OULU BUSINESS SCHOOL

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DIGITALIZATION OF A MANUFACTURING FIRM AND UNDERSTANDING THE CHANGE THROUGH FAMILIAR AND UNFAMILIAR MANAGERIAL PROBLEMS

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ABSTRACT OF THE MASTER'S THESIS

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Abstract

This study focuses on digitalization of manufacturing industry, commonly known as Industry 4.0. In this study, digitalization is viewed as a radical change from the perspective of current processes and organizational structures. In general, transformation and radical change create a threat for the existence of the organization. Simplified definitions of Industry 4.0 solution in manufacturing environment would be embedded sensor in product components communicating with interlinked manufacturing equipment. At the same time production system analyzes available data from various sources, and represent the information to human operator(s) who oversees ultimate decision making.

This study aims at supporting the strategic decision making of the managers working towards Industry 4.0 and digitalization. Secondly, this study makes an attempt to understand if ad hoc process model can be used to describe organizational success. Study combines two models, dynamics capabilities and ad hoc process in order to explain why some firms manage to go through successfully such a big change and some of them not, and which part of the successful digitization might be explained through dynamic capabilities and when the success can be derived from reacting to spontaneously appearing, unfamiliar problems.

Study uses qualitative research method, and it has both theoretical and empirical part. Theoretically formulated problems are categorized in the familiar and unfamiliar sub-problems with applicable solutions based on empirical part. Empirical has been collected through theme-centered interviews of four Finnish digitalization experts.

Results show that digitization-related problems can be divided in the unfamiliar and familiar problems. Thus, organization might be able to prepare itself for incoming change with dynamic capabilities. Findings to not represent or generate a single I4.0 framework nor organizational change theory, but provide tools for managerial implementation. Results of this study can be used as a vehicle to understand what kind of problems utilization of I4.0 technologies might generate before the actual benefits are reached.

Keywords
Industry 4.0, Ad hoc process, radical change, dynamic capabilities
Additional information

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1. INTRODUCTION

1.1 Introduction to Radical Change and Industry 4.0

Between 1947-1976 two factories of General Electric released 590 000kg of polychlorinated biphenyls (PCBs), toxic compounds, into Hudson River. The observed levels of PCBs in Atlantic Tomcod´s [Microgadus Tomcod] liver were among the highest ever met in the world. Unlike many other species in Hudson River, Tomcod survived. Even though evolution or Darwinism might be perceived to happen gradually and slowly, Tomcod proved that rapid adaption because of selective pressure can be reached; the genetic variant took over the population rapidly in 50 years (Wirgin et al., 2011.) No wonder that organizational change has been compared to Darwinism and evolution: long stable periods are self-reinforcing leading to standardized processes and structures which strengthen the organization's competitive advantage during the equilibrium periods. Just like noxious emissions in Hudson River affected to Tomcod, radical change forces firms to modify their "DNA" in order to survive (Tushman et al., 1996:10.) Contrary to evolution, organizational change and decision making are or at least should be cognitive processes. Thus, managerial skills have an impact on firm's performance and, according to Adner & Helfat (2003:1023), certain managerial actions are better than other.

In this thesis, the selective pressure, or radical change for manufacturing firms originates from recent technological development which has caused wide digitalization of the manufacturing industry, popularly known as Industry 4.0 (I4.0). Another term, industrial internet of things, has been also used, especially in US literature (Drath, & Horch, 2014; McKinsey, 2015). Even though the term I4.0 has been selected in this thesis, term industrial internet of things occurs also in the empirical part of this thesis. Digitalization per se, has been defined by Gartner (2017), a technology researcher, as "…use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business." Thus, in this study I4.0, or industrial internet of things is understood as a a) use of new digital technologies in manufacturing processes and machines itself, and b) include digital technologies and services in the finished goods.

Currently, I4.0 can be argued to be an umbrella term for wide range of technologies all targeting to improve process efficiency, increasing flexibility, and ultimately enabling to reach the benefits of a scale production in small lot sizes or even single unit production (Heiner et al. 2014; McKinsey, 2016). Especially useful for I4.0 and digitalization have been the growing computing power and the “rise of robots”.

