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*Impact of innovations on human resources in the
construction industry*

MSc in Innovation and Entrepreneurship

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ABSTRACT

My exploratory research gave interesting insights about innovations and how they are influencing and changing human resources in Norwegian construction industry. To answer my research question and sub-questions, I have taken findings from interviews with biggest construction contractors in Norway and technology manufacturers while comparing received information with tendencies in other countries and behavior of innovation processes in other various industries.

Research gave aggregated results and overview that the construction industry we are on the cusp of a Fourth industrial revolution. A development process involving of artificial intelligence algorithms, learning machines, robotic technologies in prefabrication factories and on project sites, real examples of 3D printing promise a new wave of productivity and range of technological advantages in the construction industry. Together socio-economic, technological and demographic developments and changes will generate displacing of jobs and new categories of occupations. At the same time, it will change the skill sets required for old and new human occupations in industry and transform labor employment.

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1. INTRODUCTION

While most other industries around the globe and in Norway have undergone significant changes over the last decades and reaped the benefits from innovations, the construction industry has been hesitant about full incorporation of technological opportunities and sector's labour productivity is stagnating. Today, the construction industry is having various challenges, like recruitment of a talented workforce or insufficient knowledge transfer. Have other sectors done something different, or has construction industry just not seen the same opportunities?

However, the construction industry has a vast potential for innovations on improving productivity, efficiency and quality. There is new digitalization tools and innovative technologies, as Building Information Modelling (BIM), autonomous equipments or new ways to incorporate prefabrication modules in the industry. Also, in considerations are emerging reality of disruptive innovations like robotic power, drones, 3D printing adaptation. Human resources and labour employment will have displacement of their jobs positions and skills, will come demand for new types of workforce.

This paper examines innovation processes in the construction industry and studies how new technologies are changing and influencing human resources in this industry, with particular focus on Norwegian market and environment.

1.1 Defining the research problem

Most of construction and designing companies in developed world including Norway are turning to digital technologies as a response to many industry drivers. In industry, people are now witnessing the greatest change in the industry since the combustion engine. People are discussing possibility to adapt drones and 3D printing, different designing tools, augmented reality and robotic technologies. In last years, the interest of studying innovations in the context of the construction industry has significantly growing.

Compared to other industries around the globe, the construction industry has traditionally been among the slowest at technological development, despite being one of the largest and most important industries. There have been no major disruptive changes, innovations and advanced processes. For example, 'lean' management process, which are widely applied in manufacturing processes are still not widely applied. Because of it, efficiency gains in construction industry are slight and in last 50 years' human resources productivity is declining in the Western World. (*World Economic Forum, The Boston Consulting Group; 2016*).

In addition, challenged by the recent economic crisis, the construction industry is seeking new strategies and orientation. Growing demand of customers is also lifting the potential of production efficiency. Prefabrication and construction automation was presented as an advanced strategy 20-30 years ago and has reduced the need of human resources in labor significantly (*Lara Jaillon, C.S. Poon; 2008*). The same market changes taking place now and a wide range of technologies are involved to lower labor involvement. Prefabrication technology is an example of continuous incremental innovation which is adding unique socio-economic value to the construction industry.

Recent innovations in building materials and prefabrication technologies modify limited aspects of the established approach to housebuilding, but nevertheless still institutions and actors still rely on established buildings methods and products. Despite the fact that many companies in the industry are using some of the newest inventions, many cannot define any disruptive innovations in the last the decades.

Little research has been carried on innovation process impact within the construction industry. Nonetheless, there is a high interest in such research both from the research community as well as the industry itself. With my thesis, I want to provide insight in construction innovations used by professionals and development (R & D). The study seeks to describe and explain specific opinion about the current state of innovation and future climate influencing changes in human resources and labor employment in this industry.

1.2 Research aim and purpose of the study

The aim of this exploratory master thesis study is to study innovation processes, existing innovations and tendencies in the construction industry and make predictions on how human resources could in future. To study this, I will analyze innovation processes in other industries and compare technologies developed in construction industry in the last years.

For this thesis it is important to find answers on how and why different industries are changing and what influence innovation processes have. In addition, the thesis aim is to analyze possible radical changes as behavior of disruptive innovations in all industries and analyze, how it could behave in construction industry. To help finding an answer for industry companies, how behave in innovation process to develop - not stand in a place. It is important to get knowledge and analyze approaches of innovation process. Subsequently, I will focus on the influence of innovation influence on human resources in the construction industry.

The results will be a presentation of the innovation status in the construction industry and predict it 's future, to present the organizations in this industry with opportunities to change in order be innovative and in stay in the market.

1.3 Research Question

Related literature and state of art reveals that construction innovation methodology and related management tools currently do not exist in form to support researchers. To support and answer research question, been formulated several sub-questions connected with innovations and human resource changes in construction industry. First, it had to be found which innovation mechanism are active today in other industries. Next, it had to be analyzed how changed industries production and labour in other already much more developed industries like manufacturing. Later, analyze mechanisms within construction industry and how their connection influencing each other. Further, to exploit history, existention and appearance possibility of disruptive innovations in industry, as it could shape and shake all industry from background. Finally, research goal is to analyse specific innovation mechanisms in construction industry and develop a comprehensive view or framework which could explain how in general innovation in construction are functioning and influencing productivity, directly related with human resources demand and labour skills changes.

Research question:

How is changing human resources in construction industry influenced by modern technologies and innovations?

Five specific sub-questions helping to form the theoretical framework and develop exploratory research:

- What are the main aspects of the innovation processes in industries?
- Innovations tendencies in Norwegian construction market?
- Can disruptive innovations exist in construction industry?
- Main drivers for innovations and applying process in construction companies?
- Have existing technologies in construction industry changed productivity and what are predictable changes for future human resources?

2. LITERATURE REVIEW

This chapter discusses about innovation theory in literature, disruptive phenomena and behavior of relevant innovations in other industries in the past. Next sub-chapters are reviewing innovations and tendencies in construction industry, while more focusing on most relevant and discussed by contractors known technologies, which are influencing labor employment in industry.

2.1 Innovation theory

Main reason for companies to innovate is to increase their competitiveness in a market (*Drucker, 2001; Porter, 1998*). The main aim could be profits or can be only strategy to survive competition in market. If companies fail to innovate there is a risk to be left behind or disappear from industry competition map. To gain competitive advantage is essential to innovate and to fulfil client demands. Customers can also influence innovation process in industry by raising expectations for gain products. Also, innovations can help to become international players after fulfilling demands of local clients.

While incrementally adding some innovative materials, companies can diffuse through market very fast and create disruptive innovations. These elements offer significant and disruptive benefits to customers and industry. It seems that everyone is talking about disruptive innovations and how it is changing our lives. In construction industry, the concept of disruptive innovation seems to become mainstream trend when talking about future of robotic technologies and 3D printers. But what is the background of disruptive innovations and how have they changed industries in the past? How do they impact labor employment across industries?

2.2 Disruptive innovations

The term *disruptive innovations* were first introduced by the author Clayton Christensen in his book *Innovators Dilemma* and later in *The Great Disruption*. He wrote that economies and nowadays markets depend deeply on technologies and their rise or fall according to their ability to adapt disruptive innovations in their companies. These innovations lead products to new areas where they can be cheaper, can have better quality and more convenient for consumers. The first time he used this term was in 1997, when America 's economy was growing and exploiting its boom. At the same time, the USA market put Japan's economy to stagnation. This example is illustrating the importance of disruptive innovations and possibility to appear in different future economies and industries. All disruptive innovation has huge impact on traditional human resources workforce.

Such sectors as IT or energy markets have created contests of disruptive innovations to generate radical changes or adopt them firmly enough to stay in changing markets. Nevertheless, in some markets and organizations innovations cut across organizational structures and sometimes they can have radical changes in human resources or are too difficult to adopt. In such cases the company has tendency to drop from leading positions to follower.

Disruptive innovations attract more and more attention from industries (*Chesbrough, H.; 2003*). In industries, it promotes a product or service usually in an unexpected way. Based on theoretical analyses of innovation and competence, construction companies can improve their competitiveness combining open innovation and disruptive innovation. In addition, the research suggests that open innovation and disruptive innovation can be strategies of a company to improve its competence in a market. Finally, the research (*Tyfield, D., Jin, J. and Rooker; 2010*) shows that in the different industries disruptive innovation creates an opportunity to companies overcome and surpass the different industries leaders. Sometimes the growth of the company can depend greatly from the investment to innovations.

Such authors as Nicholas Dew and Saras D. Sarasvathy (*2008*) were discussing the issue when companies without innovative ideas are only listening to customers which very often leads them to lose markets to newcomers or more innovative companies. They were investigating how entrepreneurs successfully develop or create such a new upstart firms which disrupt existing market dynamics. These authors also agreed with C. Christensen by claiming that it is impossible to accurately predict upcoming technologies or strive to build immortal markets.

The author Gene R. Simons (*2004*) argues that disruptive technologies can evolve from existing diverse technologies or can create some entirely new ones. Nevertheless, the writer suggests that innovators should no longer create term projects which could change dynamically existing markets but offers strategic planning and management because they should promote sustaining technologies and not disruptive innovations in longer term. The latter can only give short-term profitability in the changing markets. The author believes that this may have longer downstream success and that it is possible to find out specific problems which stop companies from generating innovative ideas and development. The main goal of companies should be to create entirely new market. In addition, the use of acknowledged literature and roadmaps can help to identify technical and managerial needed disciplines necessary to develop disruptive technologies and discontinuous innovations in specialized industries.

The authors Feng Wan and Peter J. Williamson (*2014*) continue discussing the growing recognition of the importance of the disruptive innovations and keep researching difference in

discovery versus creation opportunities. Unlike other authors, they are paying more attention to innovation process including goals and design. In order to realize disruptive innovations organizations, need to cultivate proactive initiatives and change in managerial level to understand future opportunities.

2.3 Innovations appropriation

Christensen acknowledges that there is no particular *right* answer to the problems related to innovations appropriation in companies. Nevertheless, he suggests some viable solutions. First, he advises companies to look for a disruptive part in any innovative technology. He also suggests to analyses innovation by raising a question: *can innovation change a whole industry or just a part of it*. Christensen has divided innovations in two: *a sustainable technology* which improves product performance and *a disruptive one* which leads to innovation.

Innovations appropriation is discussed by the author Joseph Fiksel (2013) by introducing a word 'resilience' to describe a needed combination of flexibility, adaptability and foresight in order for organization to be sustainable, make inside changes and to be able to survive. The author suggests that the main principles of resilience imply the easiest way for companies to become their own victims of previous success. To develop and be innovative, enterprises should learn and see the world beyond the existing pattern. Existing systems are unpredictable and may be described by phrase 'creative destruction', or as Clay Christensen call them 'disruptive innovations'. Though idea and analysis mean similar in both terms: the companies should compete, learn, most importantly improve and create new services which can lower costs or innovate something unique. In addition, the ability to change is vital in industries wanting to succeed in the future. This may work between two different universities as well as between the same industry organizations.

Further, if company want to remain innovative then entrepreneurial movement and thinking take an important part. This is discussed in new research, provided by Julia Planko and Jacqueline Cramer (2016) about how entrepreneurs should strategically shape field in which innovations are created. In case of successful coordination disruptive innovations become sustainable innovations after some time. The authors are discussing manufacturing industries and claim that there are already many generated great innovative technologies' ideas but they simply fail to enter the market and become disruptive. Appropriate researches enable entrepreneurs to optimize technology and at the same time to developed an economically viable product which could be attractive to potential users. Nevertheless, sometimes even without

entrepreneurs' help innovations can arise themselves when their process is carefully planned, they can be serendipitous and spontaneous:

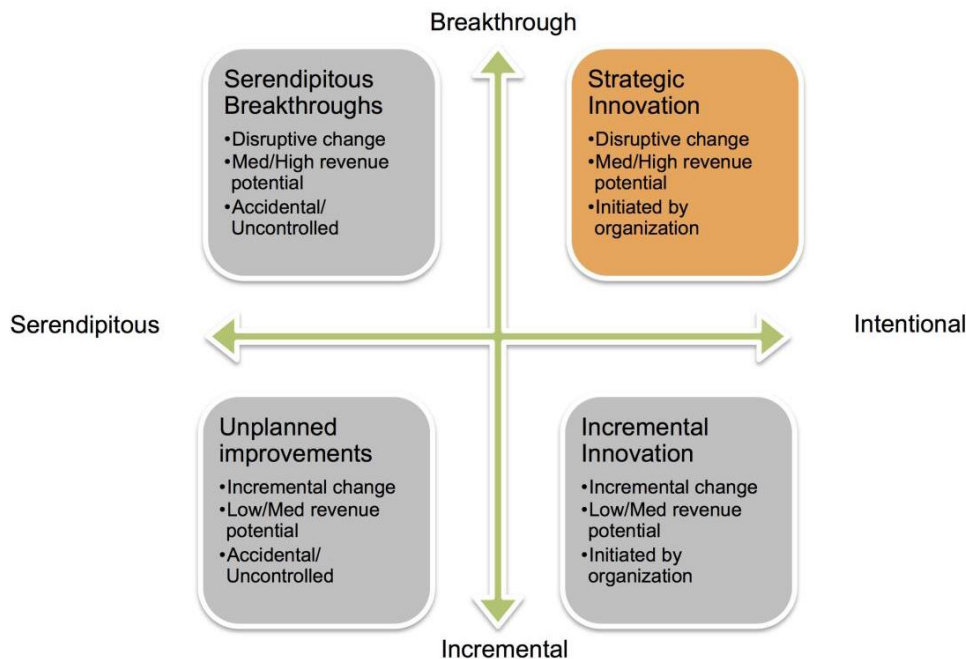


Figure 1. (Helen Goodland, Chris Lindberg; 2015)

Finally, when talking about innovations' appropriation:

- Newness is relative element. Something innovative can be new in one company or region and at the same time already established in others. Also, some organizations can simply use existing products or processes but in different or even new way.
- Innovation should be fully implemented in organization. Before implementing, an innovation is just an idea for future use. The presence of innovation should give a value for company, also improvements, environmental issues' impacts, shares in industry or some learning benefits.
- Investment in research strategy inside organization is not the same as innovation. Research and development (R&D) are only the activities needed to support innovation but they are not any type of innovation themselves.

2.4 Beneficiaries of innovations

The notion innovations is still poorly defined in terms of economics. In some ways, it impacts both participants, producers and consumers in the market. Disruptive innovations make these shock waves through market changing behavior of both consumer and producer. Nonetheless, the author (Bozzone, S.O.; 2013) verifies innovations which can improve profit by reducing

costs but gain efficiencies which sustain innovations growth. All innovations are created to add some value and attract more customers.

According to Ronald N. Kostoff (2004) the already mentioned disruptive technologies and innovations are important in creating something cheaper and faster produced. In other words, to create what could give better value to customers or would be cheaper to buy. It makes common growth and sometimes change or even create entire new industries. There is no doubt that the disrupt workforce lets technologies and unsophisticated individuals become the competitors in industrial workforce.

It is true that all sorts of forces change markets. Firstly, the democratization and disintermediation, processes started by the software revolution, have made many industries to feel disruptive innovations changes. The newest appearances of their industries are publishing, retail and computing. Both described forces are related and removes traditional barriers in order to access markets and tools (Hoover, S; 2015). Technologies like 3D printing are rapidly bringing forces to industries such as manufacturing, oil, gas, mining and they are irreversibly changing how we make things and how much workforce we need. In a next decade, this technology will come and in to slowest to adapt construction industry.

2.5 Innovation behaviour in the manufacturing industry

Different manufacturing industries can be a key source for innovations in analyzed construction industry because they are creating an innovative component for market and are building products (Anderson, Manseau; 1999). It is easier for manufacturing companies to innovate then for construction companies, as they are standardized and have more stable consultants and clients than construction industry. In addition, they are willing to remain competitive in market and as a result keep maintaining and investing more in R&D programs. Manufacturing companies are also better in establishing the learning process and growing the knowledge base, as most of process activities are not project based which lets them to stop discontinuities in learning. Innovations developed by manufacturers are very often adopted by contractors and construction clients which results in improvement of construction industry according Anderson and Manseau (1999).

Likewise, 3D printing is a classic disruptive technology (Banning Garrett, 2014), which has a widespread impact to world industries. This revolutionary technology is likely to dramatically change business models, shift production location, moderate supply chains, alter the global economic and change demand of human labor. Nowadays, it is risky to project the continued growth in the manufacturing revolution that has been sparked by 3D printing from plastic

industry to possibilities in our research. Also, any other technology could theoretically simply replace 3D printing and would most probably go in the same disruptive direction and do the same job better and cheaper. Such a disruptive innovation can have huge impact on all industries and will be called fourth industrial revolution in history books.

