31]Videoclip Don Tapscott Recombiant Growth:
https://www.ted.com/talks/don_tapscott_four_principles_for_the_open_world_1

NORSOK Z-001 Documentation for operation (DFO)

This standard defines the extent and details of technical information which shall be available for use in the operational phase. The main objectives are to ensure that only necessary information is kept available, to facilitate the safe, effective and rational operation, and maintenance and modifications of the installation.

NS 5820 Suppliers Documentation of Equipment

The standard NS 5820 gives a frame for the extent and presentation of the suitable documentation for equipment deliveries. The standard can be used for all types of equipment, from standard products to package equipment. It defines suitable documentation for the different phases of a delivery, and it gives an overall description of different types of documentation and a way to group these.

Life Cycle Information (LCI)

Information required by the Company for engineering, preparation for operations, start-up, operation, maintenance, repair, modification and decommissioning of a unit. LCI includes both information submitted to the Company and retained by the Supplier on behalf of the Company. LCI includes what has previously been termed in NORSOK Z-001 Documentation for Operations (DFO) and NS 5820 Suppliers Documentation of Equipment.

3.3.2 General Definitions

Differences on LCI and DFO and how they are interpreted to various sectors:

• Industry definition of DFO: « Documentation for Operation, i.e. Information (data and documentation) required for engineering, fabrication, preparation of operations, start-up, operation, maintenance, repair and modification of a plant».

• NORSOK definition of DFO quoted in standard Z-001: «Technical information which shall be available to facilitate the safe, effective and rational operation, maintenance and modifications of the installation».

• (LIFE CYCLE INFORMATION) is generally defined as “all technical information produced and modified through engineering, construction/fabrication, and operation phases throughout the life cycle of an installation”. LCI include both DFO and non DFO documents as well as digital information transfers.

3.3.3 LCI and (DCC), is it not the same! The main differences:

3.3.3.1 LCI-Coordinator

This is a position appointed from company, contractor and supplier. The position's task is to ensure requirements and deliveries are met per contract specifications (scope of work). A LCI coordinator is seen to be a single point of contact between company and contractor, or contractor and supplier, regarding LCI. This position is involved in all phases of a project. From tendering to final handover.

3.3.3.2 DCC

DCC's responsibility is to ensure that all documents and drawings are coded correctly, contain all relevant classification metadata such as system code, doctype, tag reference, etc. as per contract/project specifications, and that documentation is being submitted to all relevant recipients at the right time (specified by submittal dates in document lists).

Compare the roles to that of sending a letter; LCI checks the content of the envelope, and DCC makes sure it has the right address and postage on it, before posting it.

Document Control Center (DCC) in projects are mainly focused on ensuring that the proper documents are created, and to control the flow of these within the framework of the project (internal and external). Documents shall be established in accordance with specified requirements, undergo professional assessments internally and at customer, or supplier. There shall be registered and measured and propulsion shall be reported, and the documents will be completed per the project network plan. Document Controller will report deviations when encountering so (someone else) can take necessary actions.

DCC are usually included as an integral part of LCI-coordinator responsibilities when such is established. In larger projects, it is just as common with a separate executive document control that receives control from LCI-coordinator regarding everything related to customer LCI-requirements.

Many interpreters document control as "checking documents" (as in Tax Administration, Customs Service and other government regulatory agencies such as checking that certificates or other documents are consistent with requirements in legislation and regulations) or use it as a "nicer" name traditionally "archival work" in public administration, as the importance of the archive service on behalf of the agency responsible for the overall and practical check and approve or control of the overall document management.

3.3.4 DCC Stage gate process

A project usually starts with a kick off meeting between customer and vendor. Here the contract is settled, containing issues like; bid, scope of work, dating of milestones and final handover. The appointed LCI coordinator for the project interacts with the customer and project managers. Defining all the required standards and specifications required for the projects documentation according to the delivery. DCC receives the requirements to follow

for review and approval of the projects documentation. The same goes for the technicians who will interact with project manager, DCC and LCI coordinator during the project's design and production phase.

As a project carries on, it will pass through several “Stage Gates” (SG). There are probably many methods and software programs related to a BIM structure that can run this process, but as an example a systemized Excel sheet can be used for this purpose as shown in Figure 8. This is a system obtained from an industry company. The Excel spreadsheet is linked up to a documentation management system provided by ProArc, a program previously used by Statoil. In the transition between each SG, the Workflow (WF) must pass through DCC, before entering next stage. This is shown as a very streamlined process throughout a project. Projects are well known to not work out according to plan. Typically, different obstacles will entail activities to be postponed. Constantly project managers must reorder resources seeking the optimal progress in projects. For most cases, projects will be carried out on several SG simultaneously, the project's overall progress will not wait for the ‘Stage Gate Workflow Sheet’ to be complete on each SG before conducting work that lies ahead. The intention of this spread sheet is to ensure an overview of completed documentation for projects. An overview of completed milestones, and a summary of the overall process.

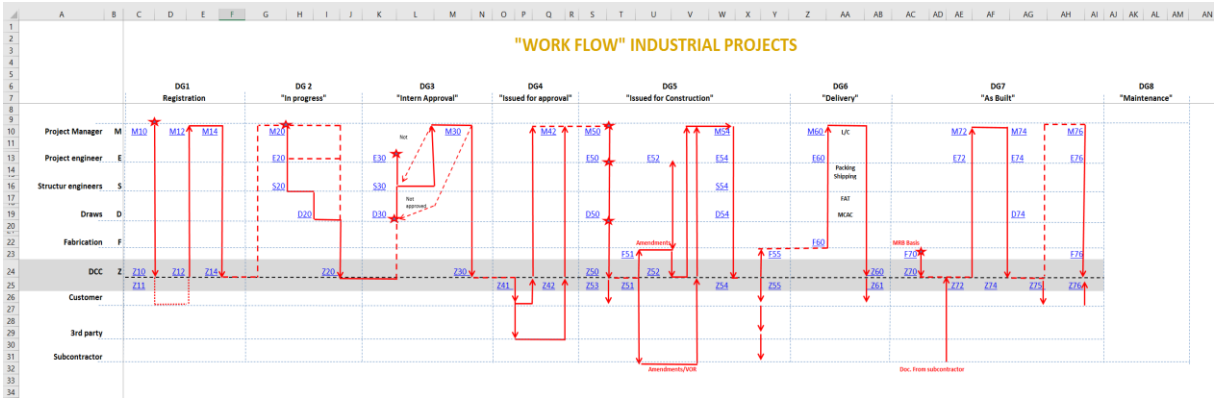

Figure 10: Excel Spreadsheet, Stage Gate Work Flow[32]

[32] Picture obtained from personal excel file, shared by experienced LCI personnel

4 Technology to Support Engineering, Construction and LCM

The chapter is divided into five main parts. Part one considers possibilities for automation of documentation processes (DCC and LCI) with the use of RPA. This part continues with an introduction to the concept of centralized digital document system operating through cloud-service. With data gathering through cloud for optimization of products and customer support. Part two - Technology to Disrupt Construction goes through McKinsey & Company report 2016, "Voices on Infrastructure: Rethinking Engineering and Construction" with reflections on concepts presented in Chapter Three, and products on the market to support McKinsey & Company ideas to disrupt construction. Getting in to High Definition Survey Technology (HDS) and Virtual Reality (VR) to support Design, Built and Operate (DBO). Part three presents the concepts of 5-Dimetion Building Information Modeling (5D-BIM), and presents Algorithmic Design with the ability to support design with artificial intelligence for optimization. Part four - Building Optimization, Designing with AI. The process of Generative Design is presented, and how new digital tools make it easier for designers without expertise in programming to use such processes to optimize design. Part five considers some risk related issues to the presented technology, technical and organizational risk. Human factors in the approach of implementing new technology.

4.1 Automating DCC and LCI Management

This part considers opportunities for Robotic Process Automation (RPA), Cloud computing and robots/machines to support automation of DCC, LCI, LCM.

4.1.1 Design Rules and Documentation Standards

Standards for what DCC and LCI imply in relation to documents and information are given in Norsk Standard, NORSOK as presented in Chapter Three, part Theory for DCC and LCI.

Requirements for design regarding capacity and performance in relation to class standards and scope of work. Non-regulatory requirements are added to agreements entered between the manufacturer and the provider.

For 3D modeling with Computer Aided Design (CAD), a Software can control the 3D model against delivery requirements, a "Model Checker". Solibri Model Checker (SMC) is such a software.[33] CAD designers are informed about requirements and the SMC in its rule set before 3D modeling is started. SMC can check requirements such as wheelchair circles, component number (chairs in a room relative to delivery), and clearance. The software also checks crashes and will state the location where requirements are not met. According to Solibri, SMC check designs prior to delivery to construction company, or building owners (Solibri Inc., 2017).

[33] Website SMC: https://www.solibri.com/products/solibri-model-checker/

4.1.2 Automation of DCC Stage gate process with RPA

With the clearly defined demands for the DCC this could be related to a set of rules to follow. Referring to authors Frank Levy and Richard Murnane statements presented their book "The New Division of Labor". Since computers are really good at following rules, they should do arithmetic work and similar tasks (Levy & Murnane, 2004).

> *"In any sensible economic system, people should focus on the tasks and jobs where they have a comparative advantage over computers, leaving computers of the work of which they are better suited" (Frank Levy).*

An RPA software set to obey rules implemented at the start of a project, may automate tasks in DCC. As Figure 10 illustrates, DCC receives documents from other disciplines. Like Technical Drawings (DWG's) possibly pre-checked by SMC or similar software. An RPA may be able to use SMC for approval if implemented in the RPAs' settings.

An RPA may be set to run through a whole projects documentation from start to final handover.

PwC Denmark have listed some reasons why use of RPA is not wider spread as shown in Figure 11. If what is pointed out by PwC in Figure 11 gets examined, an adaption of RPA for DCC automation might be considered as possible. Added with connectivity as shown in Figure 3 (IBM Watson). The RPA can cope with more advance tasks as pattern recognition can understand the contexts in documentation received from subcontractors or a third-party supplier. Gather and place the documentation received under the correct codes and folders for final handover to end user, or directly into an organizations DCC and LCI system. Machine learning will make this system continually improve, sharing experience with other machines as for the self-driving cars will provide further improvements.

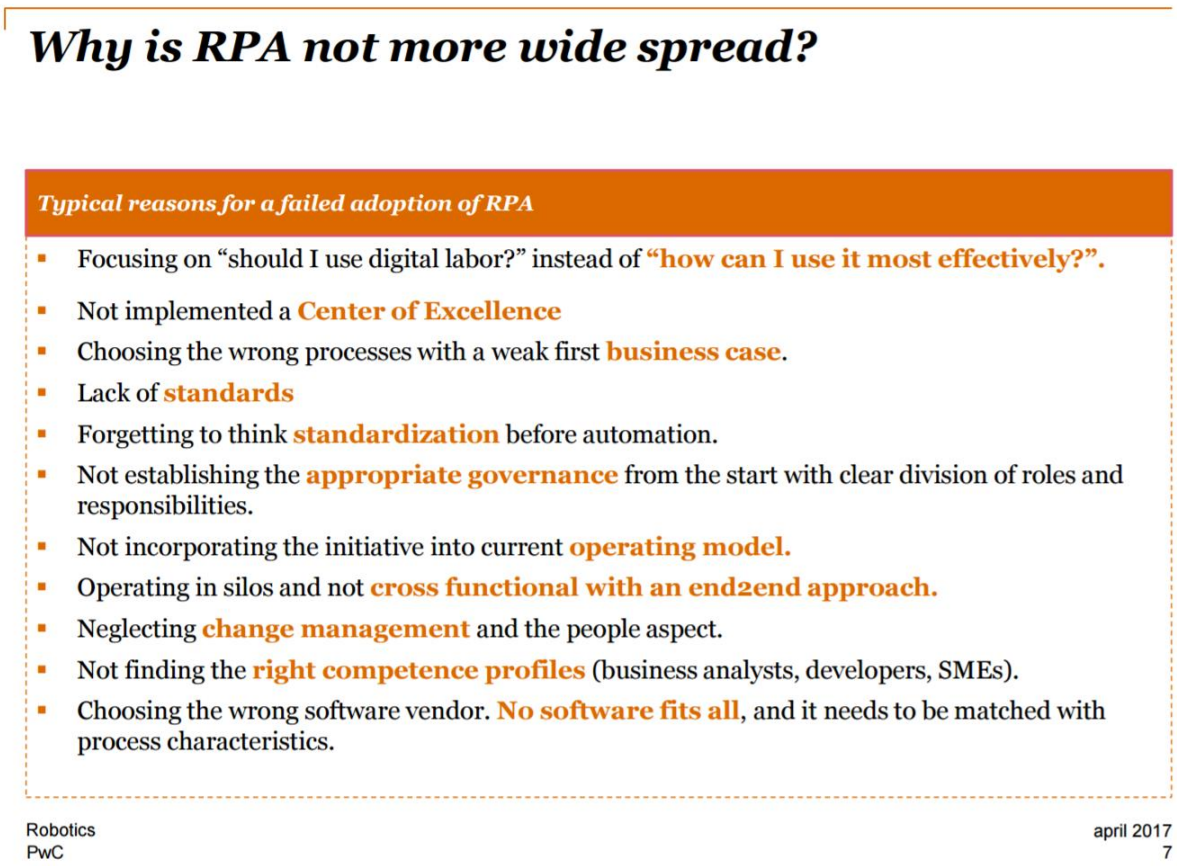

Figure 11: Listing what RPA needs to be adopted[34]

4.1.3 Cloud-based Construction Document Management

Typical sharing of information and documents in construction industry or operation and maintenance operations are done by paper, e-mail, communicating by telephone, chat or directly from leaders. This is time-consuming and ineffective. Things get misunderstood and forgotten easily, documentation gets missed and control can slip. All this demand extremely active leaders to constantly checking activities and control for errors, also constantly seeking feedback for improvements and better calibration between workers in all disciplines. Cost Controllers to operate Enterprise Research and Planning system (ERP) to seek control over budget and logistic.