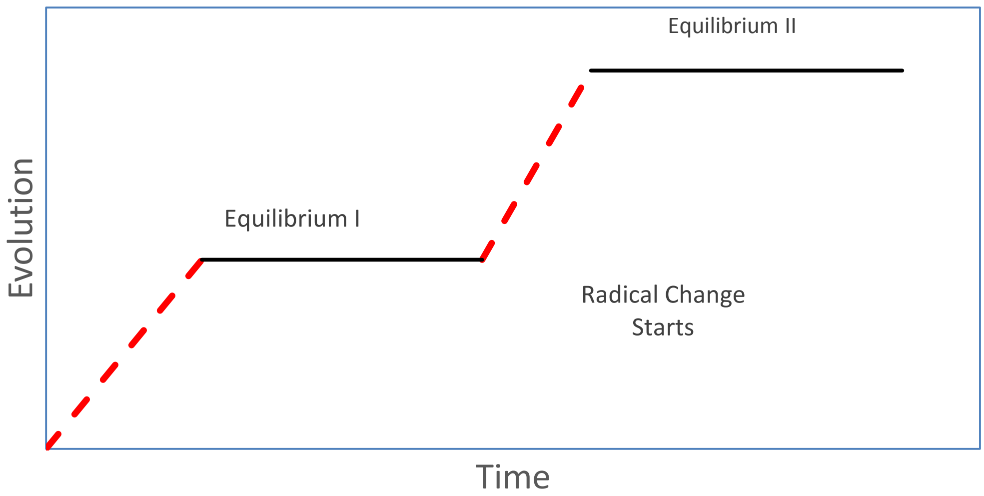
Increased computing power and decreased prices have enabled the wider use of advanced data analytics techniques and led “creation” of artificial intelligence (AI). Firstly, AI algorithms are already now outperforming humans in predefined cognitive tasks such as face recognition, medical diagnosis, or board games. For example, AlphaGo’s victory in 2016 over the human champion in Go, exponentially more complex game than chess, took place a decade earlier than it was expected. Secondly, computing power enables to analyze almost all possible data created in the factory floor operations, gained from the markets, signaled by customers etc. In practice, firm could track the movements of a single component in real time and incoming processes for the component could be adjusted automatically based on real-time information Thirdly, improvements in robotics and automation have assisted the number of operational industrial robots in the world to increase by 9 % on average from 2010 to 2016 and annual growth is believed to reach 13 % between 2017-2019 (Heiner et al., 2014; IFR 2016; Metz, 2016; The Economist, 2016a.)

Retuning to Hudson River example, without any further evidences, one can assume that a significant number of unfit genotypes failed to adapt in the new circumstances. However, managers can cognitively impact how the firm adapt to new circumstances and thus survival is more by design than pure accident (e.g. Adner & Helfat, 2003; Kor & Mesko, 2013.) Previous research in the I4.0 (e.g. Acatech, 2013, Vogel-Heuser & Hess, 2016) and the general facts that investments require capital and causes opportunity costs, point out that digitalization of manufacturing processes or adding digitalization into products are difficult tasks. This study believes that adding few sensors into machines and finding interesting patterns from collected data is over-simplifying the truth.

This thesis understands radical change and organizational evolution through punctuated equilibrium paradigm [table 1.1]. The theory itself is derived from biological evolution, and simply assumes that long, rather stable periods are followed by radical change. Periods of radical change per se require different kind of management compared to equilibrium periods (Gersick, 1991:10-12; Stoddard & Jarvenpaa, 1995). Table 1.1 also present the equilibriums periods in rather stylized and excludes incremental evolution which might occur during stable periods. Similarly, one can quite evidently assume that Tomcod population in Hudson River is under constant minor selective pressure as per Darwinism. In business world, as Tushman et al. (1986:29) state, most of the successful firms manage to maintain their success for years or even decades but eventually the ultimate managerial challenge comes in the form of rapidly changing competitive conditions.

Fundamentally, equilibriums are hard to modify due to deep structures which area highly stable choices or decision about organizational structures, basic activity patterns and processes (Gersick, 1991; Stoddard & Jarvenpaa, 1995). In the context of manufacturing firms, deep structures could mean how the manufacturing processes are arranged, and how the firm or whole industry is organized.

Table 1.1: Punctuated Equilibrium Paradigm



1.2 The Significance of the Study

Manufacturing industry origins, for example, 23 % of the total GDP in Germany, 16 percent of the whole Euro area, and 12 % in USA (The Economist, 2016b.) Digitalization (or I4.0) is believed to impact significantly in the basic fundaments of manufacturing industry, such as the ways how firms operate, processes are arranged, and future of the employment (Drath, & Horch, 2014; Ford, 2016). Thus, one can clearly see that from the perspective of a single firm or even nation, it is essential to understand how to utilize digitalization.