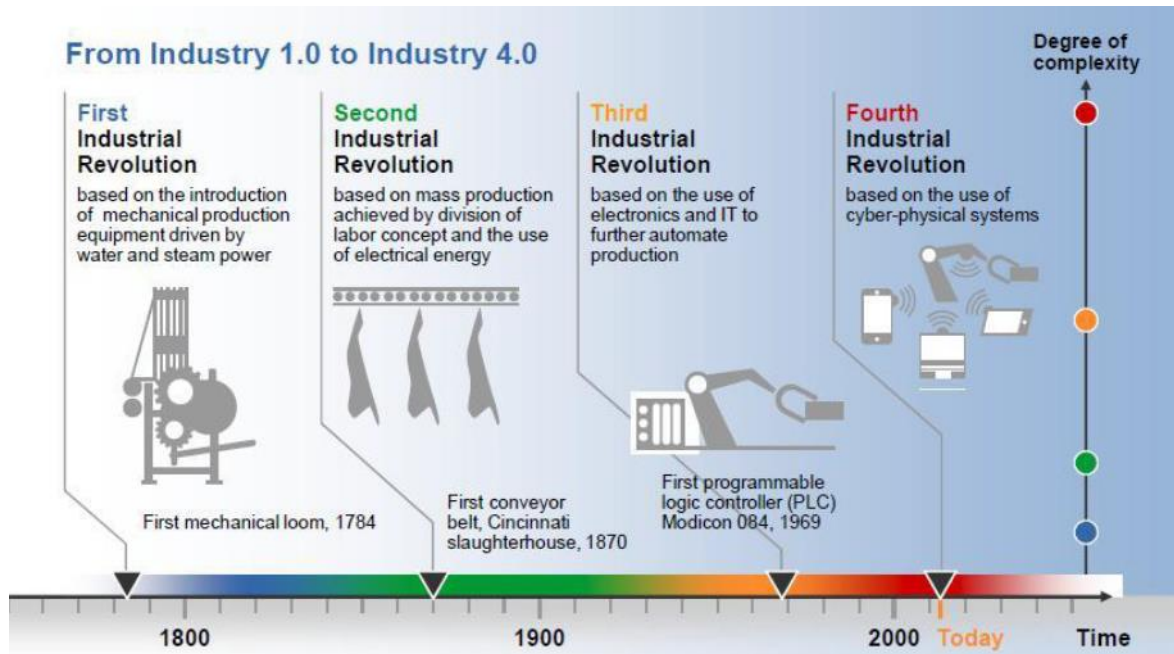


Figure 2. Infographic defining ‘Industry 4.0’ (source Siemens AG)

2.6 Innovations in the construction industry

In the history of humankind, the construction industry was one of the first developed businesses, also it shapes everyone’s daily life differently. Most of other businesses rely on the world’s biggest industry which provides accommodation and infrastructure for all humans. Construction industry technologies determine architectural ways in which everyone lives.

According to most researchers and common opinion, the construction industry is one of the least efficient as it was once described as *the last craft industry*. While manufacturing and production have become oriented processes with quality control, prototypes and testing, almost every building in construction site is still very often built without a design, constructed piece by piece on site. All this gives inefficiencies to building process phases from procurement to design and construction.

The authors Winfred Ikiring Onyas and Annmarie Ryan (2012) are analysing in their research what actualize construction market innovations. Their study has found that construction industry is one of the slowest to developed new innovations. Authors claim that in construction industry is needed huge effort to shift from new innovation to mainstream product in industry.

Also, commitment to operational superiority differs around the world, mainly because of combination in markets of market volatility, population aging and changing global demand. However, by adapting new technologies and innovations construction companies can execute performance better and approach strategies in their industry.

In addition, there are not many researches done on construction industry innovative processes comparing with other industries. The extensive body of different knowledge surrounding this industry stop researchers' efforts. Definition of innovations in construction industry has been developed by Manseau (2001). After examination of different countries, the author understood the main issues. It was determined as needed impact for innovations to appear in industry. Innovations within industry are recognized not linear model as in most of manufacturing industries, but closer to the concept of complex products and systems which are based on knowledge sharing and flow of information. Another researcher Brandon (2008) has identified importance and impact of clients in construction industry innovation processes.

2.6.1 Innovation types in the construction industry

We will review some of comprehensive models and individual aspects for innovation to appear in construction industry, nevertheless generation of innovation and systematic classification has not been developed in industry enough.

Traditionally, in the last few decades construction industry innovations have been mainly dependable on suppliers delivering products while improving performance of materials (Gann; 2000). The main aim was to keep the competitiveness and meet customers' needs. The same principles of innovative processes have been developed in manufacturing companies while producing construction supplies. Construction companies followed suppliers providing components and materials to projects.

Industry relationships between companies have very strong influence on construction market's innovation (Dubois, Gadde; 2002). Firstly, the interaction and flow of knowledge is important between companies from different industries. These interactions help the integration process of different related products, e.g. between construction assembly teams and manufacturers. Processes can be connected to diffusion of technologies, project coordination or information flow between and about various sources (Anderson, Manseau; 1999). These relationships arrangements between individuals from different companies can encourage innovative process, for example to make some 'experimental workshops' in construction sites. Innovation can be continuous to other projects and learned ideas can develop further. Building market is a complex industry and capabilities of one firm to produce innovations should be taken and

adapted by some degree in other cooperation. This concerns most of innovations in industry like development of products, processes and designs.

Existing innovations in the construction sector can be divided in three key areas:

- Construction business management – the way managers are leading companies;
- Construction products – the way companies use products and materials to construct buildings;
- Building and designing methods - the way companies are constructing and designing buildings.

A recent study by Helen Goodland, Chris Lindberg and Paul Shorthouse (2015) analyses main elements helping construction industry to innovate. The authors claim that embracing innovation will grant success to various projects and improve business performance in general. However, a comprehensive industrial action plan and coordinated efforts are needed to be able to capture industry innovation. This study offers four main pillars to serve as a guiding framework:

- The importance of leadership – a cohesive element for industry to celebrate innovation;
- Performance —economic, environmental and social performance should be developed in projects;
- People – construction companies should attract skilled, technologically-savvy workforce;
- R&D – develop and implement new products, processes and business strategies.

These four pillars are recommended ways which reflect best practices and strengths needed for construction companies to develop and be innovative. Implementation will also require government support and acceptance from construction industry.

Authors continue, why is important to define required key reasons of innovation in construction industry:

- To integrate supply chain;
- To improve performance;
- To accommodate changes of workforce in the future;
- To introduce new management styles;
- To get better universal value of buildings working for all society (reduce building, life cost).

Innovations in construction industry are in theory mainly influenced by existence factors known as motivators, drivers or enables (*Bossink; 2004*). According to other authors (*Gambatese, Hallowell; 2011*) diffusion of construction innovations does not occur in absence of a motivators. Authors have identified six key factors influencing innovations the most in this industry:

- Clients;
- Production structure;
- Innovation networks,
- Procurement system;
- Regulations;
- Organizational resources.

These factors can be connected to potential strategies top-down and bottom-up through organization in construction industry in attempt to develop or implement innovations. A innovative technology is about to become an everyday tool in many companies and also become a proper innovation inside industry.

2.6.2 Tendencies in Norway and the rest of the world

The construction industry is a manufacturer of technical and complex system (*Gann, Salter; 2000*). Various temporary organizations are involved in production of heterogeneous sets of mobilized actors with different knowledge bases for an execution of projects. There are different challenges involved in this complex industry, though project performance can be improved through innovation (*Atkin, Borgbrant; 2010*). Productivity from innovations in the construction industry is the most interesting part to study and the most expansive. Over four decades of research models and methods have developed for evaluation multiple factors influencing this industry. Different statistics have been analyzed in researches and construction industry has been described as ‘last among equals’ in innovations completion and performance (*Reichstein et al. 2005*).

In Nordic countries, several governmental reports have been done to investigate this matter, but all have concluded that construction industry lacks a culture for innovation (*Shields; 2005*). Most observers claim that this issue exists because of rooted problem in the culture of individual’s companies and a skewed incentive system (*Lepatner, 2007*). However, some argue that used methods and concepts to analyze statistics for innovations research in construction industry are not with adequately measured benefits from innovations. (*Aouad et al., 2010*).

Technology enthusiasts, academics and software companies are a little bit concerned about a slow pace of technologies in construction industry around the globe (*Macomber, J.D. 2003*). Tools which are in industry are mainly available to make improvement and disrupt market for other players to process design or construction. Sometimes we raise questions such as why companies are not involving these technologies into day to day work. Usually the answer is simple: companies are not considering possible monetary implications. If companies are only enlightened by self-interest economy, then innovations are slow.

A Swedish study (*Seeger-Meriaux, 2002*) show that contractors in Scandinavia generally have self-believe that they are innovative and creative enough, but especially medium and small-size construction companies are hindered around by small economic margins in market and think only about short time aims. Also, because of formal structure between clients and contractor, companies stop their potential to be innovative while having full potential to innovate. Comparing the construction process with innovation process can help to determine similarities and discrepancies, this could help make some conclusions how better organize the construction process.

Construction industry around the globe trying to follow some main tendencies of innovations processes to keep competitiveness in market: (*figure follow on next page*)



Figure 3. Summary of current trends in construction innovation (Helen Goodland, Chris Lindberg; 2015)

In construction industry project management is traditionally the most important part of the delivery construction processes to customers. However, the importance and value of traditional project management and project management theory as a whole have been questioned by *Lean Construction methods* (Daniel Forgues, Conrad Botton; 2016). For processes, many construction companies in England, Canada, USA, Australia and some companies in Norway are already realizing production-based project delivery Lean Design and Construction, which offers great environmental value. Applied in project delivery and design, it helps to improve total speed and performance. Nevertheless, it is more directed towards comfortable of customers, not so much as innovation changing labor employment, so will be not discussed so much in our research.

Today, what is changing human resources are some powerful digital tools, which have ushered in construction industry and deliver some innovative ways to construction solutions. In literature, they sometimes called *Modern Methods of Construction (MMC)*. It is usually a

combination of traditional assembling on site with new extensive factory produced sections and components and everything is added up and based on one BIM (Building Information Modeling) model and designed background. This investment for construction companies gives better results in time, materials and money. Other prominent issue is delivery and assembly planning of prefabricated modules by using Integrated Project Delivery together with BIM modelling. Finally, for all this to made and even mount on project site, there are many robotic technologies in development process, but it still continues to fall slightly behind other mentioned technologies. All of them will be discussed separately in the following chapters as it is most influencing innovations which changing nowadays construction industry.

2.6.3 Prefabrication technology

Probably the biggest innovation in the last century is prefabricated building components. Prefabrication is a manufacturing process, generally executed in a specialized facility, a manufacturing place in which varied materials are joined to form a component elements of the final installation in the project building site. The manufacturing process is usually undertaken in a factory, but also can work very well under the open sky at the building site (*C. Testa; 1972*). All construction process from prefabricated modules undoubtedly are saving a lot of human resources hours on building site, as it takes much less time to mount prefabricated modules and elements on project site.

Over the years, recasting techniques have developed in different building projects. In the last decades, prefabrication started to be used more and more in private housing projects like residential buildings. The research made by Lara Jaillon and C.S. Poon (*2008*) presents that a greater extent of prefabrication was used over the years, in terms of prefabricated elements percentage by quantity and types of precast elements utilized. Major prefabrication innovations have been introduced, in private housing and public sectors influenced by the technological advancement in prefabrication industry.

It is very important to note in this work that prefabrication has been identified as the first degree of industrialization in the world, followed by mechanization, automation, robotics and reproduction (*R.-B. Richar; 2005*). Prefabrication techniques have been progressively adopted in the construction industry in many countries.

From Asia to Europe, prefabrication building is now in use for high-rise buildings and private housing. An interesting continuing example was made in the mid-1980s when the prefabrication together with standard modular design was introduced and outstandingly developed in the Housing Authority's public housing projects in the biggest Asian cities, especially in Honk

Kong. After being approved, this mode constitutes one of the most extensive applications of prefabricated high-rise buildings in the world till today and shows a unique experience and possibilities in the use of prefabrication strategy in any urban environments.

The same development process appeared in Japanese construction industry, while advanced technologies have been used to improve buildings' efficiency with mounting prefabrication and automation technologies. The biggest market contractors were developing super high-rise buildings' systems by using high-stress steel, tower cranes, lightweight curtain walls and firstly computer-supported structural analysis, all innovations were reflecting economic boom in a country as a very productive and efficient method of construction.

In the past decades in Norway, it has grown a demand of volumetric prefabrication of timber-framed dwellings. This way of building has clearly identified advantages such as less subcontracting, indoor prefabrication and better quality assurance, long-term relationships with manufacturers, less working hours on project site (*Nord; 2008*). Unsurprisingly, Norwegian customers are mainly positive about this building method because of expected benefits and saving costs. However, the clients in Scandinavian markets are not actively impressed by the change of building industry into industrialization (*Engström, Stehn; 2009*). According to governmental investigation in Sweden clients do not facilitate timber-frame mass production in construction industry because they simply will not buy buildings produced in series.

Global environment preservations also influence innovations fusion, like concrete recycling system. Prefabrication which is important player in reducing construction waste and recycling of concrete waste, which is later used in producing new prefabricated modules. Prefabrication manufacturing technologies are now incorporating concrete recycling system as inverse technology.

Implementation factors to on-site construction tasks usually demand high degree of adaptation, thus it is difficult to accommodate irregular tasks and vary on conditions like weather. Prefabrication of construction elements while manufactured in factory and then transported to site for assembling removes many adaptability requirements. Also, which is most important is that it allows many construction processes on site to perform by robot's power like mounting prefabricated elements under controlled conditions and eliminating task variability. This method is becoming discussed for some projects in Japan (*Linner, Bock; 2012*). More about robotic technologies in next chapters.

2.6.4 Building Information Modelling (BIM) innovation

The main principles of Building Information Modelling (BIM) have been known since 1970s (*Eastman, Fisher et al. 1974*), but only in last five-ten years have started to be used in construction industry around the world. It seems that there is a huge gap in industry between developments of new technologies, but BIM made significant change to markets adapting process and had benefits from it. It seems that integration has offered the best chance for significant performance improvement in industry. Nowadays companies in Norway and around the world systematically start to take initiatives in business by adding BIM programs in their tool boxes.

BIM has been introduced as a disruptive innovation in an industry, showing possible potential to remove many of the factors in construction industry negatively affecting productivity (*Eadie et al. 2013*). Interest is growing and studies are analyzing the impact of BIM on project effectuation and performance. One of the reported BIM benefit are improving productivity for work in office and in particular significant improving labor productivity. In Norway transition has started as organizations are looking to transition to BIM, but how to grasp these benefits of productivity and viability of the BIM implementation process are mostly still in progress and not so much done relevant strong researches on it. Nevertheless, found articles around the globe presents significant gaps in developed countries between the as-planned BIM managing and after used in real projects, but gives a lot of benefit to productivity and communication in building process.

One of found research findings (*Erik A. Poiriera, Sheryl Staub-French; 2015*) suggest positive and clear impact of BIM on labor productivity on the studied medium size projects. The areas which were modelled and used for project used prefabricated modules, showed an increase of productivity ranging from 75% to 240% over the areas that were not planned by BIM. Research give results in usage of BIM as it consistently assesses their performance relating to labor productivity.

Discussed BIM approach in construction industry is significantly changing information managing ways in building and engineering industry. Building Information Modelling have completely revolutionized how construction projects can be planned, designed and built. Construction designing becomes more sophisticated by using BIM software which coordinate a build processes, manage information and workflow (*Eadie; 2013*). Complexity of information in industry is considered as one of the most important resources to be managed in construction projects. Most important feature of BIM technology is information sharing between individuals,

this makes faster movement and can reduce some human resources in office, but without doubt it is a game changer for project sites for planning, management and reducing workforce costs on site.

2.6.5 Robotic construction

Nowadays robotic technologies in construction industry are getting attention as artificial intelligence, advances in robotic, self-learning machines are ushering in a new age of automation. Machines already match or even outperform human performances in some fields in various work activities including some requiring cognitive capabilities. Automating in industry can facilitate different endeavours such as production of low-cost building and alleviate everyday problems on construction site, like high accident rates. Particularly useful automation can be in dangerous settings when human presence is problematic (*Justin Werfel, 2016*). There are many emerging robotic technologies around the globe created to work in construction industry like drones, robots, welding robots, exoskeletons, forklift robots, roadwork robots, humanoids and even 3D printing machines. These are already tested technologies and can have potential influence to affect existing traditional ways to deliver construction process.

There is always a place for improvement in traditional surrounding of construction industry and automation processes with robotic technologies can play key role in it. 'Robotics is the science of designing, building, and applying robots. Robotics is a solid discipline of study that incorporates the background, knowledge, and creativity of mechanical, electrical, computer, industrial, and manufacturing engineering' (*Jackson; 2015*). In the last year's robots are primarily aiming to make easier work for humans and are developed for sectors in industry where labor conditions are poor or they are much human energy consuming works, like drilling holes, cutting walls, handling heavy loads, laying down heavy materials, working at hardly physical positions, hazardous areas to humans and difficult accessible locations, like works under water.

However, the full potential of robotics will unfold as soon as robots will not only copy human work, but will be also oriented to robotic planning, management, and engineering or even labour training duties. Processes could open the possibilities for software creation where computers will be used instead of manpower performing certain activities like higher extent of design, analysis, information management and all this handled without human interaction. The whole process from architect to structural engineering can be standardized and operations can have

more or less automation in this process. All interpretation of building design and creation of specific models can be automated and simplified. Automation in construction industry can integrate planning system, produce buildings, operational planning and a very important question about logistics to building sites (*Thomas Bock, 2010*). Due to high wages and labor costs in construction works, all phases will face the largest rationalization effects which are achieved by intensified automation components. All robot systems will be integrated into human labor procedures. Robotic in general has many estimated advantages and benefits.

Today, there are over 200 different prototypes of robotic solutions which have been developed in the construction industry and tested on building sites around the world. All of them have determined and specified tasks under construction site conditions and worked separately from building site workers. Nevertheless, researches and experience has shown that only few robots can be applied economically today. There is no doubt that modern technologies will let benefit percentage to grow exponentially in future. Nowadays and during the last few decades world's most advanced construction industry market is in Japan.

In Japan robots have been already introduced to the third industrialization process and now are introduced to fourth, also significantly advanced technologies are presented every day. The main reason why it's in Japan is because of the lack of qualified workers, quality assurance and enhancement in Japan market, labor and environmental protection, also growing productivity demands (*Yusuke Yamazaki; 2016*). It is worth mentioning that lack of skilled workers measures comes from very restrictive immigration regulations which is opposite to regulations in Norway.