Key factors for managing activities during construction and operation and maintenance tasks are QA/QC. The combination Quality assurance (QA) and Quality Control (QC), where QA is the process or set of processes used to measure and assure the quality of a product and QC is the process of ensuring product and services meet consumer expectations. *Implement a centralized digital document system operating through a cloud-service* can support QA/QC. As construction projects and LCM moves from paper plans and drawings to digital and mobile, quality assurance and control can become faster, more effective, and better at mitigating errors and risk. Workers can get and share information in real-time, and can constantly document what they are doing into the document system. This can be a synchronized document platform for all disciplines in an organization with the ability for

[34] Picture obtained from CXO-konferencen 2017 Robotic Process Automation - PwC, website: https://www.pwc.dk/da/arrangementer/2017/cxo-konf-2017-rpa.pdf

suppliers to connect by access to the cloud-service. If such a document system is added Building Information Model (BIM) from facilities under construction, or for existing facilities for operation and maintenance tasks, or generally LCM, such system becomes even more interactive. BIM is a virtual 3D model that contains information about the structure and its components. By opening a BIM model on an electronic device, you can virtual click on the structure or on components and be given the information that is added to the BIM model, also virtually "look-through-walls" to detect location of hidden components or structure. Components may be tag-numbered in BIM and physically be labeled with barcode or QR-code in addition to the tag number. This code can then be scanned by mobile devices, and the information about the component is automatically shared from the cloud service. The data can include details about the components manufacturer, when it was installed, the necessary maintenance that it requires and when, how to operate it at its optimum level to enhance performance or conserve energy. The information you want to share is added to the cloud service, and access level can be defined. New information can be added from maintenance work or under compilation by operating personnel. Updates, notifications and information are shared in real-time. Sensors can be applied on components and structure and share data into the system by a IOT solution. These data can be used to detect errors, but also to improve components, analyzing data can provide optimization and innovation to products, where both customer and producer can seek benefits. The manufacturer can assist customers with improvements to components and facilities based on the data added from the cloud and optimize products for their new projects. Hence sell more, provide good basis for innovation and shorten the development cycle. The customer receives better products and stronger support for maintenance and optimization (service and strategies). The solution provides greater value for both customer and supplier.
For construction document management, Autodesk offers the solution, BIM 360 Docs.[35] The solution is an application that manage all projects documents with unlimited storage in cloud. Allowing to create and share from any device, it's adaptable for specific user set up. The application has access control for user and permission level.

"Project administrators can link or set up barcodes in the BIM 360 Field web or mobile application. Team members can use the BIM 360 Field mobile app to link codes to equipment, locations, or documents" (Autodesk, 2016).

The BIM 360 Field solution makes it possible to use the BIM-model for use on site under construction, and for the end user to support operation and maintenance work. With the use of barcodes or QR codes located on different equipment and areas, it's possible to calibrate to synchronize the BIM-model on a tablets screen to the building or construction surroundings. When moving around the BIM-model follow on the screen, allowing to "see through" walls and getting out information and documentation for different components. Scanning codes on equipment, all information and documentation to this pops up on the device screen. A quick and easy way to record, retrieve and share information. Providing documentation and LCI processes to be carried out directly in field as well as feedback on projects progression. Creating a complete digital record.

[35] Autodesk BIM 360 Docs website: https://bim360.autodesk.com/docs

4.1.3.1 Direct Documentation, Decisions On-Site

Autodesk 360 Field Glue is a software that designers and administrators use for connecting the 360 Field solution (the cloud service) to their BIM model, the "heavy" model containing all sorts of information. This is a purchased application that connect your assets to the cloud, it's the subscription to the service. The 360 Field Docs (Docs) solution is a free downloadable app for smartphones, tablets and computers that anyone can use. Through Docs you get access to the project or asset you work on; the managers choose access level and what to share from the original BIM-model to the cloud. This way all workers from different suppliers' work in the same digital environment, directly update punch lists and documentation on site also access relevant information and have directly connection to the office managers and engineers. The managers can open a dashboard shown in Figure 12, connected to all the activity and follow up on progress and status in real time at any location. This dashboard also provides information to an assets ERP-system. Supporting automation of logistic and cost control.

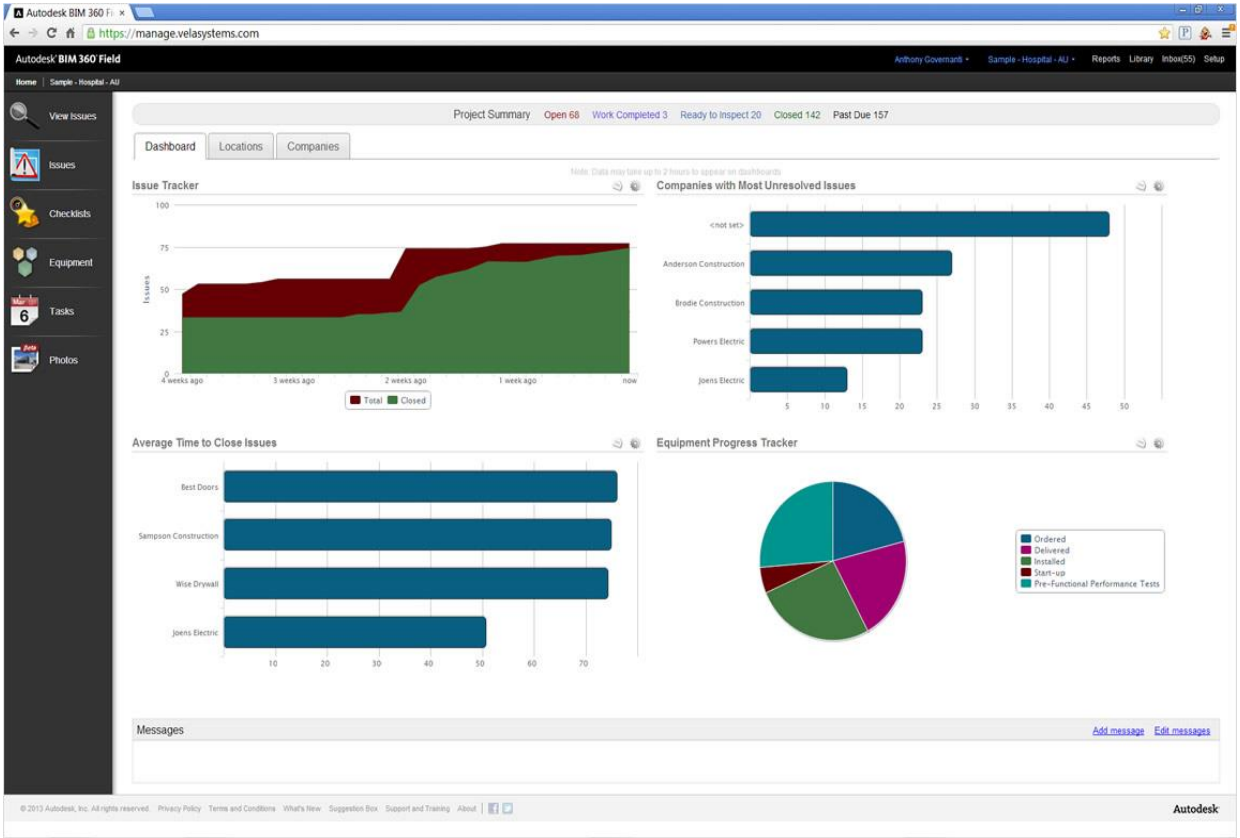

Figure 12: Autodesk Field 360 BIM, Dashboard (Autodesk, 2017a).[36]

The Field 360 dashboard (Figure 12) is a real-time indicator for managers. A well-organized overview for feedback and control in new building projects as well as for operation and maintenance work when facilities are put into use.

[36] Illustrating dashboard at website: http://www.autodesk.com/products/bim-360/overview

This sharing of information and cooperation allows more decisions to be taken on site as long as managers receives required knowledge from the system. According to E.G Frankel, Information Requirements for Decision-Based Management, the Field solution fulfill the authors statements to requirements for decisions on site:

- *Performance data*
- *Recourse information*
- *Status and condition information or reports*
- *Physical parameters and availability of asset such as equipment and fixed facilities*
- *Performance standards*
- *Manpower availability, location, and capability*
- *Regulations and other restrictive norms or measures*
- *Operational plans and operational sequences*
- *Decision structure, sequence, and interdependence*
- *Decisional interdependence*
- *Decision triggers, implementation, outcome, measurement, and reporting*

(Ernst G Frankel, 2008) chapter 7.1.

Documentation also get digitized and uploaded on site in real time. Referring to the total quality control principle;

> *"Everyone in the organization at all levels, supported by systems in place to make it happened. This is meaning of "Total" in Total Quality. Essential to the application of Total Quality in an organization is the systematic, continual improvements in the capability, reliability, and efficiency of business processes."*

(Christopher & Thor, 1993).

Figure 13 illustrates how this system can be operated out in field, and how to cooperate with managers, engineers and ERP-system through the cloud-service.

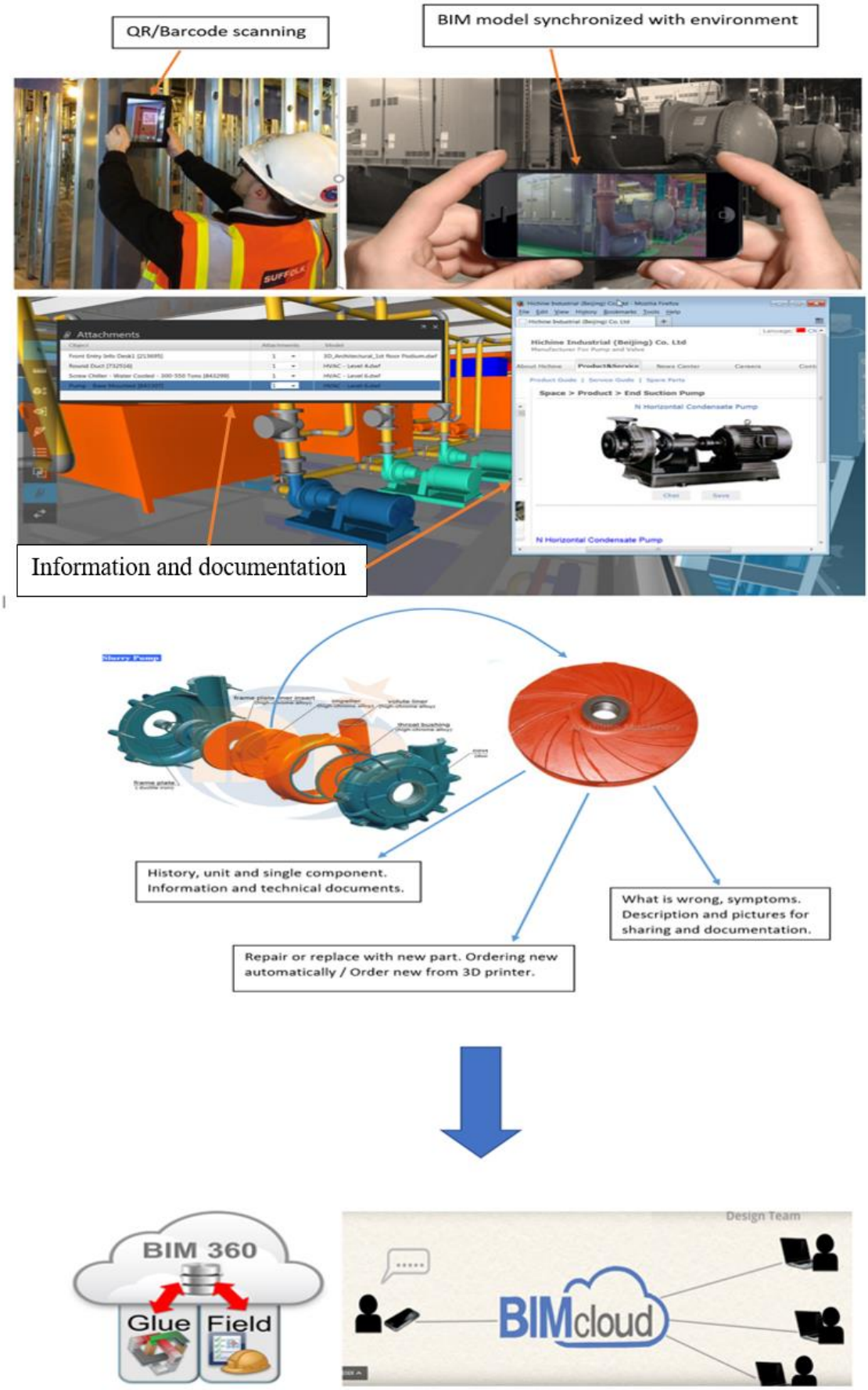

Figure 13: Picture illustrates digital Document system working through cloud-service, obtained mixed sources.[37]

The BIM 360 Docs provides Construction busnisses the consept of Virtual Design and Construction (VDC) as it offers the use of BIM on-site, and in building meetings for all workers in a project with the use of mobile devices. Project participants reduce misunderstandings and increases the possibility to do things right the first time by clearly communicating their needs. Using visual tools such as BIM to discuss challenges and solutions, and collaborating with designers from construction site, providing feedback and markup on the BIM model in the document cloud-service. This digital calibration and mobility referres to one of McKinsey & Company report 2016, "Voices on Infrastructure: Rethinking Engineering and Construction" as one of the five big ideas to disrupt the construction industry (Agarwal et al., 2016).