Also, organizations tend fall into crisis when they are forced to “recode their DNA” (Stoddard & Jarvenpaa, 1995; Tushamn et al., 1986). Secondly, earlier automation and IT have increased the productivity enormously since the Second World War; in 2010, the productivity in USA was over 250 % higher than in 1940’s (Ford, 2016.) To decrease dependency on the labor costs and further increase productivity, manufacturing firms must utilize growing computing power and industrial robotics which successfully embedded in the processes might deliver another boost to competitiveness at national and firm-level. Thirdly, managerial skills define how successfully organization survive through radical change (Adner & Helfat, 2003; Kor & Mesko, 2013; Ritala et al., 2016.) Based on previous three examples, the fact that digitalization of manufacturing firms has not been studied enough (Vogel-Heuser & Hess, 2016), and managerial doubts about digitalization and perceived lack of required skills (BCG, 2016), there seem to be room for further examination of the phenomenon.

1.3 Research Problem and Purpose of the Study

Traditionally, dynamic capabilities (DCs) framework has been used to recognize the methods, or “best practices” and sources of wealth creation of private firm in rapid technological change (Eisenhardt & Martin, 2000; Teese et al., 1997). However, the model has drawn critique especially by ignoring path dependency which locks certain structures and limits performance when the problem is unique. Ultimately, DCs might lose their strategic importance due to these limitations (Ritala et al., 2016; Schreyögg et al., 2007). Thus, manufacturing firm which has developed DCs for digitalization might waste its capital in the structures if they became a burden and limit the variety of possible technologies or business models which firm can eventually use or pilot.

To overcome these limitation, this thesis combines DCs model with ad hoc process. Based on Nickerson et al. (2007) & Ritala et al. (2016), ad hoc problem finding/solving (ad hoc PF/PS) model expects that some of the problems occurring in business are rather fast emerging and unknow. Therefore, firms cannot prepare themselves for those challenges with traditional DCs. This study believes that digitalization of manufacturing processes and radical change are a combination of familiar and unfamiliar problems from the perspective of the management. Thus, there is a change that firm must build some structures prior the change and solve occurring problems with ad hoc solutions during the transformation.

This study has two main targets. Firstly, identify solution to support strategic decision making of the firms and managers working towards I4.0 and digitalization, and tools to stabilize organizational structures and processes. It is expected that selected combined ad hoc PF/PS model and DCs can decrease manager's uncertainty on digitalization, and provide better analysis of the situation and required capabilities. Thus, the target of this thesis is to formulate a managerial overview of digitalization in manufacturing sector, rather than study single components of I4.0, generate a single I4.0 framework or organizational change theory.

Secondly, the study tries to contribute to ad hoc process research. As Winter (2003) mentions: "Probably some of the mystery and confusion surrounding the concept of dynamic capabilities arises from linking the concept too tightly to notions of generalized effectiveness at dealing with change and generic formulas for sustainable competitive advantage. " Thus, understanding dynamic capabilities and how they are linked to surviving through change, can ease firm's decision making when better tools to consider between DCs and ad hoc processes exist.

This study often refers to term worker(s) and manager(s). A worker is understood through the definition by Merriam-Webster (2017b): "One that works especially at manual or industrial labor or with a particular material", and managers by Oxford

Dictionaries (2017): “A person responsible for controlling or administering an organization or group of staff”. Thus, the terms are also used to refer a hierarchy within the organization and allocated responsibility.

1.4 Research Questions

This thesis makes an attempt to generate a managerial overview of digitalization of manufacturing industry, and study if ad hoc process can provide tools to understand the digitalization of a single firm. To answer these question, one main research question and two sub-research questions are formulated.

The main research question of the study is:

Q1: What are the typical managerial problems related to I4.0 and digitalization of a manufacturing firm?

In order to achieve its target, thesis includes the sub-questions 1 and 2 into consideration. SQ1 focuses on categorizing the recognized problems into the ones which can be solved with DCs, and the ones which requires ad hoc process. In other words, what are familiar and unfamiliar problems of I4.0. SQ2 evaluates how useful understanding ad hoc process might be for a manufacturing firm and whether results indicate that ad hoc PF/PS model can improve understanding on sustained competitive advantage.