In addition, an important aspect for Japanese companies is an enchasing image of all building branches in this high-tech developed country. The developments of last fifteen years show significant success with this innovative strategy in Japan building market (*Yusuke Yamazaki; 2016*). The reason why Japanese have not offered their robotic technologies for others to use is because major building markets around the globe has no proof for their assumed unsuitability. The fully automatic systems building with superstructures also presumes serial production, which could be not fitted in some markets like in Scandinavian.

Firstly, in Japan was developed SMART system. It is a strategy part of developing an automated construction system by integrating prefabrication, automation and robotic technologies in high-rise building process. Also, management systems for information sharing between automated robotic technologies and designing, engineering, planning. While introducing SMART system in Japan, construction period was reduced significantly and at the same time amount of labor

required, management and planning productivity have increased (*Yamazaki; 2016*). Until now the system has been modified and improved several times and is currently vital in some big projects in Asia. Focus is on effectiveness of technology in usage of applied robotics technologies driven by engineers on specified BIM systems and are now driven by fusion between many companies in market.

Comparing Japan market and Norwegian, worth to mention system AMARUD (Automatic Up-Rising Construction by Advanced Technique) used by Japanese companies many years. This system was used firstly to construct oil rigs and now in construction, in central part of Oslo for new building of Deichmanske Bibliotek. The “field factory” is located on the ground floor as an on-site construction system producing each floor from concrete components. Subsequently, all finished floors are pushed upwards by hydraulic press system, and then the next floor is also built on the ground level. This shows that some technologies are coming to Scandinavian market, but much later then they are developed abroad.

Robots have significant potential if adapted on the construction sites, they can be used in varying tasks, move and even interact with environment. In nearest future, all construction process may be divided and performed in 4 steps using different kind of robots:

- Assembling robot for handling and mounting large components (like pre-fabrication elements);
- General purpose robot who can do walls from bricks;
- Interior finishing works
- Floor finishing robot available to approach large horizontal surfaces.

Next, despite of being in early development stage, there is coming 3D printing technology to construction industry, also described as robotic technology. Already with some examples of printed components from steel and concrete, it has full capabilities start *printing* houses in faraway future. Firstly, it can be fully adapted in manufacturing companies to make prefabricated elements applicable to low volume, high-value parts. Nevertheless, it is a lot of space to improve for this technology, as today's printers are slow, big in size and expensive (*Jackson; 2015*).

Preliminary feasibility study presented in World Economic Forum (*2016*) justifies economically robot usage for construction processes. First of all, to get better conditions and to benefit from growing productivity and quality of works. In all processes a leading role will play Building Information Modelling (BIM) discussed in previous chapter. Combining robotic, 3D

printing for prefabricated parts and BIM modelling, can be developed economically viable and innovative way of building new generations houses, by reducing cost of human resources in construction industry significantly.

2.7 Human resources and productivity

Terminology of technology and innovation can be used not only for manufacturing changes but also for transformation in labor as human resources management, capital and information to create more valuable products (*Clayton Christensen, 2011*). According to the newest author's research many companies fail because of 'their inability to assess future', because they do not have 'separate value networks and resource' to allocate and find systems in a company for development of innovations or disruptive technologies. Instead they have only standard and popular management idea.

Already according to old research made by Ricardo (*1819*) labor saving technologies reduce human resources demand for undifferentiated labor, but lead to technological unemployment. However, innovations that replace workers by machines will influence all factor markets and products. Nonetheless, this efficiency in production will increase real income and demand for other goods, while reducing the price of ones currently existing.

Another very important issue currently being discussed is workforce aging. New data shows that population in most of European countries suggest huge drop down in production-age population (*Tateyama, K, 2016*). In construction industry, this can bring severe reduction in the number of workers. This will bring society to the future where will be much more difficulties in construction market, if modern technologies will not be adapted. Already, in construction industry there are more complex projects started with limited manpower and budgets. This problem can mainly be solved with extension of innovations adaptation or even disruptive innovations appearance in construction industry (*Cunningham, R.; 2015*).

Aging workforce could leave companies with limited resources to adjust, that is why need rapidly evolve set of innovative technologies to improve operating efficiency, develop more accurate planning and collaboration with partners (*Sganzerla C, Conti. A., 2015*). New analytical capabilities, autonomous manufacturing systems and digital operations are examples of how technologies can disrupt and change human resources by lowering demand in industries.

The same is in construction industry, which are facing headwinds by automation and digitalization future. There are expected solid growth of engineering and IT specialists over the coming years. Increasing sophisticated technologies, will demand broader skill sets. Industry

will face stiff recruiting in construction workers field, as demographic shifts in developed countries. According world economic forum (2016) for example in United States between 1985 and 2014, average age of construction worker surged from 36 to 43 years, so following this proportion soon retirees in this industry will increase from 25% to 40%. In addition, today there is high volatility of workforce in this industry, as staff demands becoming evident in a short notice and many contracts are in short-term integration with workers.

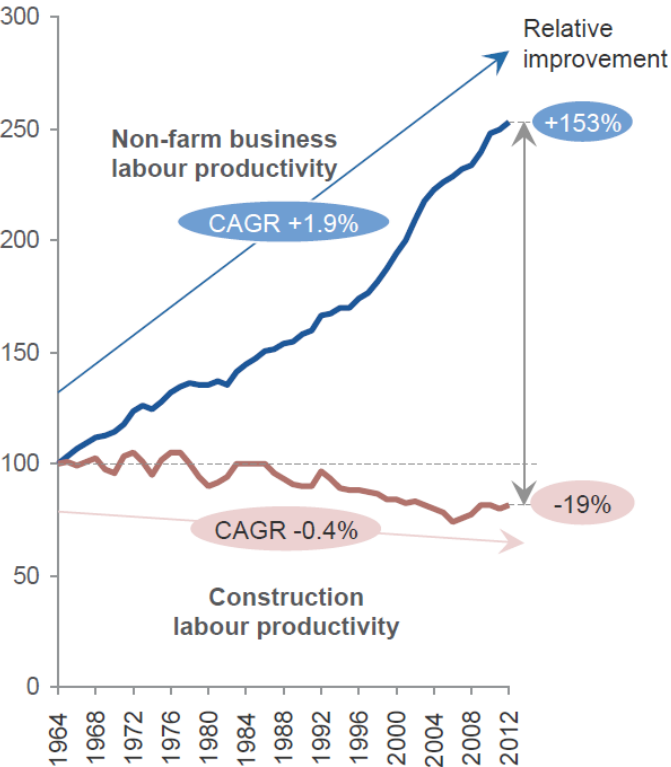


Figure 4: US Industry productivity and performance, 1964-2012 (sources 'World Economic Forum')

Industrialized construction processes' initiatives are growing productivity last decades mostly, was research by Swedish author Jensen (2010). During the last century mainly the big companies were developing exclusively these pre-fabricated building systems. In the last decade, the situation is changing and more medium-sized and small companies are investigating the possibility of industrialize construction, in order to grow productivity and lower the needs of human resources. The change of industrialization process alters different work methods, as to design and work with one kind of solution while later multiply template products and work with different spectre of product range, thus every time productivity differs a lot. Much more work should be imputed in development phase of construction systems while mounting and

realization phase are shortened. On negative side, in this construction type some architects believe in losing space for creativity, but on positive side it requires less designing work for engineers, and even much less time for realization phase for workers. When automation will be involved it could be found an optimal alternative for both sides to function and switch between projects much faster, according author.

According to McKinsey Global Institute (2017) automation in nearest future will cause significant human resources displacement and will probably grow existing employment gap between high-skill and low-skill workers. This analysis suggests that in automation and robotic new occupations in the beginning will be only partly automated and will need human resources to handle many things, later all process will become fully automated and this process could have various implications between various skills workers. Firstly, for low-skills workers, this process will depress wages unless a human resource demand of low-skills workers will grow. Nevertheless, in long time perspective large-scale structural shifts will be in previous industrial revolutions, fourth industrial revolution will also cause job losses during the time for some of very common employment places today in construction industry. On the other hand, it will create a multitude of new jobs and types of works as discussed above.



Figure 5: Importance of different transformation areas for the construction industry (Source: Future of Construction Survey; World Economic Forum; The Boston Consulting Group)

There are reasons why human nature has prevailed relates to adopt new skills by learning them (*Goldin, Katz; 2009*). Although, when robotic and automation will enter cognitive low-skill domains this will become challenging, as study made by Beaudry (*2013*) shows and it is significantly concerning. A decline of human resources demand even for skilled and educated over past decade continue to grow. Research has shown that high-skilled workers after transient computerization revolution have moved down the occupational ladder and have taken the job places traditionally performed by low-skills workers, by this pushing low-skills workers even further down the occupational hierarchy, acquainting even lower works wages and other benefits unlikely the years before.

How technological progress and fourth industrial revolution will impact twenty-first century construction industry labor employment, will be researched after many years. Nevertheless, throughout history and previous industrial revolutions we can try to find some similarities. Previous technological progresses have vastly shifted human resources employment from agriculture to manmade manufacturing and finally computerization process. Though, the concern about technological unemployment can be exaggerated as humans adapt to new opportunities quite fast.

3. METHODOLOGY

3.1 Research design

Exploratory research is described by Wilson (2010) as a research problem where there currently exist very little or any work to refer to. There is a lack of published and done research and very little knowledge about given topic. Research design is a detailed framework or a plan that helps through research process and allows to achieve objectives and assumptions.

For this study, I found the comparative research design are most appropriate way to meet objectives. We can use It when are compared few groups on one variable and they can be measured.

In addition, to make research plan, to find out how disturbances behave in construction industry while adapting innovations, I have undertaken a broad secondary research as this thesis is exploratory in its nature thesis and compare with primary interviews data from the Norwegian construction industry, to answer this need to:

- Understand the factors influencing innovation process in industries;
- Understand how construction processes work today and how innovative technologies are adapted;
- Compare the construction process with innovation processes.

To achieve this, three methodological approaches are used (*Arbnor, Bjerke; 1997*):

- The analytical approach
- The systems approach
- The actors approach

There are many different parts to build processes of innovation and most are not independent, which implies that an analytical approach cannot be used in thesis. The aim is to understand the factors changing cooperation process in the construction industry in general, which are not depending only on a individuals involved. This implies that the actors approach, cannot be applied either. Thus, the best approach for my research is the systems approach.

3.2 Secondary research

Firstly, I have started research process by defining research question for my master thesis. Mine goal was to search term and define lowest common denominator of many possible different phrases which exist in literature. I have structured my research by setting operative framework regarding the key texts when searching for approached literature. Main key phrases was made

in English like „innovation process and human resources management “ „market changes and disruptive innovations“ „construction industry innovations“ „disruptive construction future“

Secondly, I have defined a database. I have used University of Oslo online library and Google Scholar for research of relevant literature. On online library research gave a result from 120 to 350 different literature source, according used key phrases. I have analyzed most of them and found most relevant literature from all articles and books using an approach form of qualitative content analysis.

Finally, using possibly relevant documents, I have started reviewing all of them by comparing the papers according to their content and generated the clusters based on their communalities and differences. Additionally, I have separated articles and books, which are describing theory of disruptive innovations, new technology in industries and construction innovations which possibly changing human resources demand.

Next phase, I have started by comparing a newer literature and done research of literature written in past years about impact of modern technologies to manufacturing and construction industries. Reading and analyzing different changes in different industries like manufacturing, technologies, construction, mining. Comparing what changed from first theoretical approach to this field in 20 years and how practically disruptive technologies evolve and disrupt, change or create new markets. Main point was to get knowledge of innovation theory and adaptation in different industries in years and to compare with construction industry. Also, how existing technologies and innovations in last 20-30 years have changed already this industry to get better background for research.

For me to start researching and reviewing was important to understand overall trend of the literature regarding innovations theory drivers by trying specified in construction and manufacturing industries. Most of found articles was published in last 8 years and newest articles are describing and analyzing reviewed matter with deeper understanding and higher interest.

In analysis, I find out that disruptive innovations gain more and more importance in scientific research world as years followed to these days. This showing that to survive for existing and new companies, technologies and innovations are very important part. This information, I have used to review in my thesis. Separation of different approach to new innovations are important to understand, as my research and my analyzing subject are how disruptive innovations can

change specialized industries, in my case construction industry and more specified in innovations changing human resources demand in organizations.

In addition, literature review gave me mutual understanding and needed theory to analyze construction industry. Now, I could do much better complexity and clarification from my side. Also, were much easier to determine final research questions and database for my master thesis. Finally, to include extra search terms and synthesizing methods when searching for narrower surveys and analysis of changes in specified industry. Now, I can use empirical research data and compare literature with deeper knowledge and industry interviews.

3.3 Primary research, unit of analysis

In this section, it is described information how we were collecting information for primary research to find an answers from the construction industry, that later to sort it out and compare with secondary research and make final conclusions.

The design of exploratory study primary research is holistic (single unit of analysis) with multiple units of analysis embedded within it.

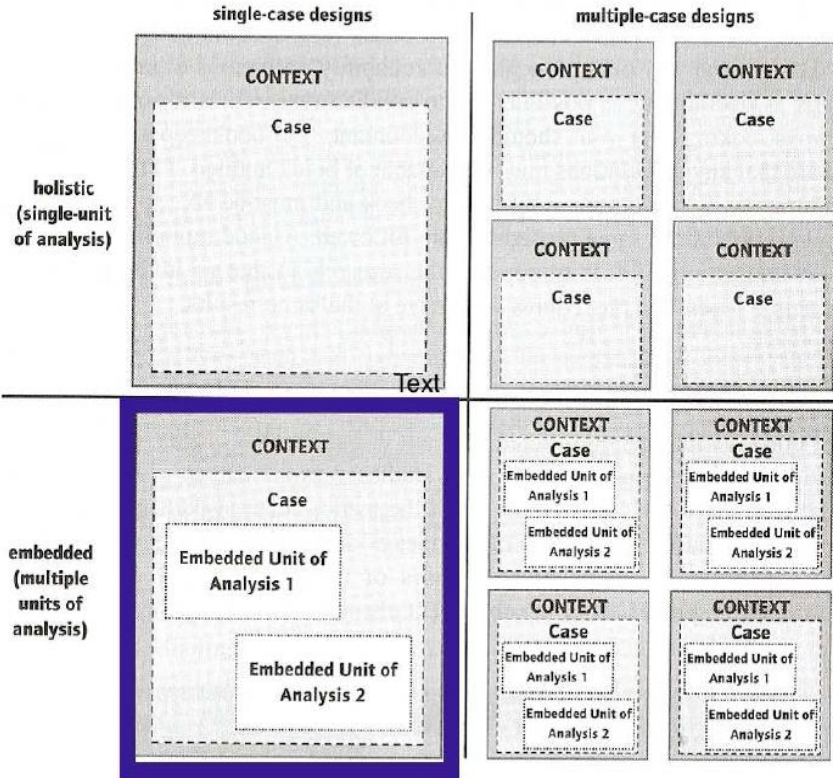


Figure 6: Design of case studies (Source: Yin R. K. (2009))

We skew our primary research towards three types of companies in one industry: important strategic persons in one of the top 5 biggest construction companies in Norway, respondent

from medium-size construction companies which not have separate strategy and innovation subdivision, and third part some of most important innovations creators in Norway. All interviews and questions are attached in appendix.

To make interviews, were done questionnaires with semi-structured interview questions and targeted most important people in strategy and innovation subdivisions in all discussed three types organization. Everyone I spoke was engaged to meet and actively shown interest in my study field, as they thought it is not enough research subject.

Primary research interviews also helped to gain much more better picture of innovations used in Norwegian construction industry as today on ongoing projects.

3.4 Delimitation

According to Wilson (2010) reliability issues are most of the time closely associated with subjectivity and once a researcher adopts a subjective approach towards the study, then the level of reliability of the work is going to be compromised. Primary data regarding the innovation process in construction industry have been gathered only in Norwegian market, this could give the risk of overlooking something essential in comparing with secondary data. The construction process described in thesis secondary data are mainly the construction process of the Western World or developed countries. Legislation and other standards have not been taken in deep consideration.

There are different forms of research validity specified by Cohen et al (2007) and measures to ensure validity of a my study include, but not limited to the following points:

- Appropriate time scale for the study has been selected;
- Appropriate methodology has been chosen, taking into account the characteristics of the study;
- The most suitable sample method for the study has to been selected;
- The respondents was not pressured in any ways to select specific choices among the answer sets.

The construction industry process is a large area to study and research, with many various parts and stages. In this thesis, the stages in focus will be those concerning recent adapted and known future innovations in industry which are shaping industry and can change human resources employment.

Many problems in the construction process can seem influencing discussed matter, so focus will be on how supported the innovation process are in other industries and in construction industry itself today.

Other issues that could influence the human resources, for examples, the capability of individual companies to work in an innovation process, will not be covered. The validation of methods to investigate issues about industrial ties between industrialized construction, building systems and manufacturing should be investigated deeper. Companies with broad field of practices is best to cooperate, if discussing whole construction industry, but instead we will have specialized and fragmented mainly a market of buildings construction.

4. FINDINGS AND ANALYSIS

In this chapter, the findings from the interviews will be compared with tendencies in the researched literature. The findings from the interviews with industry representatives are sorted and divided by sub-chapters to help answer our research and sub-research questions.

Status of innovation processes in the construction industry:

Almost all interviewees from the construction companies do not agree with a statement that it is one of the last innovated industries around the globe. Through interviews after this represented statement of literature, I felt negative response to this proposition. Respondents were claiming that researchers forgot the innovations like a wide usage of prefabrication, which is growing productivity. More advanced modularization process today and digitalization in total. Most of interviewees think that innovation processes are happening in construction industry every day. This opinion is opposite and do not agree with studied literature statements.