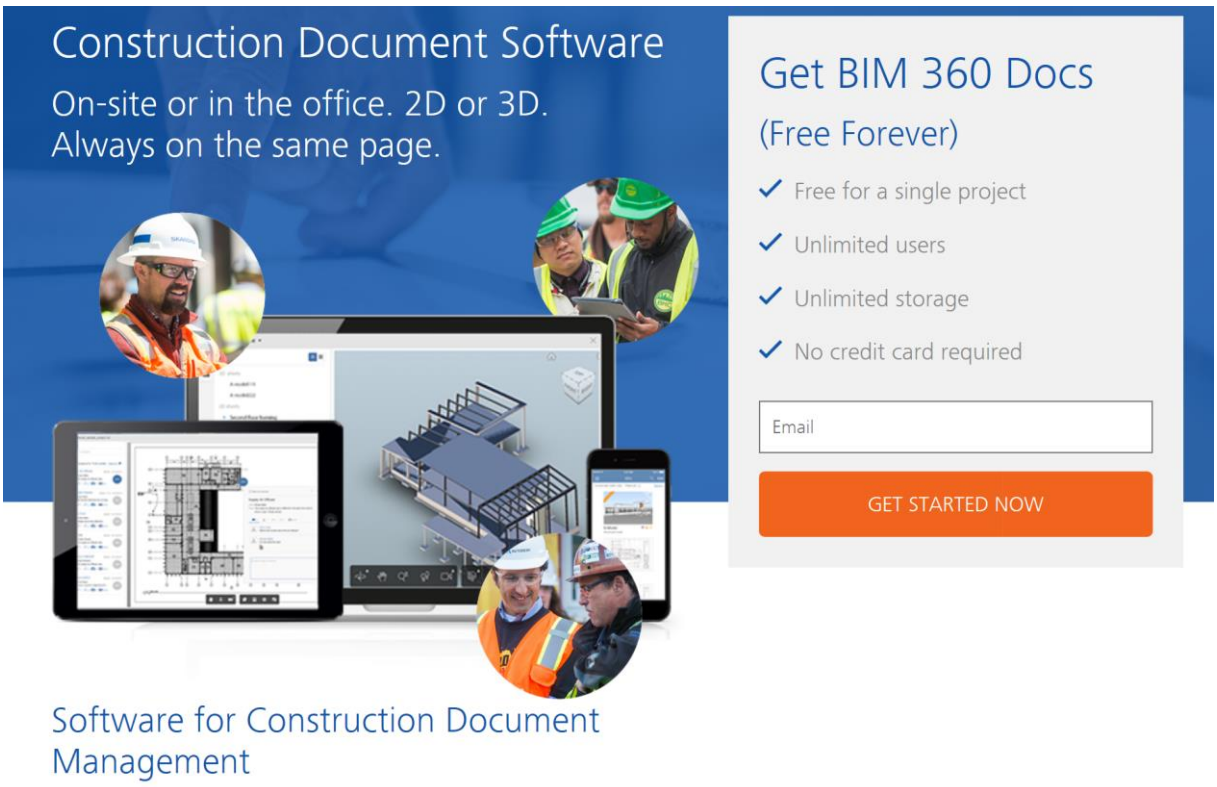

Figure 14: Picture Autodesk Docs on all digital devices supporting VDC.[38]

4.1.4 Automation of ERP-System from Cloud PLM solution and CAD

According to Symetri, a provider of management systems and CAD applications, PLM (Product Lifecycle Management) is a strategic business philosophy and a solution that includes a number of business processes. These processes cover everything from developing new products, innovative collaboration, global production, and dissemination and use of product data to all project-involved throughout the product life cycle (Symetri, 2017).[39] Cloud solution can bridge the systems gap between; PLM, Product Data Management (PDM) and ERP-system. Integrating a PLM cloud solution with ERP access to PLM documentation such as drawings and spec documents more automation and greater productivity can be

[37] Website and videoclip illustrating digital document and management system: https://connect.bim360.autodesk.com/construction-quality-control-plan
[38] Download Autodesk Docs at website: https://bim360.autodesk.com/docs
[39] Definition of PLM, Website: http://www.symetri.no/plm/

achieved. Device mesh and cloud computing with sensor technology and IOT concepts support this integrity to bride these systems gap.

4.1.4.1 Device Mesh

"Device Mesh", or network of devices which Gartner describes it ("Gartner's top 10 technology trends for 2016.(INFO TECHNOLOGY)," 2016). Devices interact with each other and revolves around the individual or users of system. The devices can be computers, sensors or cellphones and tablets, all sorts of electronic devices. They form a network structure and entangle the user. Thereby more meaning is divided, this increase information exchange and optimizes work flows.

Device Mesh illustrated in relation to maintenance operations;

Sensors on a machine part alert an electronic device about defaults, responsible personnel get notified. Further, the mesh alerts a spare part system to deliver a new machine part, or a 3D-priter to make the replacement part. The user can concentrate on other tasks until the new part arrives. Sensor technology and cloud computing have started to provide such solutions for all kinds of industries and services. The telecom company Telia are active in creating innovative solution in collaboration with other sectors. Telia and 7Sence, a Norwegian technology company, have developed Scandinavia's first commercial solution for Internet of Things, and are ready to share knowledge with technology companies who want to take the future of the communication standard in use. They have delivered a solution for smart agriculture.

"With a new product from 7sense Technologies farmers will control the status and position of all their irrigation systems comfortably from their smartphone, tablet or PC. Equipped with sensors monitoring the water pressure, GPS for positioning, and Narrow Band IoT (NB-IoT) connectivity, the product is just what farmers need to regain peace of mind during the watering session. Relying on the unparalleled coverage of NB-IoT, very low power consumption, and the superb quality of service on the cellular network, farmers will enjoy the simplicity and control the product gives day and night, season after season. The result; no more costly damages from watering, and plenty of time for other tasks"

(Telia, 2017).

Along with entrepreneurial company ContinYou, Telia has developed a solution for a health watch that can record fall and health condition of the user. Sensors on the watch share information through cloud and inform persons who access the data (health personnel and relatives) on their mobile devises and computers. Data shared and gathered trough cloud can support analytics in predictions and to optimize products and processes.

With sensors on equipment sharing trough cloud service. Condition monitoring of dynamic machines and static mechanical equipment can be linked to mobile devices. Data from the sensors can further be used for condition monitoring and analysis for maintenance strategy and subsequent optimization of components.

4.1.4.2 Digital collaboration and mobility

Develop and apply digital collaboration and field mobility solutions for cloud based services, mobile-enabled field monitoring and sensor technology. Companies like Telia has developed solutions for agriculture for easier monitoring of irrigation systems and farm animals.[40]

With the use of Google App Maker an asset can customize their own applications for their own purpose.[41] Autodesk provides their Fusion Lifecycle solution[42] with applications for mobile phones and tablets for both the design phase and LCM. A type of platform that integrates project planning, engineering, physical control, budgeting and document management for large projects. Sensors on components share data to a cloud PLM solution to support a product innovation platform, were data can be used for improvements and innovation.[43]

The book "Sustainable Operations and Supply Chain Management" (Belvedere & Grando, 2016) addresses the most relevant topics of operations and supply chain management from the perspective of sustainability. The authors Valeria Belvedere and Alberto Grando describes the possibilities of how intelligence and connection is incorporated in equipment and machinery defined as smart machines which can interact and compare with one another, and produce as well as use data by sharing. Following a path made up of the following steps: product design, sourcing, manufacturing, packaging and physical distribution, reverses logistics and recovery. They provide a step by step guide for managerial decisions made along products life-cycle. This is exactly what this cloud based documentation and Product Life Management solution from Autodesk offers construction and LCM.

IOT for all kinds of business:

Ideas and concepts to take more advantage of digital technology for industrial purposes. Use of digital technology to support higher efficiency and more secure processes within various sectors. From municipal, government agencies and healthcare, to in general all types of businesses.

The number of people interacting on development and use in any fields of applications are growing, from remote medical diagnostic to home automation and smart buildings, from electrical network control systems or new generations of automobiles to M2M control devices. The success of this technology has created an exponential increase in the demand of connectivity and integration between the operators and the various parties, rendering the boundaries between competition and cooperation increasingly faint and simulating the convergence of different industries (Belvedere & Grando, 2016).

[40] Telia IOT sensor technology website: https://telia.no/bedriftsmagasinet/telia-forst-i-norden-med-fremtidens-teknologi
[41] Website Google App Maker: https://developers.google.com/appmaker/
[42] Website Autodesk Fusion Lifecycle: http://www.autodeskfusionlifecycle.com/
[43] Videoclip link, Introducing Cloud PDM in Fusion Lifecycle: https://www.youtube.com/watch?v=jCHY9th8ev0&list=PLQ_I2j-3dBCON24KlU5vmJkx1Lfb1c215&index=5

4.1.4.3 Bridging Gap Between PLM and ERP

All this data shared in a PLM cloud solution from documentation and sensor can be used to support the ERP-system for automation by analyzing trends.

Together with CAD engineering data that typically have been transferred manually between CAD-Files into the ERP-system have now been supported by an application to bridge this gap. Providers of CAD software have been integrated by a development partner to SAP, a provider of ERP solutions. CIDEON is SAP's development partner and the provider of this integrated solution between these systems to bridge this gap and support more efficiency and automation to logistic and cost control. Management accounting can be provided with data shared from the PLM cloud-services (both documentation, and sensor data through cloud-services) and CAD-designers bridged into the ERP-systems, supporting automation of an assets accounting system.
Figure 15 illustrates the virtual wall that typical exists between engineering systems on the right side and ERP-systems on the left side in an asset, CIDEON have a solution that avoid this manual transference of data and automate these actions.

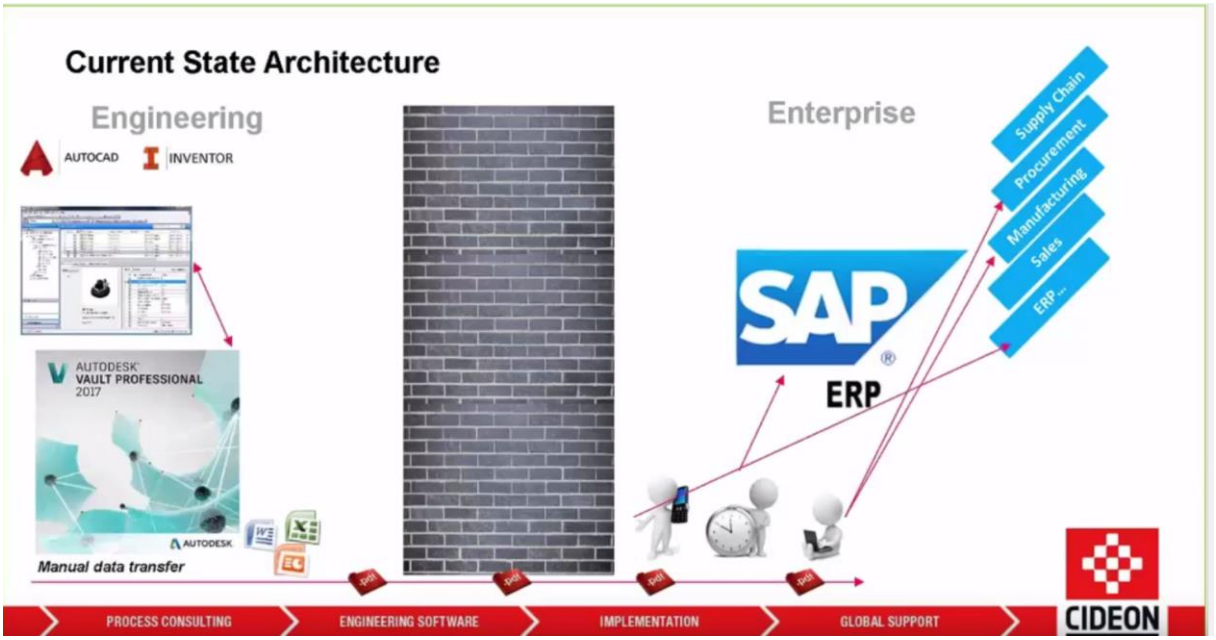

Figure 15: Illustrates how CIDEON solution transfer data between Engineering and ERP.[44]

4.1.5 Future-proof design and construction Reduces Document Work

3D printer is taken outdoors, assembly robots for advanced constructions ablest increased use of machines doing manual tasks that previously have been reserved for human workers. Reflecting on the DARPA Robotic Challenge robots as seen in Figure 9, the capabilities of robots to manage advance tasks in various environment have increased a lot lately. Advances in user interface makes it possible for workers without special expertise to operate and program the machines. Industrial Robots like Baxter illustrated in Figure 6 are equipped with cameras for machine eyes, patter matching, machine learning and M2M interaction. This allows the robot to understand the variation in processes such as devices on an assembly line

[44] Picture obtained from videoclip at website: https://www.youtube.com/watch?v=RP3GTjsNdGY

arrive differently. When using CNC machines, robotized processes and 3D printers for production manufacturing or construction work. The requirements of detailed drawings or other documentation in relation to the execution of an operation is no longer needed to the extent as for human labor work. CAD-files can be sent digitally to machine centers and robots from CAD-designers after the BIM model is approved by Solibri Model Checker (SMC) and executives, so that parts and assemblies follow the virtual 3D model. This will, in addition to automating the physical tasks, reduce the documentation work. The machines can record, document and approve their own work if equipped with cameras and other tools for inspection, and digitally transfer the inspection documentation directly in to the DCC and LCI system (as-built documentation).