SQ1: Which of the problems should be solved with DCs and which with ad hoc processes?

SQ2: How well ad hoc processes help to understand digitalization-related problems in the context of I4.0?

1.5 Used research methods

This study has both theoretical and empirical part. Considering the nature of research question, qualitative research method was selected to compare theoretical findings with empirically formulated solutions in digitalization of manufacturing firms.

This thesis represents an exploratory study as it tries to understand and gain insight about I4.0 and digitalization, and defining clear causalities and generalization might be difficult at industry-level. Approach of the study is abductive; data collection is used to explore phenomenon, and identifying themes and patterns. Study incorporates two existing competitiveness theories (ad hoc process and DCs) to find heuristic solution for I4.0 (Saunders et al., 2015) Theoretical part of the study focuses on discussing radical change in the context of I4.0, and how to manage it. As results, familiar and unfamiliar sub-problems related to digitalization and change from managerial perspective are recognized.

The interpretation is done by analyzing and summarizing the findings and cited problems in existing literature. According to Eriksson & Kovalainen (2008), the purpose of qualitative study is to interpret and understand the final findings, not to explain nor test hypothesis. Also, according to Saunders et al. (2015), qualitative research is often associated with interpretive philosophy as it tries to make sense of subjective and socially constructed meanings of studied phenomenon. Selected methodology is especially suitable with I4.0 and accompanied change as the prior insights is modest (Eriksson & Kovalainen, 2008). The methodology also helps to limits the examination into radical change in the context of I4.0.

The information used to interpret the mentioned aspects is gathered through literature review of a carefully selected, peer-reviewed, and widely referred articles from Scopus and EBSCO databases. Due to novelty of the topic, Industry 4.0-related examples and definition include business articles, and special reports by well-known consultancies and research centers. Most of the literature used in this study is also qualitative. Empirical methods are introduced in chapter 4.

1.6 Structure of the study

First chapter familiarizes the reader with the research topic, main concepts of the study, and overall setting of this thesis. It includes the description of the research problem and the purpose of the study. Chapter closes with the research questions and theoretical methods.

Second chapter defines furtherly and create overall picture of I4.0 through literature review. It also summarizes what is the purpose of digitalization and what might be the reason why digitalizing is perceived as a difficult task. Finally, the chapter introduces the base structure for problem finding analysis.

The beginning of third chapter prepares reader for the framework and explains why DCs should be fortified with ad hoc processes from the theoretical perspective as well as to maintain firm’s competitiveness.

Fourth chapter describes the research methodology, data gathering, and the methods used for data analysis in chapter 7. The validity and reliability in business research are also introduced briefly.

After the research methodology, chapters 5-8 covers how familiar and unfamiliar problems are recognized and solutions searched and evaluated. In chapter five, theoretical discussion around I4.0 and digitalization is used for problem finding. These findings are then evaluated by comparing them to previously cited problems by global management consultancies. Chapter six focuses on recognizing problems occurring around radical change. In chapter seven, solutions for I4.0-related problems are conducted from empirical data. Chapter 8 concentrates on the best practices during radical change and applies them with digitalization.

Chapter nine discusses about the main findings, possible limitations of this study, and recommends targets for future researchers.

2. INDUSTRY 4.0

2.1 Definition of Industry 4.0

McKinsey, a consultancy, defines I4.0 as a digitalization of manufacturing sector which origins from four disruptive technology groups: 1) connectivity, data, and computing power; 2) Analytics and intelligence; 3) human-machine interaction, and 4) digital-to-physical conversion. Simplifying that would mean embedded sensor in product components communicating with interlinked manufacturing equipment. At the same time production system analyzes all relevant (big) data from various sources and represent the information to human operator(s) who is in charge of ultimate decision making. Also, Heiner et al. (2014) note that Industry 4.0 refers to a wide range of different concepts and technologies which clear classification is not possible in individual cases. Thus, I4.0 can be viewed as an umbrella term for broader digitalization of manufacturing industry. First time the term Industry 4.0 (in German Industrie 4.0) was used in 2011 at the Hannover Fair. Currently it is widely used in Germany to indicate goals to maintain country's industrial competitive advantage through digitalization (Vogel-Heuser & Hess, 2016.)