Two interviewees were trying to find explanation for these researchers claims, they think this is happening because it is biggest industry in the world with millions of workers with no lack of human's labour today. In addition, because of a vast number of projects, low margins in industry and risk of serious mistakes which could lead to uncertainty, as innovations always are connected to new risks. So, if it is connected to low margins and risk, motivation to innovate is always lower. Very interesting explanation and insight was said by one respondent about Norwegian construction industry *It can be that we are least innovated industry because Norway do not have some much international competitors in this industry in Norway and because we are protected by oil industry.*

Other good point was made that about building architecture, if design always will be the same then innovations can be adapted much faster, it would be possible to optimize prefabrication and robotic much faster for the same action hundreds of time. On the other end manufacturers agree with researchers and think that construction industry is very much behind and has a lot of space for innovations. Some processes *like tiling for example, it has been the same process for 3000 thousand years, as romans been on their knees doing the same way as today. Just a few years ago people used simply nails and a hammer.*

Implementation drivers of innovative technologies in the construction companies:

By almost all interviewees was confirmed that, the biggest driver for innovations implementation is without doubt a possibility to reduce costs. To push innovation forward

inside a company is usually a challenge and acquires some resistance. Almost all interviewers mentioned that to implement innovation in company, takes an effort and need to show profitability for management. Sometimes only results can convince management to invest. *Changes are always difficult, and especially in industry which have not changed in generation. Changes is one of the most complicated things.* Nevertheless, I had a good impression in most of interviews that industry is ready, wants and agrees to change, *there is a burning platform for changes, it is very clear that things should change soon.* Some companies are already very open to try innovations like drilling robots in huge projects. However, robots' manufacturers respondent had a comment about how some companies still *laugh about robots and think it is a faraway future*, but later in interview he added that if companies are willing to learn they should be not afraid to try and if they did, they will learn innovative technologies fast.

Other important part mentioned by most of the interviewees: customer's importance to innovate in industry. *It is impossible to predict the future, but I am sure that companies which do not recognize innovation as a solution, will run into a problem very fast.* On the one hand, if respondent said if company want to use some technologies in projects we need to invest a lot of effort to convince customers and to show clear benefit from something new, provide detailed explanation about how project would work better with suggested innovation. Were literature and findings agreeing 100% are that sometimes customers themselves want to challenge companies to find cheapest and fastest options to build. In this case, companies still need to be profitable, so it means they need to look for innovative solutions and innovations in existing processes. *So when customers start requesting innovations and challenging us, engineers are used to find good solutions.* Especially private customers usually want to have something special, according to one respondent *'we can present some innovations for lower costs and make project different from one standing in neighbours plot'*.

In one interview had interesting discussion about processes happening in some rich Asian countries like Singapore. They used to hire people from abroad, as there are not enough people to fulfil small country's big construction market, but government decided to take step forward and put huge regulations against hiring workers, cheap labour from neighbouring countries. By this step, government wants to increase productivity, but with less people on project site *now as they are trying to use machines instead of people power from abroad, they are pushing innovations a lot.* Today in Norway everybody is trying to realise a project as fast as possible, but process of hiring people from abroad is not regulated. To lift productivity and to reduce expensive human resources, get better conditions for workers, everybody agrees that investment

is necessary. In addition, I heard some serious acknowledgments from the same industry players, like *If you not invest, you will be one of the companies left behind and will do only assembling work, left to die*, which is a loud statement even for medium and small-size companies.

Innovations and new technologies benefits for the companies:

All interviewees believe that innovations help for companies to get better results and profit in the industry, what agrees with literature. For example, respondents were elaborating that technologies of automated labour can save a lot of costs and it can be even game changer for some companies, there have already been many good reducing costs innovations adapted in industry, like prefabricated bathroom cabins used by most of interviewed companies in the industry. In factory, it is easy to structure and standardize, so need to try developed production outside a project site, this can be achieved by industrialization, it is confirmed by literature.

Few companies said openly that they were currently investing a lot and only into IT, as firstly they saw how much benefit and better financial results can give BIM modelling, this is confirming researcher's estimations. Companies are investing in iPad consoles for workers on project site to work with model viewer platforms, making checklists or notes that they could appear on the same time on colleague's desktops around the globe with the help of cloud solutions. *Yes, if you don't [invest in BIM software], you will simply be excluded from new projects. Owners pay for making modelling, so they want them to be used afterwards.* Companies' representatives were telling about positive results in using 3D and even 4D modelling, they could see benefit in reduced building time, so it means reduced costs.

Most important innovations of today's construction industry:

All interviewees were talking about innovations today with impression mainly focusing about BIM [Building Information Modelling] modelling as nowadays adapted innovation. This gives strong confirmation for literature studies. Everybody believes that BIM have a brightest future for the next 5 years, as not only for visualization, but mainly for a background of prefabrication and robotic technologies, designing, planning, censoring and building processes. And it is really easy to understand why, because like one respondent commented, until now we have being used to typical traditional information carriers, like templates, papers, drawings etc., but now with BIM there is one information carrier, in one place, for all players in new project process *to have one single source of information, we have a BIM modelling. We have till now started using BIM*

modelling from development of the project in early phases and all the way through to the end when process is finished.

Interviews clarifies BIM benefits and importance in nowadays construction. Most of the companies are sending engineers to learn BIM software, as it is much more innovated then 2D modelling programs having existed for decades. *And of course, the more information we can bring to a BIM model, as early as we can in a process, we will benefit more from all these automatic processes.* Each hour spent on planning with BIM is saving a lot of hours on project site. *It can be so much easier to plan using BIM and robots and after all, less time, less logistic problems.* Also, logistics can be planned according to 4D BIM modelling solutions.

Respondents believes that all design will be done only with BIM modelling programs and will not be other alternatives not to use BIM. There is a clear vision of the biggest software developer for construction industry *all information will be in a models in a future. Subcontractors will get all information what they need in models. Also they can collaborate in cloud based solutions between more and more, on exactly updated documents and models, newer then could be printed drawings or information. Everybody will work on the same models, schedules etc. at the same time. This will be for everything.*

Firstly, architect will start to demand modelling, and then contractors will demand subcontractors and etc. *All industries are made from digital planning, like car industry and similar to very detailed element.* Soon, it will not be any new projects not design with BIM 4D modelling. *We are now having [software] which also adds time to 3D and makes 4D, for planning. So, fourth dimension is time. This is reach in 3 years. From today until that goal, as architects wants to be like that will be 4D with added time to 3D.* And comment from a construction company: *it is impossible to think that there is future in 2-3years as projects without using BIM modelling, it means even small companies should use BIM modelling in office or on site with Ipad for BIM viewer.* In addition, interviewers confirm with that BIM modelling will be so important and will connect also prefabrication and automation processes, because all information will be taken from models. *I think if we weren't investing in robotic and BIM in last years, we will be losing new projects for competitors.*

As mentioned in literature and confirmed also by interviewees that BIM modelling can be used in factories for prefabrication. Biggest advantages of prefabrication *like technical things can be done much better in factory in almost perfect conditions* or reduced time on project sites has been well known for many years. Full connectivity between BIM and prefabrication, what

makes process much faster and gives a belief in prefabrication as a main construction style even more in the future. According to manufacturers, in their factory all information is already sent to cutting robots directly from design BIM models. All information, like width, materials, every screw can be estimated and found in useful design BIM project model, as modules' manufacturer is saying it *[BIM] means less error, exact measures. It is great step for us and we believe we are the leaders in this field.* Other important thing is scheduling for construction companies: *now we are planning all works before the schedule that everybody would know in advance what would be performed on that day – to avoid errors on site [with BIM].*

One company already included in their projects censoring technology for tracking materials on site and censoring of transportation scheduling. Also, some companies mentioned the change in processes of organizations, what was discussed in literature. Coming management 'lean' process in companies, but till now it hasn't given any visible human resources changes in offices and is still not fully adapted, opposite then manufacturing industry according literature: *we have been a part of third industrial revolution 'lean' and automation, that really didn't come fully in construction industry. What we see now is that everything hits at one time like third and fourth industrial revolution hitting at one time.*

Future of innovations in the construction industry:

All respondents agree that construction industry have very high possibility to innovate much more in future and many innovative technologies will come. All companies believe very strongly that in future will advance and will be leading all construction processes a form of prefabricated modules building. Already now, we can see prefabrication modules of bathrooms, walls, floors, but in future everybody thinks it will come even more parts from off-site fabrication. *I think you will see more prefabrication then we have today, all parts and different parts. Will be whole buildings raised by modules like by complete apartments.*

In addition, according interviewees robotic and automation power will be included, firstly for manufacturing modules in factories and later for mounting on project sites, this claim totally agrees with literature. Respondents also thinks that *...repeated manual work, I am sure in future will be robotic power to change that. I know that many companies in Norway are already using robotic power to drill holes. I think it is a marvellous technology, but I think it could be better innovation instead of having a robotic on site, to have a supplier delivering those modular systems already with made holes, before delivered on sites. So robotic like this they can have*

in factories. Lifting robots and drones will be used to mount different elements, like Lego houses, was told by another interviewee.

By manufacturers of robotic technologies was given most optimistic answer about usage of robotic in future *I believe in 10 years we will see a lot of robots on construction sites. Especially, like simple robots like ours. Robots which can carry stuff. We will see an automated cranes to carry materials. A robots who can carry materials, because wasting electrician's time for carrying rubbish, it is waste a talents time.* Most of all manual processes, will be automated, and all interviews agrees fully with literature on this matter.

Respondents had they opinion about more further future. One of the company's is building a new library in Oslo centrum (described in literature chapter) and they are using special gliding concrete technology, first used in Asia. It gives efficiency and high speed, nevertheless, there is still a lot of manual work involved. *So, instead of people pouring concrete, you can image 3D printers doing the same. But I am sceptical, if it could be cheaper to use 3D printing instead of manual work, if you were building 10 same museums, maybe, but we are building only one.* It is showing that industry could really be threatened in future with 3D printing, but mostly believes that many years will come when it will become more efficient and reducing costs technology. 3D printing is already used in many manufacturing processes, even in construction industry prefabrication manufacturing processes, already printing some samples or parts, and this demand will grow. *Robots [3D printers] can work 24/7, so investment will be very good on machines. Prices need to be competitive to robotic innovations happen faster and it is coming.*

One interviewer gave his opinion, when machines and automated processes will be delivering cheaper house solutions then are today, so customers simply will stop buying from old contractor. In the end the most important for customer is simply the price according other respondent. *Today people are still cheaper then robots, as using cheap labour force. But prices on robotic and computers prices are going down, so when robots will be cheaper and they will be easier to compete with humans.* Especially, robotics will be used for processes of manual large and repeated work. *We will see a robots on project sites producing and mounting, also 3D printing even further into the future. But for now, robots like ours are doing small specific works. We know robots development of different parts like tiling, painting robots and many other tasks. Also we are in creation of more universal robots.*

Innovation perspectives and challenges in the Norwegian construction industry:

Huge innovative processes and changes in Norwegian construction industry will happen soon, all respondents agree. Most of interviewees believe that it is happening a lot in Norway construction market nowadays, if to compare with other countries around the globe or *At least we are exploring these thoughts and ideas how things can change*. Also, respondents believe, that if we will see any disruptive innovation in this industry in future on global perspective, it will appear in one of Nordic countries, *as here human resource are expensive, so especially digital innovations are not so relevant in low costs countries*. To stay competitive, companies will more and more *improve and implement small incremental innovations inside companies, like existing drilling robots*. Technologies manufacturers have a strong message to a Norwegian construction industry leaders and believe, that companies should invest even all profit for innovations, *because it will come other companies from other countries, who are good at that, then some of these giants [Norwegian construction companies] will wake up and will see out of business and this will happen to many of them. They are just working the same way all the way, but one day some new technology involved company will come and will take a market, and then to late are start to learn what is digital solution, robots, it needs already now to practise and invest*.

Biggest contractors believe that all innovations in theirs companies have butterfly effect to all industry, like for medium and small size subcontractors. In order survive, this smaller companies will be tempted start to use concepts themselves.

Other important factor according respondents and literature are sharing of knowledge, this helps industry to shape much faster *also most of our innovation we sharing with our competitors. I believe if several big contractors will use the same innovations, then subcontractor in other project will now this innovation in other project. I think the more you share, the more you get*. Nevertheless, today medium-size companies are much more laidback and scary to invest, and mainly trying to follow only processes innovations. It happens also because many medium-size companies, which are working in many smaller reconstruction projects, where to adapt innovative technologies, especially, on building sites are extremely difficult and far away from being profitable.

All biggest companies are already using BIM and prefabrication modules. *Challenge will be what architects and engineers put in modelling, according what customers asking, and now most of clients are asking that, so if you do not use that on building site you are simply kind of lost in a chain scope of work, because you have to use those tools in order to work as subcontractor. Lot of man hours are used and paid in planning phase for planning, engineering*

etc., so if you cannot use it, why they paid in first place? So, interviewers think simply, if contractors or in later stage subcontractors will not engage in BIM modelling, will be simply left out without option to get new job. Old style to work with 2D drawings and text documents, simply will not work, so companies should adapt very fast to these future processes.

In addition, there are lot of changes in management leading and execution processes. Also, respondents believe, time will help a lot for innovations be adapted itself, when younger generation, all compatible with newest technologies and ICT era, will take engineering and management places from older generation. Moreover, there are customers and architects, whom vision always asking for innovations, like better values for modules, environmentally friendly modules, elements with solar power, green technologies, requiring other innovations and special requests. This helps to push technologies much faster. Other prominent issue to innovate according respondents are start to deliver construction products or modules, which are low maintenance for many years to come, after delivering a project.

Disruptive innovations in the construction industry:

Everyone in interviews had common ideas and answers about disruptive innovations in construction industry, this is letting us to make a clear opinion about it. All respondents do not think that there has been any appearance of disruptive innovations in the last 20-30 years. *Computers have changed industry a little. We have an email, but it made for us even more paper work, less time on sites. Nevertheless, it is not a disruptive innovation, it didn't make any significant changes.* There has been no innovation changing and shaping industry from background, all players in Norwegian market are almost the same, just some are changing places between themselves according to sales. BIM technology, prefabrication and modulation are coming to new projects, but they are not seen by companies as a disruptive innovation, what validate literature research. Robotic technologies are also not seen as a huge process shaping industry today, there are some examples in industry, but only for execution of some separate works, not as a everything shaking innovation, according disruptive innovation theory. *Nevertheless, existing robotic technologies are not disruptive technologies, they are not the game changers.*

Mostly interviewees have used example of 3D printing then talked about disruptiveness. They believe that 3D printing is already showing promising results of printing possibilities around the world, by printing some parts or even whole concrete houses in China. Also, many mentioned robotic revolution and automation, which could be connected with things like

prefabrication modules and robots can make modules in factories and then other types of robots drones would mount modules on project sites, this system could have ability to work 24/7.

Nevertheless, what is most important for my study is that, all interviewees strongly believe that we will see one disruptiveness in the industry in the nearest future, especially, when respondents from biggest construction organizations in Norway are saying this. *From time to time, I am wondering, when this company can come, because I am sure it will happen. People in this industry should be more terrified, how they work, because our industry is threatened. Most likely in future, our company biggest competitor would be not one of the already established 'entreprenørs', but some start-ups with something on science, who will do construction in non-traditional way. They go delivering services on both sides, on R&D and customers orientated side. This will make them huge profits. Basically, commodity of people and managing them will disappear in a middle.*

Other company from top 5 list of the biggest construction companies in Norway, believes also in changes and threats from some newcomer companies with disruptive innovations...*basically, our business model is analogue information sharing, we take information on paper on one side and give it to other. So now on digital possibilities and tools, everything changes. I believe many new players will come and challenge us.* Most interviewees think similarly that some innovative company will appear *who will crack a code how to make money with newest technologies and methods so if you were not into it, you will be left outside and your market share will shrink accordingly. Or... people behind these projects, can be even not from construction industry, it can be some upcoming start-ups, not necessarily being start up by people from industry, but can be from other industries, typical bold, young people. Also having new business models, like complete modules systems taking all market and then we will have no chances.*

So, if disruptive innovation can happen in this industry, everyone agrees that it could be in a form not like some new technology, but like a company who will change existing biggest players in a market: *so in this market, there's unlikely that it would be some disruptive innovation, more likely is that some disruptive company will come and change an industry. It will be not a standard building company to overcome, because it needs a lot of investment, but a start up with one process selling.*

According to one respondent, with whom literature theories agrees strongly, *traditional companies will have linear growth, but disruptive companies will have a long term growth.*

Also they can work abroad and worldwide, not only in Norway. He continues, that most important are to have right product in which all can see value in it, like drastic reduction in building costs, and then it can spin of immediately, this will be like disruptive innovation and would change industry. I think start-up companies can overcome existing traditional companies. It will not change things much how we built, but will come one company with new ideas or robotic power and just win a contracts.

Human resources change of high-skill workers in the construction industry:

Finally, to answer our main research question, we need to find an answer about changes in human resources. First of all, all interviewees agree one way or another that it will happen change of human resources demand in offices will happen. Most of respondents thinking that demand of high-skill workers will grow, which confirms researchers claims in literature *I think we will need even more office workers because now digitalized planning and designing go faster, so people can start fast one project after other, but in future will be needed less.* They see a high growing potential of engineers and IT specialists for the construction industry... *this moves people to planning and observing, monitoring, and not so much in lifting and hammering on project site, as all this can be done by robots. So we need to focus on 3D, BIM and digitalization.*

Some changes are coming from discussed technologies, but some are coming from processes in management. The construction industry are among the last in introducing the ‘lean’ management method, but all believes that it will shape companies significantly and will give huge benefits, which has already happened in manufacturing industry. *‘Lean’ are known many years, but just now we are taking it to construction industry. But for example, in some countries it was started top used much earlier, like Japan, but of course Japan it is also much bigger in inhabitant’s number around 200millions, then Norway 5millions. So much more customer focused.* ‘Lean’ process already giving significant changes for some interviewed companies, as personnel start to see all benefits from them. Internet technologies, support systems also give changes for company’s administration. Everything now is checked on computers, without need to print, send directly to automated machines, automated invoices and accounting, with less manual input work.