4.1.6 World Class Manufacturing by Automation of DCC and LCI Processes

RPA, cloud-services and robots/machines to support automation of documentation processes and LCM. For Develop, Build and Operate (DBO) facilities and manufacturing operations. The construction industry will be moving towards a world class manufacturing environment (WCM). Referring to Brian H. Maskell book "Performance measurement for world class manufacturing: a model for American companies," the term world class manufacturing is very broad but will generally include the following:

- *A new approach to product quality*
- *Just-in-time production techniques (JIT)*
- *Change in the way the work force is managed*
- *A flexible approach to customer requirements*

(Maskell, 1991)

According to B.H. Maskell, the WCM approach to quality primary emphasis the resolution that cause poor quality, rather than merely detection of those problems. Traditionally construction work and manufacturers have a large staff of inspectors whose job is to check and record the quality of everything that is brought into or is construct/made by the enterprise. Inspections is performed by independent, trained inspectors rather than by the operators who are making the goods or performing the physical operations of building or maintenance work. The method is not only an expensive way of attempting to assure production quality standards, but is also ineffective.
The concept holds that a high-quality product is one that is studied and inspected at every step of the manufacturing/construction process and the goal of zero defects, or 100-percent quality. A world class manufacturer is not satisfied until the rejected rate is gradually and systematically reduced to zero. The sharing of data from sensors on components through cloud-services to support customer and improve products support this philosophy like the Autodesk Fusion product innovation platform.[45] Also, a second aspect of WCM is that quality control is placed on the shop floor with the production operators. This might be what a centralized digital document system operating through a cloud-service can provide the construction industry and LCM. As Maskell puts it, *"the operators are responsible for doing their own quality control and a pride of ownership attitude is fostered"*(Maskell, 1991).

[45] Autodesk Fusion product innovation platform, videoclip link: https://www.youtube.com/watch?v=wH-AmZp88lo&list=PLQ_I2j-3dBCON24KlU5vmJkx1Lfb1c215

Working with applications like Autodesk Docs the operators on a construction site can solve tasks together with managers and engineers allowing them to be integrated in decision-making, quality control and documentation of work performed.

4.1.6.1 Just-In-Time Manufacturing

A second element of WCM is a JIT approach to the production process. The prime purpose of JIT is to eliminate wasteful activities (Maskell, 1991).

Maskell defines waste as any process that increases costs but does not add value to the product. These activities include:

- Inspections
- Unnecessary movement of materials
- Shop floor queues, *for construction workers that will more be like waiting for permission or technical documents.*
- Rework or repair
- Storage of inventory (raw materials, work in process, or finished goods)
- Overhead personnel

A centralized digital cloud based system ensures everyone to share information to project progress or facility management, as shown in figure 12, the dashboard. This ensures a real-time overview of operations, personnel and equipment to support a JIT approach for management of an asset.

4.2 Technology to Disrupt Construction

This part will mainly focus on technology and techniques to support planning and CAD-engineering tasks. Starting with reflections of the McKinsey & Company report 2016, from which the first part of this chapter contains the three last technological concepts presented in Figure 16. The two first concepts, HDS-technology and 5D BIM will be considered more broadly, and concepts to ease tasks and lower risk with use of such technology are presented.

4.2.1 5 big Ideas to Disrupt Construction

According to McKinsey & Company report 2016, sufferers Engineering and Construction businesses (E&C) of low margin and relatively low productivity (Agarwal et al., 2016). Projects and contracts experiencing a continuous growth in size and scope, and clients are also increasingly demanding. Infrastructure providers are facing a world of possibilities. McKinsey Global Institute has estimated that $ 57 trillion in infrastructure investments will be needed by 2030 just to keep pace with the global economy. Although the construction sector suffers from weak productivity growth and relatively low financial returns, the industry has been slow to embrace the process and technological innovations which could help it to do better, both in terms of profitability and performance. The performance on large capital projects takes typically 20% longer to finish and are up to 80% over budget. McKinsey & Company shows to technology and trends of how E&C could do things better, and points out five major ideas to disrupt the E&C industry shown in the Figure 16.

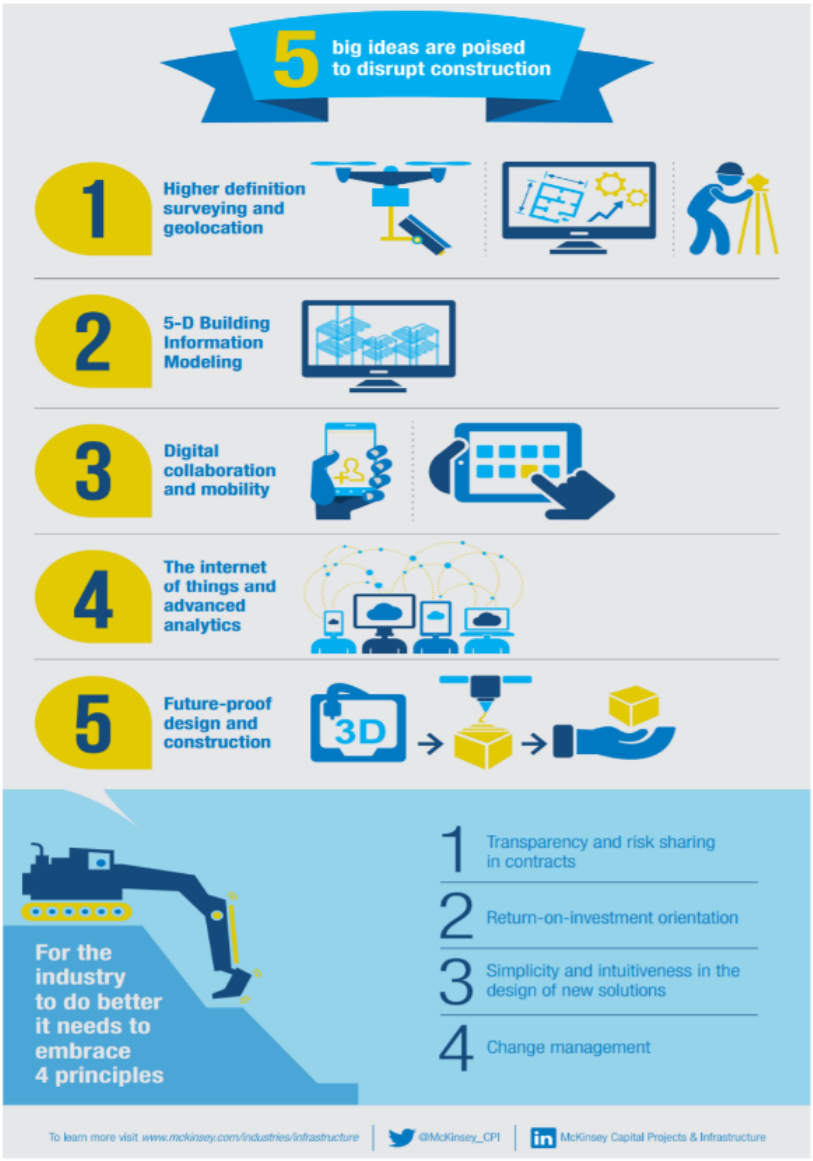

Figure 16: 5 big Ideas to Disrupt Construction ("Voices on Infrastructure: Rethinking engineering and construction [Picture]," 2016)

4.2.2 Higher-definition surveying and geolocation

High Definition Survey Technology (HDS-Technology) represent new techniques that integrates HD photography, 3D laser scanning and geographic information systems, made possible by such scanning equipment as handheld devices and scanners mounted on tripod or drones. Remote controlled vehicle as drones can be used for unmanned surveying. Scanning devices can dramatically improve the accuracy and speed of data collection and support to the engineering phases and also to LCM. The equipment is more accessible than ever because the cost has come down considerably, but a lidar scanner is still relative expensive. Referring to Velodyne from chapter three the lidar spinning on top for autonomous vehicles costed $80.000 back in 2013, This cost makes many drones use HD-cameras instead of lidar scanners, but these cameras delivers very good quality point cloud. Point cloud is the 3D image of the surroundings as described in chapter three in relation to the autonomous cars "Eye", the lidar scanner that spins on top of the vehicle and produces a point cloud that are

processed in the cars computer. Pattern matching in the computer recognizes the surroundings as cars, objects and humans. Like the cars, survey and industrial scanners processes point cloud of the surroundings, objects and geographical location. The point cloud gets processed in a computer software and can then be transferred into a 3D CAD-software. The top HD-camera drones for producing point cloud used for construction work are priced tag of approx. 450.000NOK. Drones using lidar scanners are even more costly, price tag of 500.000NOK and upwards. These scanners deliver the best quality point cloud. If the predictions of David Hall the CEO that Velodyne comes true, that mass production would allow this product's price to "drop to the level of a camera, a few hundred dollars," and the belief that Moore's Law still are kept alive. Drones equipped with lidar scanners might be a whole lot cheaper, referring to Figure 8, DARPAS lidar-on-a-chip, and the statement of DARPA that the sensor can be produced at a cost of about $10 apiece.

The point cloud of the survey sites, can be integrated to CAD-software and used to support Building Information Modeling (BIM). Pattern recognition in the point cloud processing software recognizes building structures as steel profiles and industrial components. FARO PointSense software can transferee 3D images into CAD software for infrastructure, buildings and industrial plants.

Figure 17: Illustrating process from scanning to CAD-software. [46]

[46] Software with pattern recognition, for processing point cloud to CAD-software link: http://faro-3d-software.com/CAD/Products/PointSense/3D_Laser_Scanner_AutoCAD-Revit-Suite.php

Used in conjunction with ground penetrating radar, magnetometers, and other equipment, can lidar generate above ground and underground 3D images of the project location sites. This is especially important in dense, environmentally sensitive or historic project sites, where disorder need to be minimized. Figure 18 illustrates such survey.

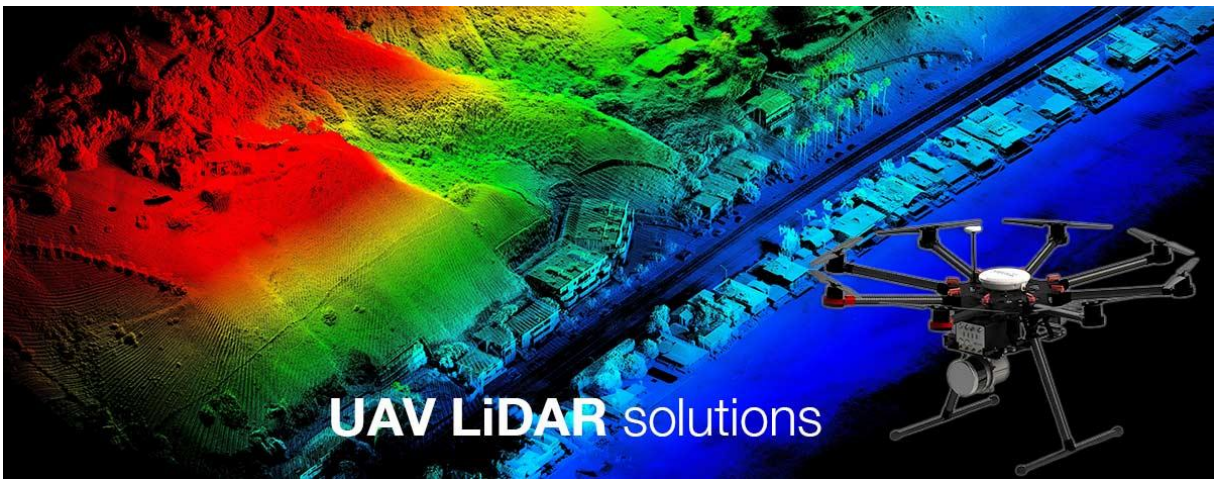

Figure 18: Picture illustrating Drone Lidar Survey.[47]

For existing facilities, like industrial plants, infrastructure (e.g. bridges), and buildings. 3D images are useful when modifying or adding new structures. After scanning a building complex with a drone, the CAD-software can look inside the building and provide spatial information of the inner structure (ARIRANG NEWS, 2016). These sophisticated survey techniques complemented by geographic information systems allows maps, images, distance, and GPS positions to be overlaid. Information can then be uploaded to other analytical and visualization systems for use in engineering and construction.

4.2.2.1 HDS for Industrial Modifying

Within manufacturing, processing, construction and the automotive industry, 3D laser scanning is a tool for the rebuilding of products, equipment, plants or factories with lack of correct 3D models or drawings, as in the reconstruction of oil rigs, vessels and aircraft. Figure 19 illustrates traditional measurement methods on the left, versus 3D scanning converted from a point cloud into a CAD software on the right.

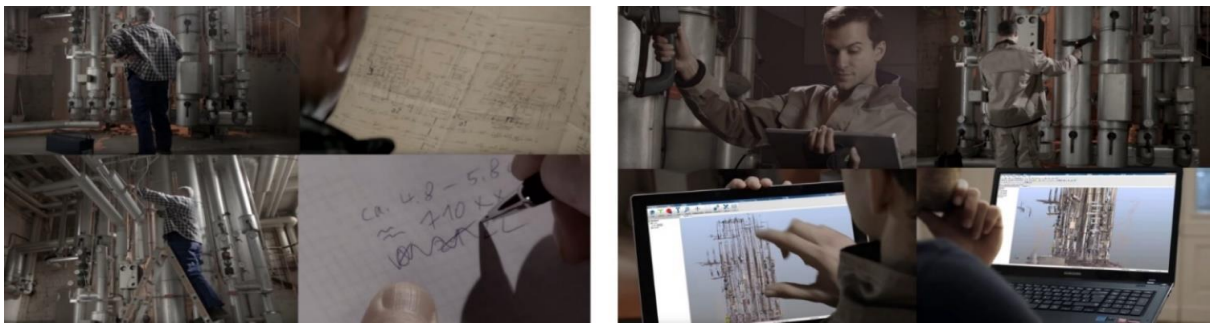

Figure 19: Illustrating Traditional Measurement VS Laser Scanner and CAD-software[48]

[47] Picture obtained at website: http://old.phoenix-aerial.com/files/4714/2783/8079/homepage_banner2.jpg

[48] Picture obtained from FARO Scanner Freestyle 3D videoclip: https://www.youtube.com/watch?v=0Bk2F3TNFGc

By utilizing HDS technology along with CAD software, accurate measurements can be made of existing structure. Prefabrication of parts can be made in advance without mistakes and fit exactly the first time. This reduces downtime of production, which lowers financial risk, and physical risk when parts are being prefabricated in a workshop instead of production areas. Planning the work will also be much easier.

4.2.2.2 HDS for VR-Simulation

In training of rescue and military personnel, simulation is absolutely demanding before operations. For industrial purposes, this kind of coordination and training are not common. Simulation for industrial tasks may reduce risk and production losses significantly.

Referring to Danielle Dy Buncio:

> "*The first time you experience disaster should not be in real world with real lives and real dollars.*"
>
> ("Disrupt the Construction Industry | Danielle Dy Buncio [video clipp]," 2016)

Danielle is the founder and president of VIATechnik.[49] She points out that so often in construction job sites, the first time we're doing something is in real life. Operations carried out in production areas, where structure and components must be dismantled and removed. Existing components are replaced with components which has other dimensions.
Temporary production shut down or reduced output is typically under such operations. Production losses can often be very costly for clients. Therefore, it's extremely important that these type of installations gets done quickly and gets done well.
To practice virtually before doing such operations in real life may yield better performance in the field, also reducing risk.

Virtual reality simulation starts with taking a point cloud laser scan of the facilities that can capture accurate existing conditions and transferee it to CAD-software. Some intelligence should be added the 3D-modell, so when clicking on a structure you get notified what it is. That way you know what needs to be demolished.
The next step is to bring this model into a virtual reality gaming engine, using the same technology that video games use, and create a simulation. The team that will perform the intended task can now simulate the operation. Virtually demolish the stuff that's goanna be replaced and reconstructed. The team can try different routes to identify the most efficient one for the operation. Everyone involved gets to understand what the operation involves and their personal roles and responsibilities to this. The team can practice the execution until they feel ready to carry out the assignment.

4.2.2.3 VR-Simulation for Rescue personnel

A virtual 3D-model of buildings or industrial plants. Either evolving from a newly built facility, constructed with designers using BIM, or an older facility that's been scanned with HDS equipment. Rescue personnel can practice virtually using gaming technology.

New and old public buildings can be brought to 3D-models with the use of HDS-technology, allowing VR-simulation. 3D-models of new and old facilities can be connected to a cloud-

[49] VIATechnik website: https://www.viatechnik.com/

service just as the Autodesk 360 Docs solution, to provide emergency personnel like firefighters to open a 3D-models of the facility their heeding on mobile devices. Getting an 3D overview of the facility and information of the structure. Calibration of the virtual model and the physical surroundings in the building made possible with barcodes or QR-codes on sites similar to the Docs solution, smoke divers might be able to move inside a building using VR-goggles for vision, also supporting them with guidance.

4.2.2.4 HDS provides BIM for Existing Facilities and modern LCM

For managers and owners of buildings that lack technical drawings, or misses updates on technical documentation after renovation or reconstruction. 3D-models or BIM models can be created with 3D laser scanning. This is an unbeatable method to create an exact replica of the building and get precise measurements digitally and in 3D.
A CAD-model for new documentation can be supplied with information. Transforming it to a BIM model. Then it will be possible to implement a centralized digital document system operating through a cloud-service and bring old facilities into modern LCM. Supported by cloud-services and applying sensors to receive data for optimization and innovation as well as condition monitoring.

HDS-technology can provide a hundred-present correct as-built documentation.

4.3 Dimensions of Building Information Modelling (BIM)

BIM refers to the process of creating information models or data sets about a built asset, formed of graphical and non-graphical information. Dimensions within BIM creates an integrated platform that spans project planning, design, construction, operations, and maintenance of facilities in building projects.

Engineering projects with integrations of 5 dimensions of BIM, referred to as 5D BIM by McKinsey & Company means:

- 3D for the visual CAD-model of the common spatial structural parameters, this includes details such as; geometry, specifications, esthetics, thermal and acoustic properties. The model contains all sorts of information that the CAD-engineer puts in it. The 3D-model is used to produce 2D drawings (DWG) for constructing and fabrication and as sales document and documentation for the client. Containing item list, measures and other relevant information.

- 4D is defined as the time aspect for scheduling data to different components, generating accurate scheduling plans.

- 5D is the linking of cost data to various components in the information model to generate cost estimates.

The principle of 5D BIM is to create a single source platform of information to facilitate collaboration between project participants that helps to avoid duplication and errors. Avoid data waste from transferring data manually between different software and digital systems. Today a lot of project owners and contractors in the construction industry still often use different platforms not synchronized with each other. Mostly, construction industry still relies on bespoke software tools.

An integrated platform allows owners and contractors to identify, analyze and record the effect of changes on project costs and scheduling. The intuitive visual content of 5D BIM gives entrepreneurs an opportunity to identify risks earlier and to make better decisions. For example, planners visualize and estimate the impact of a proposed change in the design of the project cost and schedule. The use of 5D BIM can be further enhanced through the augmented-reality technology via tablets or portable devices. A portable, self-contained device having a see-through, holographic screen and advanced sensors can map the physical environment as the Autodesk Docs application.

Companies can develop BIM-like design and construction methods for these platforms. In this "mixed reality" environment, users can attach holograms to physical objects and interact with data using motion, sight, and voice commands on mobile devices. In this development, digital assistants like Dag Kittlaus's Viv, or IPsoft's Amelia may provide increased usability for streamlined interaction between humans, software's, internet and databases. A further development of Autodesk Docs added with Virtual Assistants and Artificial Intelligence to provide faster and multiple actions for the users.

For LCI and management of facilities (operations and maintenance management), BIM can be brought to the next level, 6D BIM. Fred Mills cofounder of the website "The B1M" describes the concept of 6D BIM as; *"Dataset is handed over to client by completion, adding information on the expected lifespan and maintenance requirements of components to support Facilities Management (FM),"* or as Autodesk puts it, Production Lifecycle Management (PLM). LCI and documentation processes pays a large role to this management, applying Autodesk PLM 360 to this, LCI is by far starting to get atomized as described in the previous part of this chapter.

Offering PLM as a complete sales solution, where both customer and producer can seek benefits. The customer receives a greater understanding of what involves in his choice of products when it comes to the total cost of the facility, and future expenses. The election can then be seen more holistically, not just in relation to the purchasing and delivery cost, but for life cycle costs. The client is offered a product that provides knowledge and information that may prove extremely useful when the facility is put into use. A supreme start for maximum utilization of the facility, and foundation of required maintenance work. For the manufacturer, 6D BIM is not only a product alone, but a strategy for selling future services to the client and his/her assets, which will result in increased sales and provide market shares against competitors who does not offer this kind of product or service. In sharing data trough cloud computing, it's possible to seek more value from 6D BIM as previously described; via sensors on construction elements and equipment (mechanical, structural, electrical etc.) connected to cloud service, and manually from workers sharing to cloud from mobile devices during operation and maintenance work. The manufacturer can assist customers with improvements to components and facilities based on the data added from the cloud and optimize products for

their new projects. Hence sell more, provide good basis for innovation and shorten the development cycle. A strategy for excellent customer relationship.

4.3.1 The Engineering Phase

There are software developers like Vico Software or Sigma Estimates that offers solutions for 5D BIM.[50] The 5D BIM software has built in estimates which is developed from Work Breakdown Structure data (WBS) gathered from projects worldwide. When 3D-modeling, the BIM model gets automatically applied with time scheduling and costs estimates.
Still the situation often is more complex. As stated by the McKinsey & Company report 2016, Engineering and Construction businesses sufferers of low margin and relatively low productivity (Agarwal et al., 2016). "*Projects and contracts experiencing a continuous growth in size and scope, and clients are also increasingly demanding."*
This makes the engineering phase with BIM increasingly complexity. Having all types of disciplines using different software and working from different places and even across borders. Just for CAD-designers to interact when using different software, and differences in measurement units, e.g. millimeters and feet can be frustrating. To develop an integration platform to collaborate for all this different systems and workers have become challenging.
As Brandon Wlosinski at the American architect company Bnim puts it in a blog post on one of his company's website.[51] The concept BIM's original promise was that we would work easier, be more efficient, design better and remove the boundary of the 2-dimensional level and integrate all disciplines and systems to connect to the projects 3D model.
"However, it ended up creating shorter deadlines, larger drawing sets, and more confusing project team workflows — all while working for less money" (Wlosinski, 2016).

This means that to uncover the potentials that the BIM concepts offer design teams, and the financial benefits it can provide projects. There is a clear need to understand the vast borders of its capability better, and how we can take advantage of this potential in engineering projects.
BIM has become a mainstay which enables us to use the building data in ways originally unimaginable. For the same reasons as BIM has become very challenging, it has also become a necessity in construction industry.
However, there are some methods that can transform BIM in how we work in practice to become a lot more efficient. By allowing BIM models to connect to systems and people working in projects in a way that interact with more open viewing of data. Data flowing from point to point. This will make BIM becomes the main essence of projects process and delivery. The breakthroughs allowing more flow and interactions between software have been created with symbiotic use of interoperability tools like Flux.io that is an open source algorithmic editor that can link different software without the need for typing codes to make interactions between software, like different CAD-software and Excel, and with algorithm graphic editors like Autodesk Dynamo and Rhino Grasshopper. This is "BIM-Forward".

Flux.io can be used to exchange data between Excel, Grasshopper, Dynamo, SketchUp, Revit and more, via the Web. Flux.io is the "fabric" that ablest to connect design tools, and enabling

[50] Vico Software, 5D BIM solution, website: http://www.vicosoftware.com/bim-for-construction-software-products , Sigma Estimates website: https://sigmaestimates.com/
[51] Bnim blog, BIM is Dead—Long Live BIM, website: http://www.bnim.com/blog/bim-dead%E2%80%8A%E2%80%94%E2%80%8Along-live%C2%A0bim

smooth exchange of data between design team members and parties. Collaborate in real-time via the web and have instant access to all data and geometry via the web browser.
Writhing codes may be time-consuming and very demanding, algorithm editors streamlines this with the use of pre-coded "blocs" pulled down from a menu, then linking them together with virtual strings and adding intervals. Figure 20 shows on the right side of the figure how the blocks are added together by strings using Rhino Grasshopper, on the left is the similar algorithm are typed in codes. The codes on left side goes as far as the red stitched line.

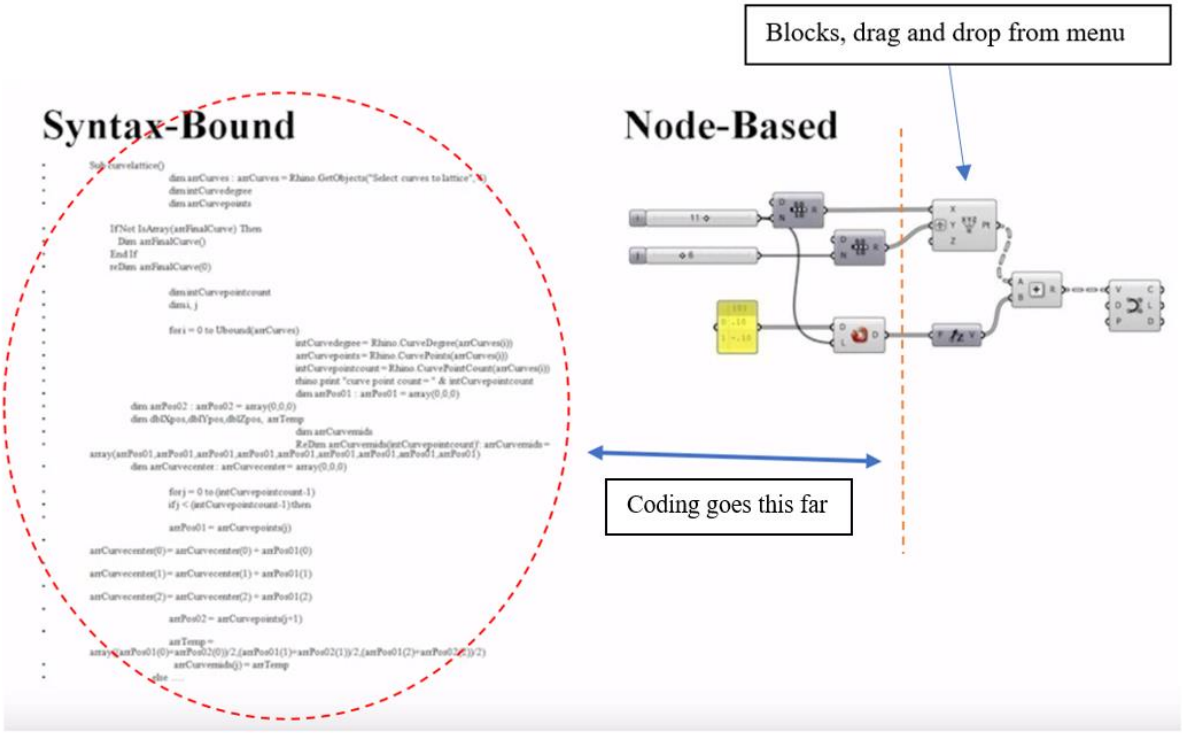

Figure 20:Illustrating graphical algorithm editors VS typing codes

The algorithm editors can be used to link different software together and lower the amount of "data waste" in projects from converting data from one computer program or system, to another, manually. *Algorithm editors allows a fast and easier way to perform encoding. Humans not specialized in computer programing and code languishes can no start to write codes using these algorithm editor applications.*

Flux.io:

"Flux is all about sharing data between people, places and design tools. Flux collaboration tools allow you to share data between people and Flux cloud servers enable you to share data between places - but what about sharing between design tools?