On the other hand, BIM engineering and automation will require much more human resources according literature and almost all interviewees agree with this claim. Will need more engineers to put data in models *You need to put more hours in to planning and engineering resources in*

early stages and get it as correct as possible. That later on project site will be clear how to build everything and not need engineering help more.

Respondents believe that for future project leaders will be much easier to work. They will talk only with engineers and IT specialists, who will manage robot and automation parameters to program them, *then now to talk with works leader or 10 carpenters*. In addition, robots will have functions that they could automatically order new parts, materials needed for project execution. Manufacturer of drilling robots in Norway have programmed special feature when robot can order new drill parts directly from shops themselves.

Some of interviewees believe that even more in future, it will come full automation in all office works. Robotic and software algorithms will have artificial intelligent and will manage to make architectural plans and design buildings themselves with almost no interaction from humans. They will estimate all data automatically themselves and will send all input direct to 4D model like BIM or more advanced. Later all modelled information will be send to robotic technologies prefabrication factories and to robots on project sites.

Human resources change of low-skill workers in the construction industry:

Interviewers agree on one thing about human resources on project sites, that automation and robotic power will change manual, repetitive work of human labour in project sites and will give more value to projects. Nevertheless, it can still take many years to before all processes will be fully automated on project sites, but all respondents believe *what could take faster, to make off-site production, this will happen much faster, to move construction off-site and have robots in factories not on site*. This happening simply because prefabrication is reducing human resources demand and taking down costs as a whole. *Like using bathrooms cabins, how much labour hours we are saving in comparison with traditional building on place process. So, when delivered cabin, you are get rid of all those people needed to deliver bathroom on place. The gains we definitely have, in higher productivity*. However, anybody from all respondents did not had exact percentage or information how different are captured productivity in modules building process, comparing with traditional building time and costs, according them it is difficult to estimate. Literature also, usually estimates productivity changes only in the past.

All interviewees believe that fastest we will see full automation manufacturing processes in modules factories, what will make fill potential of prefabrication, but on the construction site traditional constructing methods will start to vanish. *Because of prefabrication will be lower demand on human resources on sites. However, when we use modules, there much better*

productivity, so on site there is much better productive gain, but on the other hand it is not measured as a gain in statistical measurements as in this way all work goes from building sites to manufacturing factories. One respondent give clarification and threat for local construction market, he thinks it is sort of a problem for Norwegian construction industry, because of prefabrication modules demand, productivity is growing, but most modules are made in factories, which are usually held not in Norway. He not sees so huge productivity gains today as labour force simple came from project sites to factories, but more sees a threat for local industry.

Nevertheless, almost all interviewers discussed prefabrication as nearest future and one of the fastest tools to grow productivity and innovate. All agree with this quest said by one of the biggest companies in industry *Only way to move forward is using modules and prefabrication. I think It will be a major part of the project, as consist of prefabrication, a share of prefabrication will increase. Project by project, and year by year* and this as confirms with researched literature. Respondents agree that it will reduce labour employment on project sites significantly *Like off-site can be very close to project site or can be on the other side of the world, it depends on transportation method chosen and finally total price.* One company, which is producing modules already was clear about answer *Our fabric doing completely finished product and the shipping to project site, and then we saving many time on labour at project sites.* Respondent from the same company said that he saw all process and all benefit now, from full work only on sites before 10-5 years, and fully prefabricated process now. Now, they trying as much as possible to produce off-site and reduce working time on project sites.

More years in future all interviewees agree similarly with literature about human resources development *I think we will be needed less low quality people, but much more high-skilled people, IT personnel. Everybody is scared that we will loose our works because of robots, but on other hand it will be created much more works for engineers and IT persons.* But all believes that much less of educated builders will be needed on construction sites. Already drilling robots are in market, who are reducing costs for labour around 5 times, confirmed by manufacturer itself and one company. However, all respondents do not believe that this change from human labour to automation will come very fast. According one respondent in 50 years, there will be significantly less demand of known today construction worker's specialities needed *but now it is impossible to know what these new jobs can be.* But more or less believes and concluded interviews similarly *like if to go 100 years in future, maybe we will not be needed any workers and even not any architects, as robots will design, plan and built.*

5. DISCUSSION

All discussions are made by comparing literature, researcher's documents and interviews from industry by order to answer all sub-questions and finally main research question in my exploratory research about human resources changes in construction industry influenced by innovations and innovative technologies today and in future.

When comparing today's construction processes to innovate with necessary aspects described in literature with other industries like manufacturing, there is some problems and differences hindering innovations. The lack of communication and learning inherent in approaches to construction procurement impacts on extents when innovation development could be possible. Main aspects are communication and co-operation with other parties, learning and involvement of the same actors in similar projects, incentives to encourage innovations, risk and reward understanding.

All interviewees agree with literature that we will see much more prefabricated modules in advanced shapes in contrary to the traditional construction process on-site. Automation and industrialization of prefabrication process will have first break through areas where already high mechanization rate exists. According literature, by intelligent shift of processed parts from site to off-site prefabrication is possible to achieve a much higher automation and higher integration of different defined building parts rate. Through, the higher integration of the parts and automated production technologies will be enabled designing and architectural flexibilities of various prefabricated modules. Because of this, prices to construct will become similar and the competition in an industry will grow. The most efficient way of transporting modules from factories to project sites will get high importance. Transportation will become essential part of industry, what will become crucial element in winning competition against other industry contractors.

In addition, respondents also think that because of standardization, modularization and prefabrication in nearest future productivity in construction will increase sharply. Modules can be applied for many types of projects and can be manufactured as building components or modular system with larger volumetric elements like entire rooms or floors. It can be added all electrical, plumbing and ventilation systems in modules at factory conditions. It will bring significant reduction in construction costs, what is a main driver of innovations implementation according literature.

Moreover, less tolerance problems, reduced maintenance costs for end-users and much smaller part of waste materials. Prefabricated modules will help to realize the potential benefits of manufacturing environment, like increased construction efficiency, better abilities to plan and sequence processes, no holdups because of weather related problems. In addition, it means reduced project delivery time, better construction costs relative with traditional methods by building on site, much safer working environment. All this in future can be manufactured by automation machines in factories, transported to project sites and assembled on site by robots, so increasing construction efficiencies.

In addition, the modular structure prefabrication process will have even bigger impact on all phases from development, planning, production to mounting. Designs on modules are improving every day and manufacturing innovations allowing to make more elements a day and change design much faster. According literature, Japan market is mostly advanced on prefabrication usage in the world. Interviewees agree that all modules prefabrication already and will relate more to BIM designing technology (Building Information Modelling). Many smart houses designing are focused only on modular system to construct them. The same tendencies are existing in Norway and will be implemented even more in future. As literature explains, embracing the technologies that are already available in industry could enable innovations more much faster from concept to reality.

According findings in interviews and literature BIM modelling, sensors, robotic and smart construction technologies will transform traditional designing concepts. Advanced computing systems like BIM should be exploited what will help new innovations implementation throughout the industry. It offers ability to construct everything in virtually multiplied approaches and be tested before being built on project sites. This allows ideas to develop in safe process and risks can be identified and changed in digital space. Sensors technology allows assets been monitored during construction phase and sending real time information to BIM planning and to ongoing plan by reducing operational costs. According findings and literature approach, all processes will be connected in one BIM module, like planning, engineering and construction management.

Nevertheless, until today, not by literature, not by interviewers BIM, prefabrication and existing robots are not seen as saviours of industry or as disruptive innovations. Before 10 years, an era of adapting BIM, some seen 3D modelling as a revolution, but today almost nobody sees it as big disruptive innovation in industry. Buildings are started to be built from models and this demand will continue to grow, but again procurement process are still more exception than a

rule in Norway and other countries. Like comparable disruptive innovation of Airbnb (started 2008) or Uber (started 2009) have taken over all market and become strong dominators, with BIM we cannot see that, it is only a tool to work with. Today investors and architects are putting pressure on the greater efficiency and use of modelling, but it is more like pushing incremental improvement, rather disruptive innovation and all interviewers validate this.

BIM technology was mostly discussed in interviews and presented widely in literature. This technology firstly was met skeptical. BIM was not compatible with existing practices in a project, like manual drawings. Even over the years of eventual development of drawing CAD programs, data and form of 2D models remained and remains significant barrier for some companies to use BIM systems. This is one of the factors which fully stops BIM development in an industry and innovations development in the industry. Before it seemed that existing methods are good enough, but situation is changing especially now when adopters have seen benefit of this innovation and received very positive feedback from clients. Enthusiasm of possible modern technologies have boosted in an industry among players.

As validated by interviews, in Norwegian construction market 3D BIM modelling are already widely used by construction contractors as a part of business, but still not so much 4D modelling which includes also time planning and scheduling. However, most of medium and small size companies across value subcontracting chain have little or any experience with BIM. Implementing BIM and later even robotic technologies in company requires built-up expertise and human resources. Should be employed engineers sent to training courses and acknowledged with programs. Substantial IT upgrading is needed. For small and medium size companies this can be very challenging, as need to afford upfront investments.

Next, I have discussed much with industry about automation possibilities in industry and how rapidly it can progress within nearest future technologies. Researched literature and interviews shows that in construction industry advanced, modular automation and robot technology can be easily achieved as initially applied in production process and later over whole phases. Production technology are key factor in all discussed industries. Once advanced and modular production system installed, a steady efficiency performance will continue. Like in manufacturing industry now, similar terms of control, logistic systems can be applied.

All interviewers agree on one thing, that a competitive and market oriented rationalized companies of tomorrow requires start to develop and adapt automation processes and robotized construction technologies of today. This includes all process from materials production, prefabrication of construction modules and site facilities management. Construction projects

continue to be characterizing by short design and construction period and increasing demands in market of quality and lower building costs. This can be approached easier while starting innovation process in automation with robots based on computer assistance.

Findings shown that construction industry has still generally low level of automation in industry, while other industries like automotive have already reached fourth industrialization phase according literature. Some specific robotic technologies are implemented successfully in Asia countries, but also according interviews some of them already have been used by biggest contractors in Norway. According to literature and interviewers, in construction industry that is set to change as technological advances open enormous new possibilities. Existing semi-autonomous robots, like for example drilling robot already used in Norway market are capable to carry out complex tasks, but requires considerable human controlling. New generation sophisticated digital robots, out of sight drones, will leave only monitoring roles for human workers. It will offer great potential in reducing construction costs, because of increased productivity and shorter delivering time, higher and more accurate quality, less man work errors, improved safety, works in danger zones.

Interviews within construction industry strongly agrees with literature, that in nearest future we will see employment of robots in construction industry`s low-productivity and monotonous repetitive jobs areas. Also, robotic industry will help to make up for shortage of aging workforce according researchers. As well as taking advantage of human resources in areas of high added value. Realization and popularization of process like 24-hour automated operation would give ground-breaking process. Such initiatives will lead to greater added value and improve productivity.

Fastest enabling of robot-oriented construction industry will happen with modules prefabrication building features, advances like flexible industrial pre-fabrication, flexible production of various modules and easier application in construction sites. Automation in industrial and flexible prefabrication of complicated buildings will enable automatic construction using robotic technologies. Companies will be able to achieve a significant level of construction parts variations. Programmable robots will help to enable this variety and will be manage using suitable software. Firstly, prefabricated modules industry and later on-site construction would benefit from advantages, like flexibility to manufacture some large-scale parts with automation align production to meet the requirements of housing sector.

According interviews and literature in order towards utilization of robot in construction industry, human resources will be needed with knowledge of robotic in various scenes. It will

become a necessity that people in positions to collaborate with robots should acquire knowledge of robots and deals with measure of investigating. For the future for usage of robotic will be needed to develop human resources that in construction companies will be specialists with knowledge about robots themselves, but also comprehensive knowledge of IT areas, as all action will be taken from computer integrated systems like BIM and programming skills.

Also, as validate by interviews, robot value to industry could be enlarged by encompassing the all operational processes before and after deploying robots, not only on single phase. There will be created many employment places in industry to undertake formation, processing and distribution of installation, data flow and work environment settling in transition from human work to robot work. Entire system should be optimized for maximum usage of robot functions in different industry fields. Conventional construction industry has labour based production systems due to human resource nature as a natural limitation, where technology based like robotic influenced systems virtually have no limitations.

In predicting nearest disruptiveness in the construction industry interviewers had many similarities with literature research. Almost all think, that one company by combining BIM modelling, prefabrication and robotic technologies from factories to building site, can cause first disruptive innovation in construction industry, but not so much as innovation, more as disruptive company what differs from literature. Also, some researchers and respondents think that fastest disruptive in construction industry could come from algorithms rather than robots, with software changing all architectural, planning and designing work with artificial intelligent programs. High quality buildings will always need human architects, but much work especially for simple housing can be automated or architects can use for quickly design. We already have some start-ups trying to realize this in USA and Norway, but with success this could become very easy acceptable and developed around the world. On algorithms based software can be disruptive innovation in industry.

The following, all interviewers and researchers have huge interest in 3D printing technology, but thinks that it will take longer time to make it profitable in construction industry, but it will happen. Already, it is implemented in many in manufacturing factories around the globe, so now together with fourth industrial revolution coming to construction industry either. From prototyping to full scale working models, 3D printing already has changed century old idea of manufacturing and will continue to change minds for generations to come. Different prototypes already done around the globe from constructing or *printing* a home in a day or examples of printed modules for block apartments as prefabrication elements, this technology can

fundamentally change construction industry and the way we think about human's labour in construction process. While normal construction can take many months, 3D printing technology connected with BIM modelling already today can print whole structure in few days. In expensive labour countries like Norway, this could be potential threat for existing building companies and the way construction are executed. In addition, it has many benefits, like almost no waste created as robot applies only needed materials for structure. In faraway future after 50-100 years, interviewers think that 3D printing in construction industry could be alternative for construction from prefabricated modules, as much more architectural and design varying projects can be *printed* in shorter period.

Most of respondents validated literature, that wider development of 3D printing and robotic technologies in construction industry, can give amazing benefits for some companies in future competition counters. Finally, all agree that for all industry it can give disruptive impact. Apart from significant productivity gains and total reduction of labour costs, it also promises reduction in waste and enables the production of purpose-built shapes that cannot be produced by modular building or with any other known today method.

On the other hand, 3D printing technology in construction industry can give also sort of negative disruptive impact to society. In fast adaptation of technology, could arise similar reduction of human resources as we are seeing today in manufacturing and production industry. These industries were one the first to adapt 3D printing technology which is substituting labour employment as a more resource-efficient and sustainable product to use in manufacturing. Workers in lower skilled roles will be caught up in a vicious cycle where low skills means redundancy without significant upskilling possibility, as investing in this upskilling will be no point of disruptive innovations like 3D printing in construction industry. While construction industry today is one of the biggest employers in the world, not addressing and planning such an issue in a timely manner can come to enormous economic and social cost for business, individuals, families and societies.

Finally, I would like to discuss more about human resources changes and labour employment. According literature, for human being all discussed innovative technologies will have a significant impact on how people collaborate, communicate and work, as verified by industry interviews. As generations collide, workforce become much more diverse and stays in industries longer. Many roles in construction industry can change from traditional job titles to ones we have not thought of yet. Innovations and even some disruptive changes to building business model can have impact and influence the employment over coming years. Some major

drivers of transformations adapting innovative technologies will affect and give significantly impact on job creation and displacement, higher labour productivity and widening skills gaps in construction industry. For example, many specialities in industry today, did not exist before 20 years, especially ones connected with computerization integration in industry. From now, innovations will accelerate the pace even more and will create different job places in industry not seen before.

According literature, in today's construction industry, productivity is bonded mostly with human resources. Labour productivity in the construction industry, according researchers is measured by different perspectives and constitutes. Differences lies in the used methods through how and which data were collected and are analysed. Also, the quality of analysed data and almost most important are the scale of collected data. Most of researchers says, that all construction workers on-site and off-site will continue to work alongside with robotic power as some activities become more and more automated. Interviewers believes that in Norway we will see all discussed innovations and much more in nearest future, but still all educated construction workers of today will have enough work in industry for their lives, mainly because of growing demand and workforce aging.

The aging workforce is a concern according literature, but not so much elaborated by interviewees. Researchers think that there are not enough new skilled young entrants entering industry. In Norway, it is not main concern as of high numbers of foreign workers in industry, but in other Europe countries current national focus are more directed towards academic education rather that vocational qualification. Retiring skilled workers from construction industry are not serious worry now or in next five years, but according demography next twenty years can pose some fundamental questions without innovation. Nevertheless, if discussed technologies and innovations will be adapted more and more widely, this shortage can be avoided.

However, current debates in literature of potential mass unemployment predicated on a surplus of human labour was not validated by industry respondents. Interviewers agreed with other part of researchers who are claiming about a need of every working human being in construction industry in nearest future. All jobs today requiring physical abilities are expected to decline in importance, as less and less manual repeated work will be executed by humans. Literature agrees, but argument that in developed economies robots will not keep with demographic aging trends and much likely a surplus of human labour can occur as a deficit of people resources, unless automation will be deployed even faster than are nowadays trends.