Just as the meaning of a sentence can be translated from English to German, or from German to Arabic, so can the definition for a surface be converted from a geometry design tool to a BIM platform.
Fortunately, Flux doesn't discriminate between building data formats. Any data type can be transmitted via Flux or stored in a data key. But what if the data you are sending from Excel is not what REVIT was expecting? What if the data from Rhino is in feet but Dynamo is expecting millimeters? To address this translation challenge, we created the Flow.

The Flow is a tool that exists alongside every Flux project. It allows for easy creation of reusable data transformations that can be expanded and used by any collaborator on a project. Using a simple system of pre-built blocks, you can multiply values to convert between units or extract specific columns of data from a table. The key is that The Flow allows for project specific data transformations and unlimited user driven customization"

(Flux.io, 2017).[52]

This allows designers using different CAD software to add their 3D modeling work into the same BIM model. Workers designing with easy to use CAD-software like Google SketchUp can synchronize and transferee their work automatically into Autodesk Revit. Other workers not familiar with CAD can do adjustments, e.g. changes in columns sizes if new data have been given designer, can be plotted in excel and 3D model adjusts automatically.
Adjustment in excel to a 3D model designed with algorithm editors can't overrule the algorithm, so problems like crashes in the 3D model are of no concern, adjustments must adapt after the rules set in the algorithm.
This lowers the interface of many tasks. For CAD, workers with different skills can interact in multiple disciplines.
Easy to use CAD-software like Google SketchUp. Especially for designing with standard components. SketchUp can be customized with add-ons to fit the users' tasks, making it fast and easy to design and to make changes, for everyone.
Specialized CAD-engineers can use more demanding software like Revit or Autodesk Inventor for more complicated 3D modelling tasks.
Independent of skills and software, everyone can work towards the same integrated BIM platform. Also, other disciplines in an organization, like the sales team, can open up familiar programs like excel, easy provide customers with documentation for components without the need for "someone ells" to deliver them this information or documentation.
This synchronized interaction and the flexibility among workers and software systems can bring huge value to organizations in the construction industry. Enabling a seamless exchange of data, and creating a more agile workflow. *Avoid precious time wasted in converting files between formats, and reduce the chance of losing critical data along the way. With design tools working together and synchronized employees can focus more on being creative and bring this value to projects rather than doing redundant tasks and back office work.*

Also, project owners and contractors can benefit large by learning and using programming languages as C++ and Python. Use them to rediscover and explore new types of methods for calculations and interactions, and build them into systems to create a much stronger BIM tools. That collaborates designers and other disciplines in the engineering and planning phase, and creates more flow and seek more value from data sets and new possible interactions.
Implementing AI and machine learning software to BIM tasks. AI to make analyses, see patterns and make predictions to support decision-making in projects.

[52] What is Flux.io videoclip: https://www.youtube.com/watch?v=kc2ykDEeO6E

Construction AI applications

For project scheduling, managers analyses several possible schedule plans, finding critical path and try to gather data to determine the best schedule. Managers try to target rational, but also optimistically. Algorithms can now support managers in predicting the most optimal schedule, like the Alice Schedule Optimizer software from Alice Technologies.
Referring to company webpage:

"ALICE empowers construction engineering and management professionals with modern AI and Optimization techniques. Our software automatically produces detailed schedules and resource allocations, which accurately estimate the cost and time frame for a project. Users understand the construction process through an interactive visualization, and can quickly tweak or modify a schedule to reflect the shifting realities of the construction cycle"

- *Automated Scheduling*
- *Resource Allocation*
- *BIM Integration*
- *4D Visualization*
- *Cost + Time Estimation*
- *Parametric Optimization*
- *Progress Tracking*
- *Rapid iteration*

(Alice, 2017)[53]

Using data from previous projects, managers can use AI to make predictions in new projects and operations. *The predictions given by the AI-software won't be any better than the data its feed with. Managers need to ensure input of high quality data, or else the prediction will be wrong and not fit the organizations reality for projects.*

4.3.1.1 Algorithmic design

Autodesk Dynamo and Rhino Grasshopper extends BIM with the data and logic environment of graphical algorithm editor. It's a tool that can be used to design and to do simulations. Here, rule-based design can be set up with direct integration to the CAD-software, it's the similar process as described and shown in Figure 20.
For CAD-engineers, moving from traditional sketching (static modeling) over to algorithmic modeling, generates several benefits.
Algorithmic design means that instead of sketching up geometry for then to extrude and assemble components in a CAD-software, you use algorithmic codes to determine geometry and surfaces using pre-coded blocs to perform 3D modeling (Figure 20). Adding intervals to the algorithms, according to the designs demands, allows quick and easy adjustments to the 3D model, making it more floating and easy to adjust. This means project teams can easily experiment with different design options to find the most optimal solution. Some of the solution could perhaps not even been imagined before starting the design.
As stated by Bill Allen, partner and chief technologist at the company EvolveLAB (American BIM consulting firm), and experience shared form project managers in Norwegian

[53] Alice Schedule Optimizer website: http://alicetechnologies.com/

construction industry. This is not how the main stream perform 3D modeling. Static modeling is what is generally used. Figure 21 illustrates algorithmic modeling; the algorithm editor is on the right side and the visual 3D model created by the algorithm editor, on the left side of the figure.
Some of the blocks in the algorithmic editor are the defined intervals, by using the mouse button it's manually adjustable inside of the defined range of the interval. The 3D model will then instantly change to the new settings.
An algorithmic process is a series of operations carried out through calculations.
To get started with algorithmic design, insight in what to model is needed, imagine and visualize the process in advance to find out which mathematical operations that can yield the desired results, this part may take some time.
"Anything you can do with geometry, you can do with mathematics.
But not necessarily the other way around" Jose Luis Garcia del Castillo.
The advantages of such a process is immediate.
Another important factor is the way this methodology interacts with other software, and later the ability to connect AI to support optimization of the design.

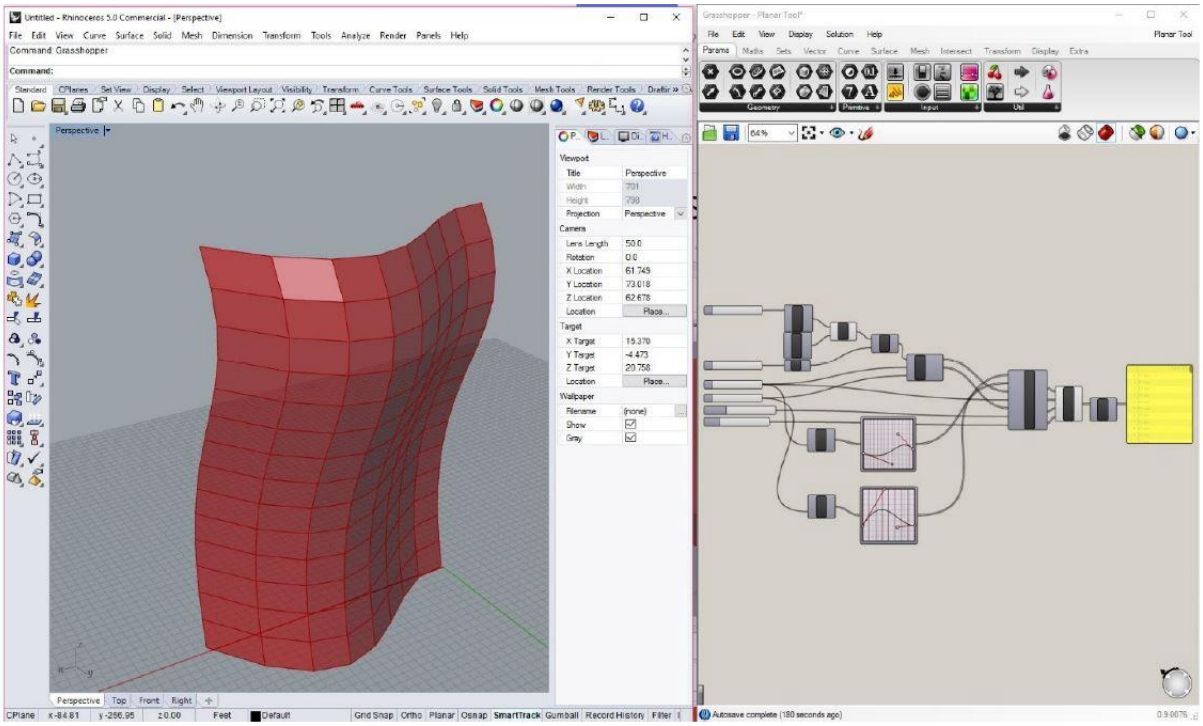

Figure 21: Illustrating Algorithmic modeling[54]

Redesign of static modeling can be so demanding that CAD engineers sometimes choose to start from scratch. Along with manually plotting new schedules and data into Excel. Going through this interaction process is wary time-consuming work. A company can only afford to design a few options, if lucky, within the timeline and budget allocated. With algorithmic modeling, changes happen instantly, by just regulating parameters inside the defined intervals. It's like tuning the sound on a stereo system, the parameters can also be linked to excel and automatically update schedules and data. From excel to the 3D model and vice versa. This

[54] Picture obtained from webpage: https://medium.com/autodesk-university/the-future-of-bim-will-not-be-bim-and-its-coming-faster-than-you-think-25bb848a6232

linking between software reduces the amount of "data waste." There is no need to first plot in excel for then to plot dimensions in the 3D model. By use of algorithmic editors to link counterprograms together. Operations can be done in one step. Reducing the number of redundant tasks, saving a lot of working hours. Especially when changes are made. Figure 21 illustrates the differences in workflow when designing with static modeling and no linking between computer programs (red line in the figure) versus use of algorithmic modeling and the use of algorithmic editors (green line) to link different software together e.g. use of Autodesk Dynamo and Flux.io for work flow.

"There are plenty of Revit (CAD-software) Excel import/export add-ins, and there is no reason we should be recreating the same data that is in Excel, in Revit. These tools can and should talk to each other"(Allen, 2017).

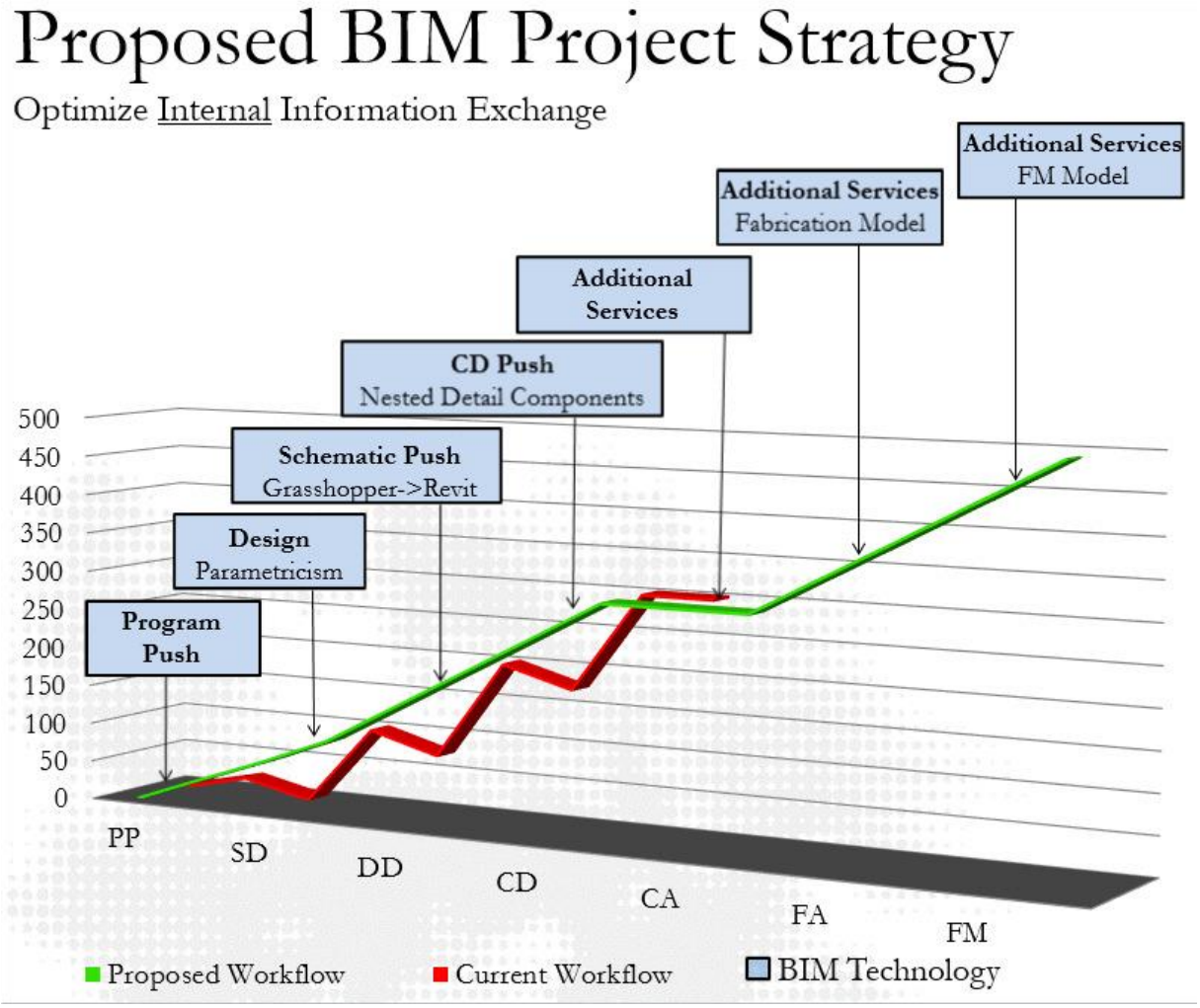

Figure 22: Illustrating "Data Waste" in BIM work flow[55]

The reasons why this alternative way of designing has not taken off may be because the software is not as intuitive as sketching such as Sketchup alone without use of algorithm editor, so designers don't want to use it, Allen claims.