As validated by interviewees, a nature of works will change, transform from the automation of individual repetitive activities to more complementary work with machines. Researchers and respondents all see robotic technologies in efficient sustainable production lines and on-site machines as strong drivers for growing labour employment for engineers, IT specialists and skilled technicians to manage automated production systems. They are anticipating that for wide range of occupations will require much higher degree of cognitive core skills abilities, like logical reasoning, creativity and problem sensitivity that are today. Our respondents and researchers expect robust growth across IT specialists and engineering employment. More computer and mathematical jobs will be needed in construction industry, as modelling design and automation taking place and growing demand of people who can follow all processes and imputing of data. Because of this, organizations structure and management styles will also shift adapting to more high-skill workers managing systems in construction companies. On the other hand, it can have some negative impact, as automation could exacerbate a skills gap, even as it touches all occupations. There is already a growing divide in income advancement and employment opportunities between high-skill workers and those who are low- and medium-skill.

All in all, industry and literature agree that in industry earliest automated activities will be ones including physical activities, especially in manufacturing of prefabricated modules. Some automation will be skill-biased to raise productivity of high-skills workers even then demand of lower-skill workers and routine occupations like assembling workers will reduce. Nevertheless, technology development will make both low-skill and high-skill workers be susceptible to automation as everybody believe that all human resources demand will drop of aging and more robotic work will take places of not only manual repetitive work, but for whole project execution from designing phase to construction site. In addition, like discussed disruptions such as learning robotic and software with artificial intelligent can completely replace existing occupations in construction industry and job categories we have today, freeing workers from routine work and letting to focus on new tasks and changing skill sets in these new occupations. So, if some disruptive changes can appear in industry pretty fast, then overall pace of industry transformation is wholly unprecedented.

6. CONCLUSION AND RECOMENDATIONS

All in all, construction industry been one the slowest to adapt innovative technologies, but there has never been a more inspiring time to innovate than are today. All industry is driven by goal to achieve lower costs, emissions and faster project delivery time. Nowadays, at the same time industry is trying to adapt third and fourth industrial revolution. Industry undergoing a modern transformation, connected with labour productivity which finally starting to grow after many years stagnation. The performance of various automated robotic technologies connected with BIM modelling are increasing and soon we will start to design, make engineering, managing most of construction processes in a robot oriented way. Soon construction companies should start to hire robotic and mechatronic engineers, IT specialist to program all inputs between modelling, robotic, prefabrication or for on-site construction processes.

We are living in new automation era in which computers and robotic technologies increasingly will perfume routine manual work taking traditional job places from humans. Robotic technologies are becoming cheaper every year, so only on price depends then automation will be cheaper to use then people labour. It also includes cognitive capabilities to accomplish activities like sensing emotion, tacit judgment or intelligent transportation.

Increasing percentage of elderly people in population affects the construction industry and it threatens to reduce available supply of construction workers. On the other hand, this threat can be seen as less dangerous than in the past, as new innovations and technologies require accordingly more skills and less workforce. Automation will have essential role in providing some of the productivity boost to industry as working-age population declines in developed countries. On extent of automation technologies adaptation, it will be many surprises, like large-scale shifts in workplaces. The impact technological and socio-economic disruption on industry will give transformations to the employment landscape and skills requirement, resulting challenges for recruiting, training and managing new talents, will require new key jobs to follow automation processes, which are not yet part of core skill set of today.

Moreover, especially in high labour costs country like Norway, automated construction technologies can compensate increasing demand in various fields on construction projects. Discussed robotics technologies connected with BIM modelling software and growing demand of prefabrication deliveries, as a key to rationalization in construction industry. This would increase productivity and reduce high labour cost share by 40 or even more percent in next decades. The reduction of human resources demand and construction time would influence whole project cost due to faster availability and return investment in commercial, real estate

and governmental buildings, etc. In addition, automated and robotized processes would give possibility of continuous working 24/7 all the year around and helps for humans to avoid of dangerous to health working conditions in some areas.

Overall, to look ahead in construction in following years, we could predict the extension of automation process and all processes combined between modules prefabrication, BIM modelling, and transportation, mounting on-site and finally 3D printing. Using robotic technologies and automation, this process can even be directly between customer and manufacturer, without interaction of traditional construction companies. Customers could make architecture and designing themselves with programmed software and algorithms according to their wishes and send directly to prefabrication companies, where data will be automatically inputted to robotic machines to make modules for new house. After modules will be transported to project sites, mounting executed by robotic lifts, drones with little input from human interaction of IT engineers. This would make drastic reductions in costs, human resources demand and all construction processes, being compilation of innovations that could enable some disruptive company to shake construction industry.

According this exploratory study, I can make assumptions that there is high possibility that architectural, designing and traditional construction companies constructing new buildings have high threat to vanish at all in the end of this century, as all process could go directly from customers to artificial intelligent algorithms for designing and later to automated factories and construction sites. Middle players simply will not be needed, it means biggest players in the construction industry can vanish together disappearing high amount of job places for humans in industry existing today, as the construction industry are one of the biggest employer of human workforce. Very interesting for this study was that most of the todays biggest Norwegian construction companies agree with these assumptions directly or indirectly.

In addition, the construction companies who are working with renovation projects will exist and will have a lot of innovative technologies like automation and 3D printers, printing new walls, floors or whole modules with robots on projects sites. This will take many workplace from low-skill workers and will displace more workplace for high-skill workers. Nevertheless, it can happen that automated construction methods will give very low construction costs of new structures building and to renovate projects simply will be less economicly profitable, then to demolish, recycle old materials and construct or print new structure.

Nevertheless, I believe that the new era of construction innovations will bring great benefits to society by reducing construction costs and adverse social effects for environment, improved

materials waste efficiency. Everybody agrees that this potential will blossom very soon and dramatically, as we could predict some disruptive innovations or companies coming to industry. In fact, changes are already taking place in Norway and around the globe, though not yet on a significantly wide scale, because innovations should change from being just application of innovative ideas to a process that can be managed and controlled systematically.

6.1 Recommendations for industry

The time to innovate is now. The rise of digital economy and automatization desperately asking industry for innovations. The facts and the figures showing that innovations can truly bring values to construction industry. In response of coming challenges to construction industry managers should engage a strategic workforce planning in companies. Leaders need to motivate and support, and ensure stifling of ideas attitudes in teams.

Need to plan direction and possible innovations involvement in company to anticipate their workforce demand in office and on-sites well in advance. This forecast should be made by comparing future skills requirements in digital space and expected productivity gains through technological advances. Changes should be developed in company both ways by upgrading relevant digital skills and provide appropriate training for workers in company. In addition, they can develop hiring and retention strategies of comprehensive talents management. There are many opportunities to innovate within own companies and change approaches on human resources management.

Almost all construction projects are different, so environment is constantly applying new solutions. But innovative solutions not always lead to innovations as gained knowledge from one project are not always shared. It is rational for most of the firms to reject innovative technologies and managers this way develop inertia and resist eventual change. At this point young professionals can play significant role as most likely they would be exposed to new technologies and processes during newer education. They will be more up to date on innovations in industry than their managers. Young professionals are lacking sober wisdom which comes with experience and they will often continue enthusiastically endorse modern technologies in industry after seniors will retire. Ignorance of youth can be powerful negative force in adapting of innovations. Unfortunately, the image of employers in the construction industry are relatively poor one. As a result, construction companies often struggle to attract a talented and younger workforce.

Innovation igniters and tips to attract talents could be:

- In any industry, R&D development are the lifeblood. The benefits are long term, as cost arises in present. Despite the low margins construction organisations should commit to investing in research and development.
- The construction companies usually functioning in traditional environment and conservative company culture. Perception is that construction companies are not sufficiently forward-thinking, this should change in your company from next month.
- Each construction project have unique characteristics, but processes of construction itself are repeated in most of the projects. Lessons learned from one project often are forgotten and no applied in subsequent projects. Companies should institutionalize such processes.

Traditionally, the construction industry has not been particularly proactive in sharing and learning from its successes and failures. The lack of knowledge capture from previous projects results in ‘reinventing the wheel’ and repeated mistakes. Knowledge sharing also promotes creative thinking. Knowing what your competitors are doing, enables others to think outside the box and come up with better ideas, thus, moving industry forward. Collaboration between companies and diverse groups including academia, consultants, contractors and institutions results a faster draw of ideas development and sharing, that benefits all players in the industry and helps to move forward.

Managers are not prioritizing enough future of workforce planning and change management features in companies. Insufficient understanding of coming disruptive changes gives mismatch between magnitude of the upcoming changes to challenge them. Not depending on company size, need to take in consideration intentions to invest in the reskilling of current employees to learn new skills like BIM modeling, ‘lean’ process adapting. Start to get more knowledge about prefabricated modules building and automatization possibilities. Most important and basic skills are active learning of ICT systems.

In coming years to cope with possible employment challenges from some disruptiveness in industry, need to pursue a range of innovative workforce strategies, as provide employees a wider exposure of roles, make efforts in targeting more female talents, much closer collaboration with education sector. Role of HR function in company will rapidly become more strategic about innovative workforce skill-building. Companies can no longer be only passive consumers of ready human capital in industry, they should put talents development and future workforce strategies in front of themselves to have growth possibilities in future.

6.2 Recommendations for research

Researchers could make empirical estimates and formulas on how innovations impact and influence construction industry beyond this paper scope. Other subject that can be studied is how the different specified actors in the construction industry can handle different innovation processes in coming years. In addition, further study can more deeply explore modern technologies influence on humanity as nature of innovations not always have positive relationships with society. Investigating innovations in industry would help to tackle future issues like specific skills shortage and jobs displacement while adapting innovative technologies.

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8. APPENDIXES

Appendix 1. Interview questions

Questions for the construction industry expert's interviews:

1. How do you think, is It possible to innovate in construction industry, in offices and in project working sites?
2. Why do you think construction industry are one of the last in all industries according innovative processes?
3. How do you think, have been any disruptive innovations in construction industry in last 30 years, in your opinion? If yes, how do you define disruptive innovations in construction industry? Can it be in future?
4. Do you think innovations and technologies can help for construction companies to get a better result?
5. Have your company implemented any new innovations in last years?
6. What could be/are main drivers to implement innovations in your company?
7. If adapting innovations like BIM designing, incorporated pre-fab tools and planning, technologies like 3D printing, robotic workforce etc. do you think It can minimize human resources demand in office? What about project sites?
8. Maybe you have some innovation examples in past years how their changed labor employment?
9. How do you think, is it worth to invest in innovations and technologies in purpose to reduce demand on human resources?
10. How do you think, is It easy to implement innovations and technologies etc. in operating company?
11. How would you evaluate the innovations in Norwegian construction market?
12. In your viewpoint, what are the main challenges will be faced by traditional Norwegian construction companies in future? How do these companies could successfully overcome the challenges?

Appendix 2. Interview AF Gruppen

Company name: AF Gruppen

Description: Big - size, top 5 in Norwegian construction industry

Interviewees: Kvalitetssjef Ronny Liverød; Prosjektleder strategi og risikostyring Ole Blaauw Johansen

Time and place: AF gruppen headoffice, Innspurten 15, 0663 Oslo. 15.00 23.03.2017. (40min)

Disruptive innovations:

No, there been any disruptive innovation in construction industry at all till now. Any progress until first industrial revolution, what we basically done takin mechanism things, but we been part of third industrial revolute ,lean‘ and automation, that’s really not came fully in construction industry. What we seen now is that everything hits at one time like third and fourth industrial revolution hitting at one time. As soon as industry realize what going in around its basically our business model are analog information sharing, we take information on paper on one side and giving to other. So now on digital possibilities and tools, everything changes. I believe many new players will come and challenge us. Computers changed industry a little. We have an email, but it made for us even more paper work, less time on sites. Nevertheless, it is not disruptive innovation, it had not made any significant changes. Even you have BIM already long time, but you haven’t really seen affect on It. It is been little bit easier to shown drawings. First signs what is possible to do with BIM are automatic model checking with Solibri. It is first thing what actually reduced labor with digitization. My opinion it is not much been reduction in labor. It is even more administration. No, not yet any disruptive innovation, but we believe It will soon to come.

To innovate in future and innovations in industry:

Defiantly, it is possible to add innovations in future in industry. Like modular building, it is been small part of industry, but if you perfected way it is done and think of it as a traditional way, I am sure building can be one of the biggest innovations in construction. Also we look to what is happening with robotic and automation. It is huge potential in it, it so much manual processes, which could automated and they will. Not directly to our business, but you got people that do engineering part of the work, you can basically now receive programs who changes all engineers using scripts, in pre-design 3D models for housing or tunnels. Which you base on couple of input factors. In addition, like Norwegian company Spacemaker, who defines how you can best use to potential of a lot which you have, without any restrictions and how to

optimize it. Best lighting condition and etc. takin all different aspects to optimize your building before starting to built. Also how Smart house concept, while introducing house buyer earlier in process, already in architect step, I think industry will change here dramatically to more customer focused. Our industry are one of few industry, as we are not involving customers, until it is build. So I think with modeling programs we will visualize much better, and customer will be introduced much earlier in a process, definitely. That will be a game changer, definitely. Like showing ,Miles curve‘, world economic forum. Made a smile curve, where you have today's development where you assembly, sales and R&D. This is the profits. If you succeed. What we see, we are going to un-productivity, which makes not profitable. What need to do, in Norway we have oil industry which have one of the kind product, but construction are not. So, need to move more to R&D direction or to customers sales, optimization direction ,where you can influence customers needs.

Future prospects for industry:

People in this industry should be more terrified, how they work, because our industry are threatened. Most likely in future, our company biggest competitor will be not one of the already established ,entreprenørs‘, but some start-up with something on science, who will do construction not in traditional way. They gone deliver services on both sides, on R&D and customers orientated side. This will makes for them huge profits. Basically, will disappear commodity of people and managing them in a middle. Maybe one the biggest possibility in future will be delivering of supply chain, of transporting modeling building in the most efficient way. Nevertheless, existing robotic technologies are not disruptive technologies, they are not game changers.

Any innovations in industry in a last years, which ones:

No, there been any disruptive innovations in last 20years. Some innovations, good innovation, but far away from being disruptive. Like pre-fabricated bathrooms, it is been changing part of how you built, but it is not disruptive. Never shaken a business, the same as existing robotic, there is good innovation, but we still building houses in the same way.

Does innovation can help for companies to get better results:

Defiantly, using innovation can help to get better results and profit. By automating manual labor, you can save a lot of costs. For us and our customers it is very important and It will be a game changer. All players, can be on one side to make innovations.

Main drivers to implement innovations in construction company:

Main drivers behind innovation. Familiar point in construction industry that it is very slow. Need to show how profitability can change, drastically to push innovation. That is main driver in digitalization. Also there a possibility to enable a customer. Actually gets customers need to give some extra input, how projects can look, that could give a way to innovations. If some start-up comes to us, and says we gathering information that some people wants to live there, and give information where they want to live, this could give huge input. That is what is happening in one of our project, where customers challenge to save costs us from first step to last. So of course we need some profitability, so we need to find some new solutions. So when, customers start requesting innovations and challenging us, engineers are used to find good solutions, when good questions are asked.

Is it worth to invest in innovations for companies, in order to reduce human resources:

If you not invest, you will be one of the company left behind and will do only assembling work, left to die. If you invest money in R&D, you invest 70% of revenue in today's business, and 10% on long shots, and then it will give you this 75% of future revenue, so when innovation hits it can be really that little things you invested, will depend on your future business success and model. Traditional companies will have linear growth, but disruptive companies will have a long term growth. Also they can work abroad and worldwide, not only in Norway. If you get right product, and everybody will see a value in it and it can give a drastic reduction in costs, I am sure can be disruptive innovation changing all industry. This start up can get an immediately spin off.

How can change human resources on project site:

Very difficult to answer, what part takes human resources today, as we hiring mainly subcontractors. So automation and robotic technologies, will change human resources, what staff are doing now. Change will be as less manual, repetitive tasks, more value to the project. But, that will take longer time. What could take faster, to make off-site production That will happen faster, to move construction off-site and have robots in factories not on site. Important issue, are how to transport. But to mount in we will fast comparing in saving costs. Legislations and EU member countries in Norway. There is lot of Eastern European workers coming to Norwegian market. That is being much more influential than innovations themselves in Norway construction industry.

How can change human resources demand in office:

Can change human resources in office drastically adapting new tools. In office also, could change a costs by introducing new tools and biggest costs now are in management

Is it easy to implement innovations in technologies in operating company:

Changes are always difficult, and specially in industry which have not changes in generation. Changes are almost one of the most complicated thing. But my impression are that many workers in industry now agree about need to change, so I think there is a burning platform for changes. There is a big knowledge, that things should change soon, but of course changes are always a challenge and complex thing. The management in our company always looks for innovations. Need to show examples, and to show that there is a need to change.

How you value Norwegian market in innovations:

Happening not so much in Norwegian construction industry, but to compare with other countries are pretty ahead then many others. At least we are exploring these thoughts and ideas how thins can change. Of course like UK are pretty ahead, USA might be similar, difficult to say. They very much depends on what they do. Like Denmark are like 8 years behind use of BIM, it depends a lot on countries. But in global perspective, if we will see disruptive innovation in industry, I think it will come from some countries in Nordics, as here human resource are expensive, so specially digital innovations are not so relevant in low costs countries.

Challenges for traditional construction companies:

Foreign companies, being draw by big governmental contracts. So it could be big challenge for existing companies. To say that disruptive innovation will hit construction industry, it is not what everybody will say and not much people even think about this possibility. So more common problem are seen as foreign companies, that is what many local companies will focus on, to improve to met and be compatible with these coming big foreign companies from abroad. So how to improve and implement small incremental innovations inside companies, like existing drilling robots. Nevertheless, it is not scalable, as it is only one operation in construction site, so it is not disruptive innovation.