[55] Picture obtained from webpage: https://medium.com/autodesk-university/the-future-of-bim-will-not-be-bim-and-its-coming-faster-than-you-think-25bb848a6232

Experience shared from project managers and CAD-engineers in the construction industry, is that there may be lack knowledge about this concept, as well as the time to adapt such new process in an organization not familiar to this way of designing are challenging.

Project teams in the construction industry should seek ways to overcome this conversion to take advantage of the added benefits that this methodology provides. *The tools to get this done are easier to use than ever and a lot of them are free.*

4.4 Building Optimization, Designing with AI

Algorithms and robotics can drastically change the engineering phase.
With advancements in generative design, software algorithms, and robotic construction. More and more can be done by computers and machines. This will allow the construction industry to become more efficient in the design and construction phase. A process further from what mainstream in the construction industry uses BIM today. With use of these advancements the BIM process will be able to transform to a process of Building Information Optimization (BIO). These are the predictions of Bill Allan the next three to ten years.

"Rather than Building Information Modeling (BIM), we are going to see Building Information Optimization. Rather than manually drawing walls, doors, and columns for what we think is a good design, we will feed the computer "rules" instructing it to give us a building's optimal footprint, structural load capacity, and thermal performance. Things that took months will be done in a day."
(Allen, 2017)

Optimization application for Algorithmic Modeling
Optimo – Optimization Algorithm for Dynamo is an optimization application for algorithmic design. This application can support in predicting optimal suggestions for design issues. Where we seek an optimal solution, like:

- The optimal placement of building cranes on construction sites
- Support designers with various suggestion of footprints for building
- Provide choices of window surfaces optimized for energy consumption combined with lighting conditions
- How to optimize for best view in the geographical direction preferred

As an example, cost-effective optimization for projects can be reducing documentation in projects. A known method for designers to reduce documentation is to reduce the number of components for a construction. Also, making the components symmetrical to ease understanding of positioning the parts. During assembling of structures this leads to less detailed and technical drawings for the workers, meaning less documentation.
An optimization process supported by AI can provide geometric shapes on a structure that can make this job easier for us.

If it would be desirable to optimize for something that contributes to more single components, robotic processes and CNC machines can defend this. As previously described, processes performed by machines do not require detailed drawings to produce parts, sending data files to the machines is enough.

Designing with the support of AI is giving designers super-powers. Figure 23 illustrates the concept of designing with AI support.

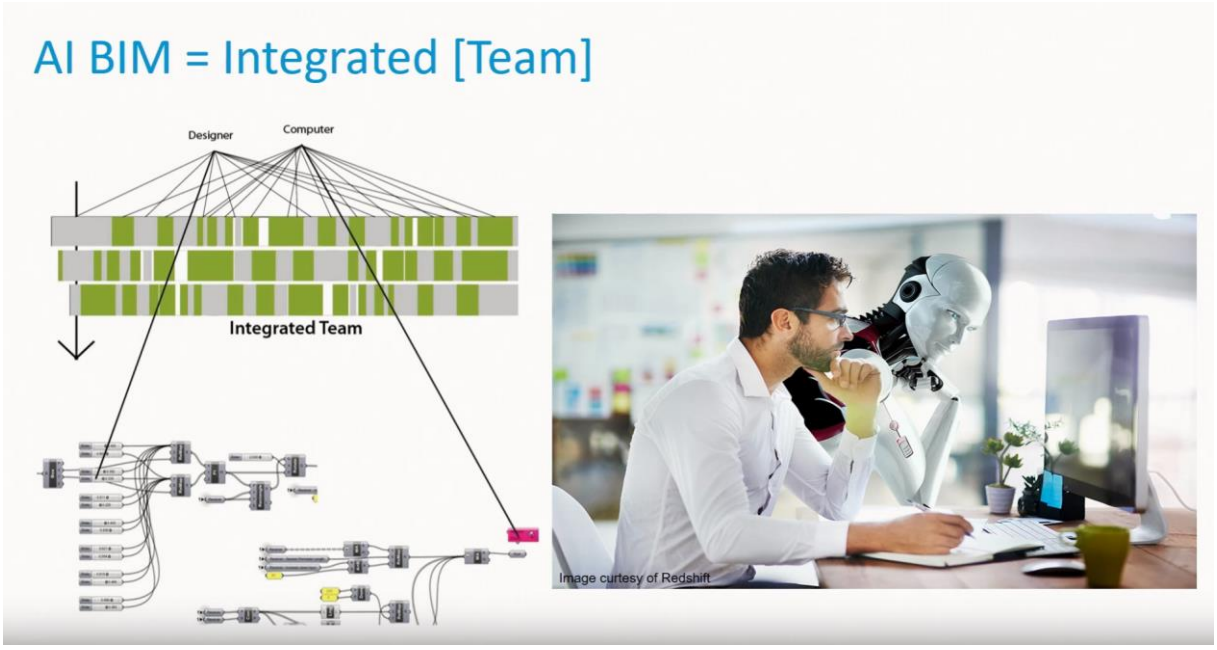

Figure 23: Illustrating robot and human designer working together[56]

"Nate Holland at NBBJ (American global architecture, planning and design firm) built an algorithm that optimized his building to increase revenue at a rate greater than cost by maximizing retail space, ocean views, and floor plates. The premise is to create an integrated team, the designer and the computer. Together the designer can feed the computer a series of rules, requirements, and parameters. The computer can then return a list of options that meet that criteria based on the parameters set by the designer.

With the graph shown in Figure 24, we can see where each design falls in relationship to costs outweighing benefits and benefits outweighing costs" (Allen, 2017).

[56] Picture obtained from videoclip at website: https://www.youtube.com/watch?v=xq6yKyauu-o

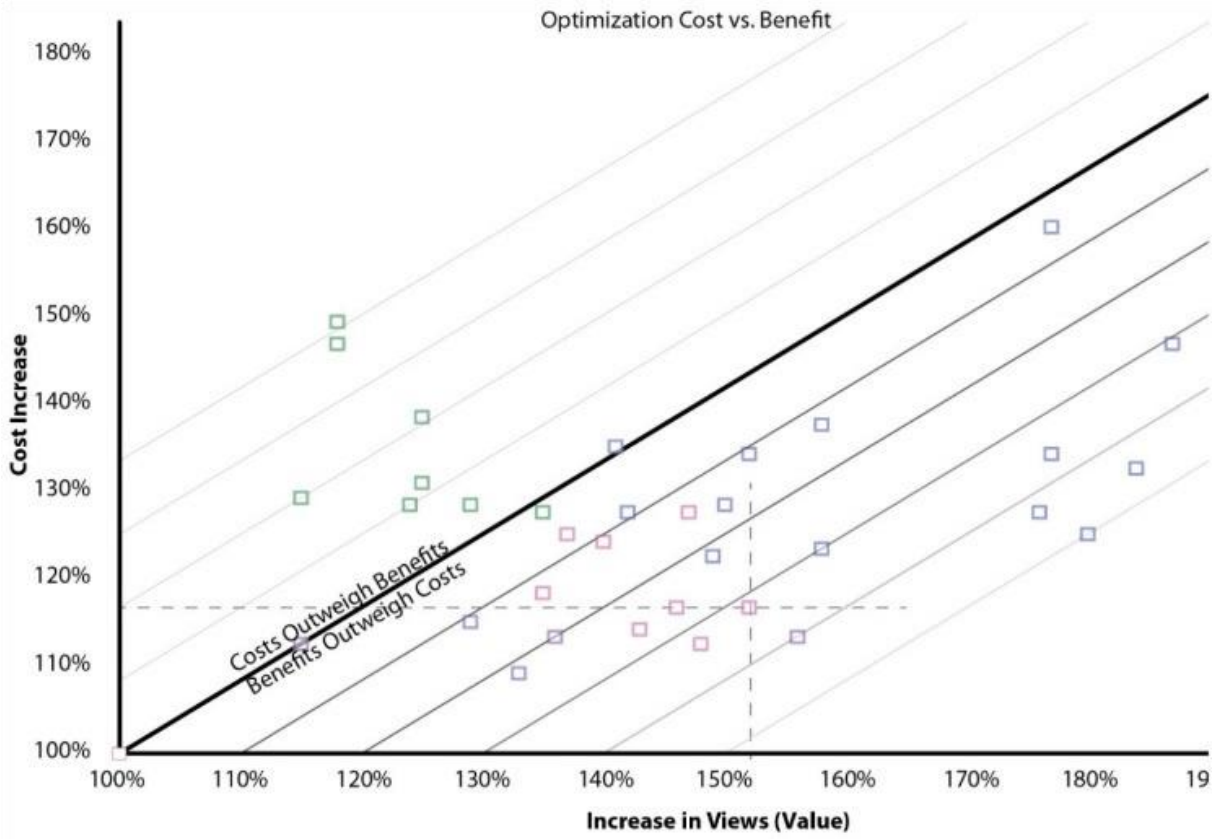

Figure 24: Graph illustrating algorithm that optimized building to increase revenue at a rate greater than cost[57]

AI BIM Plus Analysis and Design

Manual analysis and modeling is going away. The international BIM and CAD software developer Graintec have produced BIM tools to support documentation work. Graintec Advance BIM Designer Collection has already created a tool that is a design-driven reinforcement calculation program for 3D cage modeling and *automates documentation production for reinforced concrete columns, beams, and footings.*

Imagine in the next five to ten years, structural analysis having a more direct influence on architectural design. It already does today, but with advances in material science, biomaterials, and algorithmic modeling, we could see extremely efficient structural buildings with half the material (Allen, 2017).

[57] Picture obtained at webpage: https://medium.com/autodesk-university/the-future-of-bim-will-not-be-bim-and-its-coming-faster-than-you-think-25bb848a6232

4.4.1 Generative Design

Generative Design is by Autodesk defined as; *"Generative design is a technology that mimics nature's evolutionary approach to design. It starts with your design goals and then explores all of the possible permutations of a solution to find the best option. Using cloud computing, generative design software quickly cycles through thousands, or even millions of design choices, testing configurations and learning from each iteration what works and what doesn't. The process lets designers generate brand new options, beyond what a human alone could create, to arrive at the most effective design."* (Autodesk, 2017b).

Most generative design is based on algorithmic and parametric modeling. It is a fast method of exploring design possibilities that is used in various design fields. Typically, generative design has:

- A design schema
- A means of creating variations
- A means of selecting desirable outcomes

According to Renee Puusepp, the most important and distinguishing part that makes a computational model generative is the feedback loop (Puusepp, 2013). Figure 25 is obtained from the book "Generative design: visualize, program, and create with processing", the figure illustrates the generative design process.

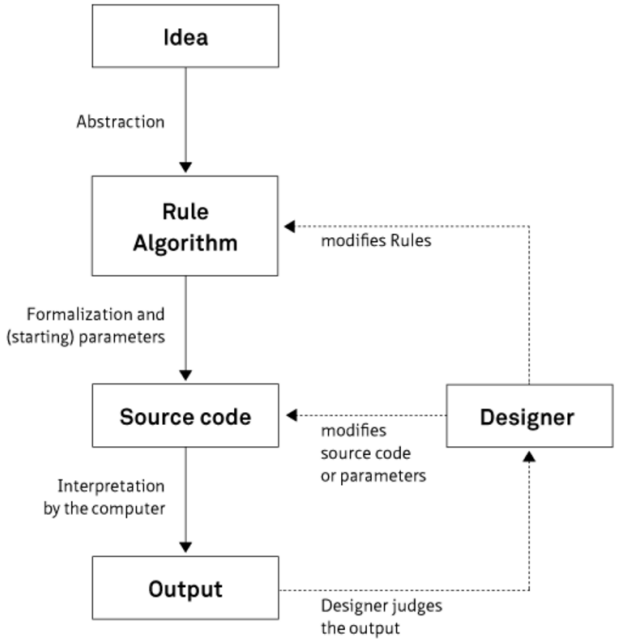

Figure 25: Illustrating Generative design process (Bohnacker, Gross, Laub, & Lazzeroni, 2012)

In the field of generative art and design, design concepts are represented as code. This generative code functions as DNA does in nature.