Appendix 3. Interview Veidekke Entreprenør AS

Company name: Veidekke Entreprenør AS

Description: Big - size, top 5 in Norway construction industry

Interviewee: Forsknings- og utviklingssjef Sigmund Aslesen

Time and place: Veidekke Entreprenør AS head office, Skabos vei 4, Oslo. 15.30 04.04.2017.
(40min)

Innovations nowadays in the construction industry:

Most related and used technologies now day are use of ICT software and in some projects using BIM. We use that for several purposes, one thing is of course are visualization component, and probably the main importance of using BIM, as well as in every project need one common carrier of information, because typical traditional projects we have a lot of information going and use lot of different templates, and software's. So, to have one single source of information , we have a BIM modeling. We are now started using BIM modeling from development of the project in early phases and all way through, to the end then process are finished. Clients would like to have some documentation of everything that has been done, and they can use for service later and prevailing after, so BIM model are very useful for that purpose. That include typical more information, that we would have usually in production phases. We using a gliding concrete technology on project Munch museum, it is needs a lot of good planning and delivery 24/7, but still all process are so innovated as used a lot of man power. The greatest achievement there are in planning of all process, not in gliding technologies it self as it is not so sophisticated. BIM could help for planning even more. We have one project were we planning to use censoring for materials tracking on site, transportation of materials censoring and even some 3D printing. For transportation, we use some we based solution to handle all material and transportation while having a censoring. That is really a challenge for transportation, when comes a lot of deliveries.

Are discussed innovations reducing human resources costs:

Oh yes, It is already doing know. All parts of the building are in one place, it is easy to structure and standardize, as our production it is usually not so easy. Like working on site there are weather conditions and all sort of it. As building stand in one place, you need to developed all production outside a project site. This can be achieved by industrialization. We use a lot of prefabrication elements in projects and it comes a lot of innovations from it and saving costs. Whole elements of wall, ceiling, slabs coming as modules. It is related in prefabrication, but I

think it is more modularization, like using bathrooms cabinets. Like in Oslo we have a lot of apartment building we developed, and the we have like 200bathrooms, then it makes total sense to use prefabrications in bathroom cabins. Some people are making statements about our industry that we are so behind, and I say also, but they are forgetting that we are using a lot of prefabrication, modularization, are quite far in terms in digitalizing a lot of things. Nevertheless, when all researchers talks about our industry, they still saying as one of the least innovated industry.

Disruptive innovations in the construction industry:

Defiantly it can happen, like 3D printing for example, it is already are in some places in use like bridges printing. So of course. Some parts could be 3D printed, and it makes total sense. I guess, we will see are lot more of that. When it comes to 3D printing whole printing, I am much more skeptical. Like in new project Munch museum, we use simple solution. We using gliding concrete technology, effective and high speed. So, instead of people poring concrete, you can image 3D printers doing the same. But I am skeptical, if it could be cheaper to use 3D printing instead of manual work, if you will build 10 the same museum maybe, but we building only one. But if there are repeated manual work, so I am sure in future will be robotic power to change that. I know that many companies in Norway already are using robotic power to drill holes. I think it is a marvelous technology, but I think it could be better innovation instead of having a robotic on site, to have a supplier delivering those modular systems already with made holes, before delivered on sites. So robotic like this they can have in factories. But I think an operations which are large and repeated we will see a robotics ben used. Like putting a light walls, we build a lot of them, and I believe it is should be no so hard to developed some robotic to mount a walls on a place. And then it can work like 24/7.

Driver to implement innovations in company:

I think you will see more prefabrication then we have today, all parts and different parts. Will be whole buildings raised by modules like by complete apartments. Typical like for student condos and etc. In USA they already using whole modules building for student houses. The main factor for innovations are to safe a costs. Like using models to build an apartments, can be difficult to convince a customer. Because all clients wants to have something special, so to convince them can be because of lower costs, as it will be needed less manual work and production will be faster. Using all different tools to shortened production process. More modular process building then now. Yes, you have to invest in innovations. But still need to convince a client that in this project we would like to use something new, so we will invest a lot

of effort in it. Typically, we have a huge projects, were we us some innovations and test different things.

Reduction of human resources:

Because of prefabrication will be lower demand on human resources. Like using bathrooms cabins, how much labor hours we are saving in comparison with traditional building on place process. So, when delivered cabin, you are get rid of all those people needed to deliver bathroom on place. The gains we definitely have, in higher productivity. But it is difficult to capture different productivity percentage. However, when we use modules, there much better productivity, so on site there is much better productive gain, but on the other hand it is not measured as a gain in statistical measurements as in this way all work goes from building sites to manufacturing factories. The same counts for prefabrication. So for sure, we can not called it disruptive innovation. It is even a huge problem, we have a lot of improvements on modulization, but productivity in total will stull fall, because all manufacturing are still in factories.

Evaluation of Norwegian market innovative processes:

We are the biggest contractor in Norway, so we should be in a lead and we have a huge responsibility in terms of pulling an industry forward. We hope that our innovations will influence a lot of other subcontractors and that they will use some of our concepts themselves. But all innovations now, are more process related innovations. We have initiated a lot of R&D projects in recent years and still do. It is not like we been the one and only contractor who is done that, but we been quite alone. But now there is more contractors coming, initiating different research projects and it is positive. I think it is positive trend now. Also most of our innovation we sharing with our competitors. I believe if several big contractors will use the same innovations, then subcontractor in other project will now this innovation in other project. I think the more you share, the more you get.

Challenges for traditional construction companies in future:

Of course, some company with disruptive innovation can overcome us. It can be some upcoming start ups, not necessarily being start up by people from industry, but can be from other industries, typical young people. And having new business models, like complete modules systems taking all market, then we will not have any chance. It will be not standard building company to overcome, because need lot of investment, but a start up with one process selling. Like modules can be build all over the world, like in India with cheap labor and then been sold

in Norway market. So time to time, I am wandering, then this company can come, because I am sure it will happen. So, like Veidekke can be to big to turn the same direction. As Veidekke, have all sorts of different markets in construction and it will be hard to standardize and industrialize. So in this market, it is difficult that will be some disruptive innovation, more common are that it will come some disruptive company and will change an industry.

Appendix 4. Interview with Kruse Smith Entreprenør AS

Company name: Kruse Smith Entreprenør AS

Description: Big - size, top 5 in Norway construction industry

Interviewee: Utviklingsleder BIM - Gunnar Skeie

Time and place: Skype conference. 14.30 28.04.2017. (25min)

Innovations nowadays in construction industry:

Yes, of course. It is possible to innovate in any industry. Potential are a lot lower in our industry than in other industries, but there is innovations in construction industry everyday. There are digital tools, or tools that you use on site, which will lead to innovative method or process. I agree, that construction industry is probable less innovated than other industries, maybe it is because low margins of the industry projects. Huge projects are huge, and if you make some mistakes, you can be in really serious problems and innovations are always connected to risk and uncertainty. So, if you are connected with your margins your ability and motivation to innovate are lower.

Any disruptive innovations in industry:

There has been no disruptive innovations in last 30years. We have not seen that yet, as some innovation have changed market or removed biggest players from market. Nevertheless, I strongly believe that It could come some disruptive innovation in future. Innovations can give some better results in now and in future: Yes, defiantly. We have implemented several innovations in last years. Like BIM, virtual designing construction, using lay our straight from the model, collision checking. We have innovated our processes and changed our processes a lot, because of the new technology and new way of doing project. There is some examples already of 3D printing, so it could happen this technology also.

Innovations reducing human resources demand on sites:

Probable nLink drilling robots, that we tried. Only way to move forward are using modules and prefabrication. I think It will be a major part of the project, as consist of prefabrication, a share of prefabrication will increase. Project by project, and year by year. To compare costs if you building on site, versus if you have 300bathrooms as you order like cabins prefabricated in factory, to compare prices and time need to install on site, it is huge difference. And speed on site will be even more important. Transportation also huge issue, one of the constrains of

prefabrication. Like off-site can be very close to project site or can be on the other side of the world, it deepens on transportation method chosen and finally total price.

BIM modeling technology, reducing human resources demand:

We have not seen that yet. Probable changing a project, when we need more resources in design stages. But we have not seen a reduction of man hours on site yet. On designing, there is hard to say, because already today there is no design which not use BIM, so there is no alternative not to use BIM. Soon will not exist any projects which are not using BIM. It is impossible to think that there is future in 2-3years as projects without using BIM modeling, it means even small companies should use BIM modeling in office or on site with Ipad for BIM viewer. Already now, almost now new projects without that. Also BIM modeling, are connected with robotic technologies like nLink. All industries are made from digital planning, like car industry and similar to very detailed elements. There is no reason to think that this will not apply to construction industry also.

Are you requiring subcontractors to use BIM:

Still not, but It will come soon.

Drivers to implement innovations in future:

It comes bottom-up, not top-down. Yes, we are ready to implement innovations everyday. Main ultimate drier for all innovations are saving costs. Building project faster on site, probable are most important factor that we see. Management in our company understand need for innovations, but It is not easy. Any change takes some resistance. Mainly, nobody wants to change anything. Only the results can convince managements to make a changes. Usually all changes need some investment in front, new technologies, and this always brings to uncertainty, will I get my money back and this makes implementing of innovations difficult.

Challenges for traditional construction companies in nearest future:

It is impossible to predict future, but I sure that company which do not recognize innovation to a solution, will run to a problem very fast. I believe there will come some company who will really crack the code how to make money with new technology and method, so if you will be not in to It, you will be left outside and your market share will shrink accordingly. Yes, so disruptive innovation can happen in this industry, like one company who will come with some interesting and disruptive technology. Nevertheless, very difficult to predict what will happen

in future, there is huge possibility in having coming technologies, so very difficult to say how industry will change

Appendix 5. Interview HENT AS

Company name: HENT AS

Description: Big - size, top 5 in Norwegian construction industry

Interviewee: Utviklingsdirektør - John Ivar Myhre

Time and place: HENT AS head office, Oksenøyveien 10, 1366 Lysaker. 15.30 04.05.2017. (35min)

Innovations in construction industry:

Need to think in a new way, out of the box, to destroy little bit traditional thinking how they are building today, and we already doing in many ways today. We use a lot of theory from 'lean' construction but trying also to challenge even more. 'Lean' thinking can be adapted in construction industry pretty well, about fundament of 'lean' construction, but we are trying now to look if there is more possibilities to include even more theories from other industries. Like design management can be from model, need to think little bit not traditional. We like best to do what we use to, we are not so good in changing in big companies, because it is very difficult. 'Lean' are known many years, but just now we are taking it to construction industry. But for example, in some countries it was started top used much earlier, like Japan, but of course Japan it is also much bigger in inhabitant's number around 200millions, then Norway 5millions. The land itself are not big, so for example Toyota factory they are making a car and then should send directly to customer, simply no place for storage new car where customers can come to buy a car. And they cannot make it wrong, are dependent every time what customer will want and deliver only what customers are asking for. So much more customer focus view. In Norway, construction industry is protected by oil industry. So, we are not so pushed to innovate, because we already have very good environment in this industry. In other industries which are selling specially abroad are much harder, for example Norway was leading in sun panels manufacturing before 10-15years, but then in China government started to subsidize this manufacturing. And because in Norway salaries are much higher than in China, this company in Norway supposed to lower their costs and innovate and finally to dislocate in Singapore. Simply they become not competitive. So just image if the same can happen with Norwegian construction industry, if suddenly can come some Chinese contractor with innovations and will take all market. Of course, It is not very easy to come from foreign countries to Norway, because of all rules and environment we have and different culture, so not so easy to come in but on other hand it is a threat. So, It can be that we are least innovated industry because Norway do

not have some much international competitors in this industry in Norway and because we are protected by oil industry.

Disruptive innovations in industry:

No, I do not think that it was any big disruptive innovation in construction industry. Not in the same way, like taxi industry was changed by UBER, not in this level. Nevertheless, I am little bit afraid that it can come some actor and will take all business in this industry in their hands. And for example, our company, are leading subcontractor's companies to make profit, and then coming some app who can do the same functions as ours and takes all our projects. Of course, they cannot lead projects, but in theory it can happen and can be big conservancies. I think that now are most interesting innovation BIM modeling, what is taking all information in one place. Let's say in our company, now our disruptive innovation are how we are adapting quality insurance system in company, that we could deliver right quality, all system and processes and how to learn from done mistakes, I think this can be little bit as a small revolution, if we will manage to adapt it, because customers are very concerned about quality, and we will not earn any money if customer are not happy. So, it can be very good innovation, if we can adapt this process of how other subcontractors can deliver best quality for us. Now BIM tool of course are innovation giving very satisfactory results. Gives full understanding how we need to build. It is like a bridge between digital construction site and physical construction site. Need to build firstly digitally correct, and of course giving less mistakes and shorter building time. More time to plan and understand. I think we implemented BIM very well in our company and we are pretty advanced in industry. Also, there is learning machines, which can see a future according input data. If it is a lot of deviations, it helps to show predictions according registered input from projects before, how much can be solved according what types they are. And then estimating a risk, to be finished on time. So, using of digital estimating models to estimate and predict how future could be.

Drivers to implement innovations and future of industry:

Industrialization can change our industry. I believe we could see much more robotic technologies in building processes. I believe we will prefabricate much more for buildings, and building place in future will be more like mounting, not like building place. Like today we are buying baderoms cabins prefabricated, which need just to lift in a place, it will be much more like this Lego building. To make it all processes easier. It is not easy to implement technologies in company. People do not like changes. How to motivate these changes, to explain why and

how innovation will take us. I think it is some difficulty in our company about understanding of innovations installing. It need to work from background and explain simple questions like why.

Innovations reducing human resources demand:

I believe yes, if to start with project sites, it will be more wealth creation by building off-site, not on building site. Will be made in production factory, and like plumbers will come with much more prefabricated product to project site. For example to build wall on place, will take to long time and details, much more will be taken from building sites to prefabrication, so of course man hours on sites will go down. In offices, designing will take more time, more people, in intense phases. Different from today, like taking to long time. I believe that standard administration still should exist, or maybe robots will change them, I do not know. I believe that because of BIM can work more engineers with it, 'lean' for example will change organization understanding and responsibility of all purchasers, engineers, but it is more for directed to customers. Of course, if we will understand and execute better, then our human resources will go down. If all processes will be optimize between each other, then it will be needed less labor because of better efficiency. But all in all, digitalization and technologies for employment also depends on size of company.

Innovations in Norwegian construction market and future challenges:

Bad. I know there is organization Bygg21, they are trying to innovate and reduce costs by 20% by 2020 in industry. To build more clever, cheaper, faster. I believe it is organization which is trying to change some. On the other hand, it is a chance to us to innovate and grow. Are most interesting are how to get best result in shortest possible time. As myself I see challenges in how to make better value, like our company we are only hiring subcontractors who are building, so it depends how we are motivating them, how helping we to subcontractors and cooperating, and respecting. I believe in general we in industry more be more respectfully. Price level of course are high in Norway, so international purchasing are challenges. I believe we are good, but can be much better in Norway. Like to think what I can do every day to be better, it can help to focus mindset. How to think every day to be competitive in industry. It is very important people in companies, and I believe in robots in faraway future, but despite people will always manage, so depends how we talking with each other and working.

Appendix 6. Interview nLink AS

Company name: nLink AS

Description: Robotic technology manufacturer in construction industry, in Norway

Interviewee: Project developer Konrad Fagertun

Time and place: Forsikringspark, Gaustadalléen 21, Oslo Science Park. 15.30 05.04.2017.
(30min)

Innovations today in the construction industry and in future:

Use of prefabrication and now more and more modules like bathrooms and kitchens, elevator shafts. I think that will change a lot and also will reduce on site production. Also, there can be a prefabrication near project site, like specially build elements and then vastly delivered and mounted on place. This also reduce a labor need. Like only left work for final connection. Also we can see prefabrication like for sprinkler pipe, precut in right lengths do not need workforce on site. I think we will see more of that. And to look more to he future ,we will see a robots on project sites producing and mounting, also 3Dprinting even further in to the future. But for now robots like our doing small specific works. We know robots development of different parts like tiling, painting robots and many other tasks. Also there a in creation of more universal robots.

Is it possible to innovate in this industry:

Construction industry have not been very good in innovating, so it a lot of space to do that. Like tiling for example, it is been already 3000 thousand years the same process, as romans been on their knees doing the same way as today. Just a few years ago people use only nails and a hammer. Now automated, but still one man, one tools. It is not enough innovation, in other industries are much more innovations like cars industry, you can see fully automated, even in farming are innovations, like they are using robotic power. So, in this way construction industry are very old fashion. It is strange for me way so slow. Maybe because one of the biggest industry in the world with millions people working in this field, so companies are not bothering about lack of employment. And people do not want to pay for innovations more, we just use that building takes a lot of time. I think it is kind of strange, but now are demanding more and more lower prices and faster building time. In Asia, they want to increase productivity, less people on project site. They are stopping to hiring people from abroad, now they trying to use machines instead of people power from abroad, they are pushing innovations a lot. The kid who grow up now, can easily use computer for drawing, then to use paper drawing. In future for project

leader will be much easier to talk with one IT guy who will manage robot, then now to talk with 10 carpenters. Also robots can order materials themselves. For now all construction workers still will have work, but I think in 50 years, there will be not needed so much construction workers as today, they will be needed to find new jobs, but now it is impossible to know what these new jobs can be. It will be a lot less needed educated builders. However, in nearest future, I think we will need even more construction workers because now digitalized planning and designing goes faster, so people can start fast one project after other, but in future will be needed less. Like if to go 100 years in future, maybe we will not be needed any workers and even not any architects, as robots will design, plan and build, but it is very far away.

Disruptive innovations in industry:

I think start up companies can overcome existing traditional companies. It will not change much how we built, but will come one company with new ideas or robotic power and just win a contract. If you can get the same house cheaper, why to buy from old contractor. In the end it is only a price what people think about. Today are people still cheaper than robots, as using cheap labor force. But prices on robotic and computers prices going down, so when robots will be cheaper and they will be easier to compete with humans. Robots can work 24/7, so investment will be very good on machines. Prices need to be competitive to robotic innovations happen faster and it is coming. Also all industries are conservative.

Future of robotic technologies in construction industry:

We are already out in industry, we drill from BIM and customers can put information to an BIM and take coordinates to robot and then he drills according that. So, it is a total solution for planning. So we after done holes, we can put in back to a BIM for future. People are already hiring us, so we believe we already started a revolution and we expect a competition soon, like in 5 years. I believe in 10 years we will see a lot of robots on construction sites. Especially, like simple robots like ours. Robots which can carry stuff. We will see an automated cranes to carry materials. A robot who can carry materials, because wasting an electrician time for carrying rubbish, it is waste a talent's time.

Innovations changing human resources:

Of course, this moves people to planning and observing, monitoring, and not so much in lifting and hammering on project site, as all this can be done by robots. So we need to focus on 3D, BIM and digitalization. BIM technology, biggest innovation in last 10 years: I think it is BIM

and will be in next 10 years and use of it. Each hour you using to plan with BIM, you save a lot of hours on project site. And logistics can be planned according BIM. So much easier can be planning using BIM and robot after all, less time, less logistic problems. People like to do changes, so changes are easier when presenting like 3D models with BIM. I think this will push to competition to people who knows how to use BIM will compete much better against who can not work in digital world. Now, one person can do more with one Ipad then 10 guys with a papers.

Robots reducing humans resources:

Easiest is to look on time savings, now we are saving a lot of time. Record for us now, for measuring and drilling are 120 holes in one hour. In best case human power can do 20-30 holes at the same time. So it is like 5 times faster. Now we saying we can save like 2-5 days for drilling work per 1000m². So if you building like hospital, or commercial building, using robot drilling, you can save some days and be finished with project faster, so we definitely we see increase in speed. Anyway, other benefit are that robots are not taking any shortcuts, it does exactly what says BIM inputs about ventilation and electricity, as robot will drill all needed holes, all in correct depths. So, it like safer work space and better quality. Healthy of worker. Like last project was drilling 5000 holes, so it is big job for people, but small work for us. And you can imagine, in big projects it can be like 100 000 holes. All process are planned in BIM, so less work for everybody. We see a lot of benefits for all subjects on site. We still developing different prototypes and ideas for drilling.

Investment in technologies in this industry:

Yes, and now more and more doing that. Now, almost all started to talk and use BIM. Development are slow, as software and computers, I pads are expensive. I think they are not doing well

Innovations implementation in companies:

No, some of them are afraid to learn new technologies, afraid to learn BIM. They lough about robots and think it is far away future. People are little bit afraid of trying, but companies which try, they learn pretty fast.

Evaluation of Norwegian market in innovative process:

I think Scandinavians are far away in use of BIM comparing with other countries in Europe. Also UK, USA, Australia are going at the same speed or even faster using of BIM, but still many

years for the rest of the world. Nevertheless, I believe they need to invest all profit to innovations, because it will come other companies from other countries, who a good at that, then some of these giants will wake up and will see out of business and will will happen to many of them. They just working the same way all the way, but one day some new technology involved company will come and will take a market, and then to late are start to learn what is digital solution, robots, it needs already now to practice and invest. Companies are becoming much better in BIM, in choosing subcontractors, better collaborating. I believe companies which will not be in using newest digital solutions will be finished. I do not think that it is much innovation in Norwegian market. We are not using the latest technology in construction processes in comparing with UK for example, so I think we are not so good. Specially, when we hiring workers from other poorer countries. The oil industry are much better, there are rule that they should use newest technologies in that industry.

Biggest challenges for traditional companies in future:

I believe in nearest future, traditional companies will compete with companies who using robots. Like architects will ask more demanding projects, and robots could make it, but humans will not be able. Small companies with robots, can be better then even large companies from abroad. You can program a robot to the best in one field, so if ou have the best productivity in one field, you can compete so much better even with big companies. So they should be afraid of small innovated companies, they can come from Norway or around the world. And it is happening everywhere.

How to overcome these challenges in future:

Do not build like our fathers does, try to search for innovations. Use BIM modeling. If you will not be able to handle BIM modeling, soon you will be not able to compete. If you are even a small electrician, if you will not know how to use BIM, you will not get a work with Skansa for example. They already started to demand it, and much more in nearest years. Around BIM will be connected everything including time. You can go to PC and see latest version and find and answer how to built. Everyone need to learn this, not only for planners or architects, but everyone, all workers and subcontractors. It is so much possibilities with it. Even like people planning, robots monitoring from office.

Appendix 7. Interview NTI CADcenter AS

Company name: NTI CADcenter AS

Description: Autodesk, biggest software developer/seller (AutoCad, BIM) in construction industry

Interviewee: Senior salgsingeniør og 4D spesialist - Pål-Aksel Sletteng

Time and place: NTI CADcenter headoffice, Malmskriverveien 35, 1337 Sandvika 15.30
27.04.2017 (30min)

Innovations today and in future:

In a future, I think more labor hours will be with robotic power and outside building site. All construction will be more like Lego system, and automated processes like concrete, will be done automatically, like with printing. Printing whole concrete with 3D printers, I think that will be a future in some years. And of course, the more information we can bring to a BIM model, as early as we can in a process, will benefit all these automatic processes. Like 3D modeling with a lot of information, lot of details, as correct as possible. Building site will consist more with automatic help, not like labor manual work. Will be like ship in to it, and construct on place.

BIM technology in industry:

3D models exist in almost all projects, but information in these models should be input. We are now having program Synchro, which also adds time to 3D and makes 4D, for planning. So, fourth dimension is time. This is reach in 3years. From today until that goal, as architects wants to be like that will be 4D with added time to 3D. Then model will be as build, and will be divided to a objects. And object, will be divided in sections and how will be build later on. All this information will be available soon and used on project sites. This information could be used later in maintenance and if it is prefabricated elements, then also connected with transportation.

Future of BIM adaptation in whole industry:

Yes, for sure. All information will be in a model in a future. Subcontractors will get all information what they need in models. An they can collaborate in cloud based solutions between more and more, on exactly updated documents and models, newer then could be printed drawings or information. This will be for everything. I believe in 3-4 years, we will have a lot of new ways to collaborate in a building processes. And all processes will be more like separate

teams doing works, companies will be working together, engineering together, on cloud based platforms. It is already possible to see some projects this way today, while big companies trying to include expertise from subcontractors in early stages. Everybody will work on the same models, schedules etc. We want to have one place, where all players in project can search for information in one model, so of course model should be also as correct as possible and used many tools to do that.

Human resources changes in office and on-site:

It will increase labor hours in office, because you need engineers to put data and want to make a model as good as possible for building later on a site. You need to put more hours in to planning and engineering resources in early stages and get it as correct as possible. That later on project site will be clear how to build everything and not need engineering help more

Main drivers and implementation process of innovations in construction companies:

It take some time to convince management. Because It is a new way of thinking and doing, not so easy everybody to get on the same page. But when you get that knowledge in a market, in a building industry, It will easier and will take less time while talking with management of companies with specially those who do not use BIM modeling today. There is been many presented positive results. Companies which use 4D modeling, can see benefit in reduced building time – so reduce costs.

Investments in new technologies for construction companies:

Yes, if you don't, you simply will be excluded from new projects. Owners paying for making modeling, so they want that will be used after that. And you will be excluded from these projects, it is already happening when specifying for contractors and subcontractors. If you do not know about technology and modeling, you will not be able to get project.

Evaluation of Norwegian construction industry innovative process:

Some of companies are very early adapters, some of them are interesting in whatever it is new. Those are the biggest companies in Norway. Many other specially medium size, are much more laidback and scare to invest, but I think then whose youngest engineers in companies are getting more responsibilities, there will be even much more bigger changes.

Overcome future challenges for construction companies:

Challenge will be what architects and engineers put in modelling, according what customers asking, and now most of clients are asking that, so if you do not use that on building site you are simply kind of lost in a chain scope of work, because you have to use those tools in order to work as subcontractor. Lot of man hours are used and paid in planning phase for planning, engineering etc., so if you can not use it, why they paid in first place? Now biggest companies started to use newest tools, but process will be like a circle, it starts like idea, architect decide on design, engineers estimating and building owners saying yes. You start to build, and if you not use that information for what customers was paying for at a building site you are out of play. Because customers also want to use all these information later for maintenance, service etc. So customers telling that it is model, how it is plan, please use it on site. So, if contractors do not want to engage in BIM, will be simply left out and will not get a job. Old 2D drawings and text documents, old planning like did many years before will not work in future for construction companies, they should adapt to a future processes.

Appendix 8. Interview Staticus Norge AS

Company name: Staticus Norge AS

Description: Medium-size construction company and glass-steel for building facades modules manufacturer

Interviewee: Fasade modules avdelingsleder - Modestas Midveris

Time and place: Staticus Norge office, Henrik Ibsens gate 90, 0255 Oslo, Norway 16.00
12.04.2017 (45min)

Innovations today in construction industry:

Everybody are concentrating to do more work on factories and just to install everything on a project site. Then you can be much faster and conditions are the same in a factory. Our fabric doing complexly finished product and the shipping to project site, and then we saving many time on labor at project sites. Also all technical things can be done much better in factory in almost perfect conditions. When we producing elements, some conditions in factory can be even like in surgery room in no air conditions. And then just shipping and hanging in project site. No we getting more and more inquiries on this, because after need much less finances on maintenance. Materials are also created much better every day, more friendly to environment. Construction on site it is still standing in place, they creating some robots to work different works, but not system, mainly because of we are not building the same buildings shaped always. If we will have the same houses always, you can optimize robots to make the same action like hundred time. No most of the buildings are different, from architecture to materials. That's why I think innovation are little bit slow in this industry.

More innovative processes in future's industry:

As every project are different, as architect want some new and different things. Yes, it is possible to produce faster but I think we have reach some sort of limit on project site, I think maybe we reached a limit for know for human power. But in office, we are trying to improve. We are not printing any copies anymore, everything checking on computers and then sending direct to machines and robots to cuts, no manually input needed. If for all project will be needed the same modules, then possibly it innovate new machines for sure.

BIM and other innovations in company:

Our goal is to use BIM in all of the projects. We are educating engineers to learn modelling. In factory, we already sending all information to robots from BIM. Also you can calculate all information from BIM, how much screws, elements you need also on site, so It means less error, exactly measures. It is great step for us and we believe we are leading in this field. It is fully connected between BIM and prefabrication. I think It is amazing technology, you can do everything in BIM, calculate, take information etc.it is much more innovated when 2D modeling and AutoCad what was 5-10 years ago. You can see all connection between plumbers, electricians, builders in one model, so nobody will mix on site. It takes some more time to input, but less on site. In office it takes more time at first stage, but in sites and for robots it is much less time. It makes much better financial results, our company now investing mostly only to IT. To new computers, Ipad for mounters to check everything on a place, they could make checklist on a site at the same time. If he will make any notes, everybody getting this note instantly. Now we are planning all works before the schedule, that everybody will now before on what day, what will be performed – to avoid errors on site.

Drivers and difficulties in implementing innovations in companies:

It comes mostly from architects, as they started to use BIM modeling, and then started to demand to use it from contractors. Contractors will start to demand subcontractors and etc. And more and more is more clear how it works and it helps to work faster and adapted with robotic in factory and human mounters on project sites. You can see all details, all subjects in one model.

Human resources changes on site in last years:

Like 10-5 years ago all the work was done on project site. All facade elements piece by piece, frame by frame. Everything was constructed on project site glass, aluminum everything, there was no system at all not in our company, but also not so much around. No we all doing on factory in modules and trying to make as much as possible more, lot less working time on project site. It is cheaper for customer also, as we manufacturing now everything not in Norway. We have in factory cheaper labor then in Norway, so we do all engineering and works on factory and sending directly to site just to install it. It means, we need much less workers on project site, but more people in factory. And of course already now, and in future we will use more and more robotic technology like cutting machines, they can perform in couple of minutes. Of course most of project are different, but still we trying to program some system to make the same elements. Also on construction site we using already special lifting robots, to lift modules

to a place on a wall. When using modules, also building can be sealed much faster and inside works can start faster. Companies are investing a lot in machines and robotics for factories.

Human resources changes in future:

Yes, in 100 years for sure. We already use 3D printers in factories to print some small elements, so maybe even in less years all houses will be printed on site from created models in BIM or similar platforms. I believe we will get everything from printers, even plumbing and electricity printed. In the nearest future, I think we will need less low-quality people, but much more high-skilled people, IT personnel. Everybody is scared that we will lose our jobs because of robots, but on the other side will be created much more work for engineers and IT persons.

Investment in new technologies in companies:

In order to lift productivity, we need to invest. To get better conditions for workers. Like investing in 'lean' thinking it helped to reach almost 50% raising in the right way of managing personnel. The same way now we see in BIM adapting. I think if we will not be investing in robotics and BIM in last years, we will be losing now projects for competitors. Using modules you can deliver works faster, and that saves money for contractors. Firstly, I have not believed so much in 'lean' and BIM, but after starting to use, I see how much value it gives for me to work.

Evaluation of Norwegian construction industry innovative process:

Last few years all biggest companies use BIM, also many starting to ask better values for modules, environmentally friendly modules, elements with solar power, green technologies are coming and Norway are starting to use. It depends all on architect vision, and they are speeding a lot of more for innovations and special requests.

Challenges for companies in future and how to overcome them:

It will be a difference between companies who work like past 10 years, and innovated companies who invest in technologies now. Companies should even more somehow to reduce hours on project sites. Like painters, other manual work should be minimized. Productivity should be raising up. The main challenge is to give good price for customer, and second are technologies. And finally how to give best possible technologies or modules which could lower down maintenance after project are finished.

Appendix 9. Interview Klima og Bygg AS

Company name: Klima og Bygg AS

Description: Medium – size construction company, renovation and new buildings

Interviewee: Daglig leder Jonas Ask

Time and place: Klima og Bygg AS office, Enebakkveien 304, 1188 Oslo. 13.00 11.05.2017.
(30min)

Innovations in construction industry:

Yes, specially for office and in design phase, maybe not so much construction stage in renovation projects. You can do much more on construction site, but more for new building. You can innovate new products and new solutions, like how to mount walls and facade, and also technical installations, there is a more possible to do with installations, but it is much more easier to do innovations with new buildings, then with rehabilitation projects. Yes, I agree that construction industry is one of the last to innovate. In Norway, if you see some of the technical groups like electricians and plumbers, they are coming a bit further then the rest of the branch, because they been better in working in a join co-operation, even different companies, to find standard solutions. Like buying from one central supplier, more electronic solutions for ordering and supplying. Like ventilation companies they do not have this, because they are not cooperating, each living in they own areas and not sharing they ideas. Demand on efficiency and costs, push innovations forward. I think 3D printing will have challenges, specially with rehab, but for building new ones, I think they will find efficient printers to print steel and concrete. No it is simple solutions, but in future will developed.

Disruptive innovations in industry:

No, I do not think, there been. In future, I believe It can happen. It may come some disruptive company, very efficient which saving costs. Good and smart solutions are pushing us forward. There will be some shaking solutions and companies will use them and will win against other companies in industry.

Innovations benefits to companies:

Yes, in every level. Our company have not implemented so much innovations in last years, but I believe we are in place that if we want to win projects in future, we should find a ways to find good solutions how to reduce costs and build cheaper. The key are to be one step a head of

other companies, that we could win competitions against them. I think in almost everything a future are in prefabrication, now you have walls, slabs, but in future will come prefabricated also things like ventilation. Competition in future will make changes. There will be standards, and like ventilation will be standardized, so it will mean also cheaper products. In the end price is most important.

Human resources changes on project sites:

Then innovation will be good solution for companies and customer, in the end for workers, maybe another different types of jobs, that is a convenience, they will go to work more in factory. On the other hand, in factories you could use in future more robotic power to build. I think new educated workers like carpenters should more focus to work with computers, not learn carpenters specially. In hundred years we will not have construction workers like we have today, 3D printers and robotic technologies will change them. Finally better productivity means less human resources.

Human resources demand changes in office:

I think in office humans resources can grow, but on other hand it is also coming many innovations in office connected with computers, like for administration, for accounting. But it is a huge question I think for the world and for the humans that we can come to situation, that it is not needed all those jobs, because you earn the same. So if you solve this challenge that you do not need to work, but you can earn, maybe you can have some other types of jobs, like for environment and community. Can be more in healthcare. However, it would be said world if we will be talking only with robots, I think will come so also new jobs, but completely new which we do not know today.

Drivers and difficulties to implement innovations in companies:

No, it is not easy. You learn all new thinks. You meet a lot negative thoughts, why to change if everything works well today, but the key are to get understanding why we have to innovate, why need to be more efficient, but it a huge job, not easy. It is easier for smaller companies, if you get the management on board, but still there is challenges. Usually in smaller companies managers are also owners, so they will work max 10 years more, they maybe do not want to start processes now to innovate. So, they should move out from management to board rooms. Competence on minimal level needed to manage, to implementation new innovations can be big difference, because some older owners, can even think innovation how to change a line in Excel,

because all the life they was working only on paper. It is better then coming demand from architect or owner.

Evaluation of Norwegian construction industry innovative process:

I think in Norway it is a head within HMS and document preparation and building rules. I believe in other Europe countries are less demands, then in Norway like TEK10, TEK15.

Challenges for construction companies in future and how to overcome them:

I think it is important to succeed in future, you have to get younger people in the management in early stage, it is also good, because you can have experience, but also hungry engineers who wants new thinks, and new technologies to adapt.