"Generative Design is a morphogenetic process using algorithms structured as non-linear systems for endless unique and unrepeatable results performed by an idea-code, as in Nature"

(Soddu, 2002)

Generative methods are repetitive processes where the solution is developed during several iterations of design operations. An evolutionary process that would take millions of years in nature. Due to new programming environments, or scripting capabilities.[58] Generative Design have now become relatively easy for designer to implement in their ideas. Even for designers with little programming experience. *This is cutting-edge technology inspired by nature which can be utilized without expert knowledge in computer programming.*

4.4.2 Airbus Example of combining new Technologies for Innovation

Bastian Schaefer is the aptly titled Innovation Manager at Airbus, the aircraft manufacturer in Hamburg, Germany. His mission is to find new ways to make jetliners more efficient and comfortable. As part of the team that developed the Airbus Concept Plane, a vision of the jetliner of 2050. A future plane design that aims to be much lighter, to use less fuel, and to leave a smaller carbon footprint than current models. *"Light is good, but we can't lose strength or safety,"* Schaefer says.

The team members began to explore components that would use the new technologies they'd proposed, Generative Design. They chose an unassuming but key piece of the aircraft: the partition that separates the passenger compartment from the galley in the Airbus A320 cabin.

This new partition had to:

- Be significantly lighter than the current partition, to meet the goal of reducing the weight of the plane,
- Be strong enough to anchor two jump seats for flight attendants during take-offs and landings,
- Have a cutout to pass wide items in and out of the cabin,
- Be no more than an inch thick, and
- Be attached to the plane's airframe in just four places.

Meeting these design constraints required a major departure from traditional engineering approaches. Schaefer began working with Autodesk Research, using generative design to develop what the team called "the bionic partition."

Airbus's bionic partition needed to meet strict parameters for weight, stress, and displacement in the event of a crash with the force of 16g. To find the best way to meet these design requirements and optimize the structural skeleton, the team programmed the generative design software with algorithms based on two growth patterns found in nature: slime mold and mammal bones.

The resulting design is a latticed structure that looks random, but is optimized to be strong and light, and to use the least amount of material to build.

[58] Example programming environments: Processing, vvvv, Quartz Composer, Open Frameworks.
Example scripting capabilities: Grasshopper 3D in Rhinoceros 3D, Scriptographer.
Example of web societies: http://www.bimtopia.com/

SLIME MOLD:
The algorithm for the partition frame was based on the growth patterns of slime mold, a single-celled organism that connects multiple points with uncanny efficiency.

MAMMAL BONES:
The algorithm for the structure within the partition frame was based on the grid structures of mammal bone growth, which are dense at points of stress but lighter everywhere else.

Figure 26 illustrates the two patterns are combined in a Generative Design process to develop an optimal new design to the bionic partition of future Airbus based on these patters gathered from nature.

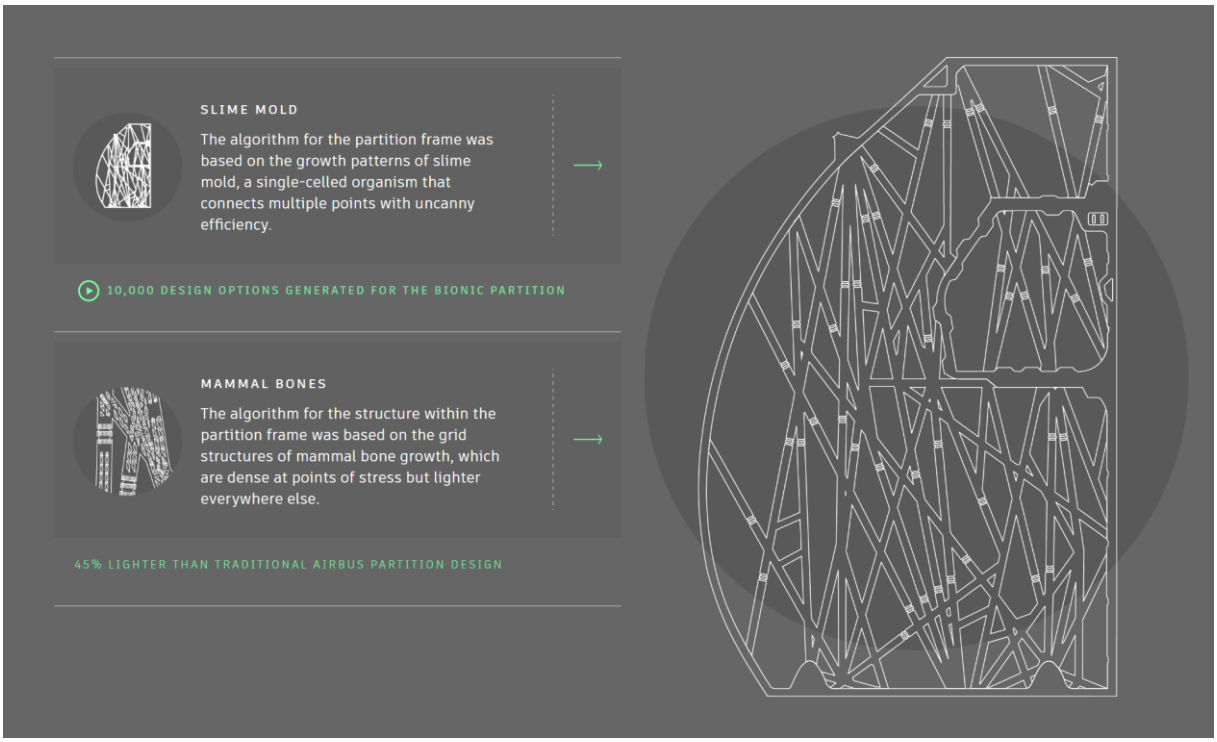

Figure 26: Generative Design process to develop an optimal new design to the bionic partition of future Airbus

The team digitally mapped the thousands of options created in the generative design process against weight, stress, and strength parameters to decide which to prototype. With the combination of Generative Design and 3D printing this team managed to reduce the weight of the bionic partition by 45%.

Source: Autodesk, Generative Design at Airbus (Autodesk, 2017b).

4.5 Some Risk Factors

Risk to be managed. Among the factors that must be addressed within all digitization are cyber security and redundancy procedures and routines if technical failure. Also, understanding how adopting introducing new adaptations. How to treat individuals, people whose job will change. Managing inequalities in employees and create time for people to retrain and adapt as these technologies accelerate in development.

5 Results and Conclusion

This chapter summaries the concepts and products presented and how they can provide benefits for the construction industry. A brief evaluation of Tag Manager from the Master Thesis 2014 and the solution presented in this report will be reviewed. The chapter concludes with reflections on how this technology will affect our work

5.1 Results

Results in the report indicate many opportunities for the construction industry and industry in general to benefit. Many solutions are free. Implementing a centralized digital document system that operates through cloud-service will require resources in the form of personnel to assess this. The Autodesk Docs system is in contrasts with Tag Manager, from Abu – Shagfa and Menyar Deyab in 2014 a free downloadable solution for suppliers to connected to the cloud-service. The cloud-service provides the use of QR-codes or barcodes to calibrate the virtual model to the physical environments, and information from the facilities BIM model. Owner of the BIM model pays a license for digital storage in the cloud (Autodesk Glue). Access level and sharing of information are managed by the owner of the license. It provides real-time interactions between managers and personnel to support decision on-site, and real-time documentation which safeguards LCI of facilities. Transferring data from this system to organizations ERP-systems can also support automation of logistic and cost control.

Since document approval is a rule based task, RPA to automate such processes seems practical possible. There might be other tasks in the construction industry that may benefit more using RPA, like salary (payroll).

HDS-Technology can support the planning phase of projects, as-built documentation and support LCM of existing facilities. In combination with gaming technology, simulations can be done virtually. A risk reducing concept for the construction industry that now can start to practice operations virtually. Refering to Danielle Dy Buncio statement:
"The first time you experience disaster should not be in real world with real lives and real dollars."
Some of the HDS equipment, like top models within drones and laser scanners available on the market, have a price tag of around 500,000 NOK and upwards, but in the belief that Moore's Law are kept alive and the predictions from David Hall the CEO that Velodyne comes true. Will price developments on LIDAR equipment be drastically reduced in a few years, especially if this is mass-produced for the automotive industry. According to the article Marius Valle it is also stated that the LIDAR's getting cheaper and smaller at a rapid pace (Valle, 2016b). As presented, researchers at the Massachusetts Institute of Technology (MIT) and US Defense Research Institute DARPA have developed a "lidar-on-a-chip" with the potential $ 10 prize. The development of software, mobile applications and digital equipment takes place in a rapid pace, to take advantage of these developments a continues focus and interest of new technology is key to stay ahead of competitors.

BIM and Building Optimization by the use AI to support design choices. Starting with the use of Algorithmic editor applications for 3D modeling with CAD-software. Which opens for Generative Design Process,[59] e.g. the Airbus innovation team. Also, the use of Algorithmic editor applications to convert files between different software, to support interactions between disciplines and employees using different software. This improves the workflow in projects. And allow workers of various skill to perform Allow several employees with different backgrounds interact in joint product. Example, use of Flux.io data exchange and collaboration platform, transferring files automatically between different CAD software like from Google SketchUp to Autodesk Revit.[60] Allowing more workers to perform advance tasks using digital tools to make the work easier.

3D printer is taken outdoors, assembly robots for advanced constructions ablest increased use of machines doing manual tasks that previously have been reserved for human workers. Reflecting on the DARPA Robotic Challenge robots as seen in Figure 9, the capabilities of robots to manage advance tasks in various environment have increased a lot lately. Advances in user interface makes it possible for workers without special expertise to operate and program the machines. Industrial Robots like Baxter illustrated in Figure 6 are equipped with cameras for machine eyes, patter matching, machine learning and M2M interaction. This allows the robot to understand the variation in processes such as devices on an assembly line arrive differently. Use of more machines supports less detail documentation as the machines don't require detailed drawings for performing their work. They can perform work by files sent directly from CAD-software.

5.2 Conclusion

The report refers to several products that support MGI's survey, claiming that partial automation will affect almost all professions to a greater or lesser extent, as much as 45% of individual activities could be automated (Manyika, 2017). "*The impact will be felt not only by factory workers and clerks, but also by landscape gardeners and dental lab technicians, fashion designers, insurance sales representatives, and even CEOs*" according to James Manyika, MGI. It is nevertheless encouraging that this survey shows that the proportion of professions that can be fully automated using today's demonstrated technology is less than 5 percent, manual labor work is still demanding for industrial businesses. Automation is a tremendous opportunity to improve our productivity. Something like a quarter of a CEO's time can be released by automation, this is time that can be done to do more high value tasks. There are set of activities which are relatively difficult to automate now, including managing other people or interacting on other individuals in a complex way that has empathy and can understand emotions. Automation can support employees with more time to exhibiting creativity and sensing human emotions, things that are unique to human abilities.

Risk to be managed, factors that must be addressed within all digitization are cyber security and redundancy procedures and routines if technical failure. Also, understanding how adopting introducing new adaptations. How to treat individuals, people whose job will

[59] Generative Design at Airbus, website: https://www.autodesk.com/customer-stories/airbus
[60] Flux.io website: https://flux.io/

change. Managing inequalities in employees and create time for people to retrain and adapt as these technologies accelerate in development.

Advices for general managers and leaders is to start to understand these technologies themselves. Find out what is possible they are advancing over time. Because there no role or function in the industry that could not potentially be impacted be some of these technologies. If a company leader does not see this, the competitors will. Starting to understand and take advantage by use of new technologies is an opportunity for new companies. Historically it's something that has happened repeatedly.

Exploring and participate in digital societies and professional networks. Seeking knowledge through recombinant growth. Webinars introduced on Facebook where participants all over the world can interact and share knowledge, like CAD-developers and project managers exchanges techniques and opportunities within BIM.

Understanding the technologies and where in an organization automation can be used most effectively. Not just to reduce label costs, but to increase throughput, quality and customer satisfaction. Managers need to understand and envisioning from where their business are today, to how it can be transferred into something radically different if technology are deployed in a powerful way to benefit an organization or company. To strengthen their position for the future.[61]

6 Further development of task

This chapter reflects on possible developments of the task, and possible business ideas based on the concepts and products presented.

6.1 Academic

How to implement these solutions and technology for Norwegian companies?

Evaluate free trails of solutions with technical support from the manufacturer. Start implementation of the solutions in pilot projects and for smaller deliveries. As project work by teams that are suitable for the task.

A further development of this task that will be of great value to industry and the person who can map this. We need to learn how to implement these technologies to make changes within our organizations. People blame the decree in productivity in construction on safety regulations standardization have changed, but manufacturing had the same improvements and they're still increasing their productivity rates (Agarwal et al., 2016). Construction is more complex and each project are unique and construction projects continually gets bigger and more advance. Still we can gather all the things that are similar, to improve productivity. Solving the gap between construction and other businesses will provide huge benefits for the

[61] Webpage and videoclip by MGI's survey: http://www.mckinsey.com/global-themes/employment-and-growth/technology-jobs-and-the-future-of-work

one that solves it. How to gather reliable data from previous projects to support new projects using AI applications.

6.2 Business ideas

Experience and knowledge about use of the presented products in the report to provide consulting services for other business. Time and personnel to get started with implementing new processes and the use of new digital tools is often a challenge for organizations. Sales of consulting services for the development of IOT platforms, implementation of new technology within RPA software, expanded use of industrial robot processes, user setup and instruction of software within BIM and Life Cycle Management (6D-BIM). Provide different services like simulation based on HDS technology and virtual reality using game technology. Specialization in Algorithmic Design for use and support of AI and Generative Design Processes to provide expert CAD services.

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