However, various studies (e.g. Behrad Bagheri & Kao, 2015:18; Sanders et al., 2016; Vogel-Heuser & Hess, 2016) refer to I4.0 through term cyber-physical system (CPS) which as a concept combines four previously listed disruptive technology groups. Heiner et al. (2016) adds that CPS connects physical factory floor, suppliers and customers with cyber computational space to turn manufacturing operations more flexible, efficient, and collaborative. In practice CPS seem to be more accurate and general term for the digitalization of manufacturing sector. Therefore, this thesis understands CPS as necessary software for "smart factory" when the term I4.0 is viewed more likely a group of loosely linked technologies. Based on assumption by Ford (2016), computing power and especially AI are developing in the direction where real-time data can be utilized more efficiently and machinery should be able to solve or adjust defected processes more often by itself. In this formula, CPS seem to be the "heart" of system and network for distributing the data.

Earlier referred disruptive technologies and disruptive innovations are according to Christensen et al. (2000) technologies which enable to offer cheaper and more convenient product or services. For example, the way how e-commerce competes against brick and mortar shops by utilizing internet. Traditional definition by Schumpeter (1943:83) describes creative destruction as "…revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one". These definitions go hand in hand with the earlier definition of digitalization by Gartner's (2017) and indicates that in addition to new processes, new business models are also enabled through digitalization in manufacturing sector. In fact, McKinsey (2016) and Reijers et al., (2004) believe that whole new business models, like mobile factories and ultra-responsive production, can be introduced with I4.0 technologies.

What makes things like I4.0, digitalization or CPS possible to emerge in factory environment, is the recent development of sensors, data acquisition systems, computer networks, robots, and computing power. All this has increased the availability of disruptive technologies and decreased the costs of using these components and solutions (Behrad Bagheri & Kao, 2015:18; Heiner et al., 2014; McKinsey, 2016.) In practice, digitalization would mean more autonomies processes with less human intervention. Ideally operator would participate only when a defect is detected (Sanders et al., 2016).

2.2 Industrial Revolutions from First to Fourth

Technological leaps have today ex-post named as industrial revolutions. The first one started in 1784 in the field of mechanization powered by steam and water in the form of first mechanical production equipment. Second revolution was started by intensive use of electrical energy in 1870, and third one in 1969 through computers, IT and internet (Davis 2016; Heiner et al., 2014: 239). Unlike the three previous revolutions, the expected revolution through previously listed disruptive technologies has been named as fourth industrial revolution, or I4.0 ex-ante due to high expectations towards it. The expectations include, for instance, shorter development times, flexibility, mass customization, decentralization of structures, new business models and opportunities, and better resource efficiency (Heiner et al., 2014:239). For example, McKinsey (2016) expects 1.8 billion new customers arising in mass markets during next 10 years which most likely will generate numerous opportunities and challenges for the manufacturing industry, and particularly to society in order to cope with resources, employment, and social issues. However, change is not expected to happen simultaneously all over the world – in many parts of the world the second and third revolution have not been fully experienced which might enable those countries to leapfrog over previous revolutions (Davis 2016.) Thus, the competition and advance on digitalization should not interpret solely among firms within the same country. Especially hyped I4.0 and digitalization overall has been in Germany where government has adapted the term to its high-tech strategy 2020 (Heiner et al. 2014.)

2.3 Current Development of I4.0

According to Drath, & Horch, 2014, extensive utilization of I4.0 technologies and digitalization of a whole manufacturing are still in the future. Even though digitalization seems to be unavoidable, this thesis assumes that I4.0 per se should not be the purpose of development nor the change. Considering I4.0 purely via CPS (e.g. Vogel-Heuser & Hess, 2016) takes only into account the software. This approach threatens to exclude firm's situation, human operator and hardware from the examination. Thus, considering problems which I4.0 or CPS can solve profitable should be the starting point for academics and firms. For example, Acatech (2013), German Academy of Science and Engineering, takes into consideration both social benefits of digitalization such as better work-life balance, solution for eldering workforce, and economic possibilities such as higher productivity and increased flexibility.

Expectations for digitalization are high, albeit the progress has not been fully started. For example, ABB (2016), an industrial robot manufacturer, states that its end-markets including automotive, chemical, machine building, marine, food and beverages industries are only starting to digitalize. Heiner et al. (2014:240) note that industrial-related innovative technologies are not widely spread nevertheless the extensive use of technologies such as smartphones, apps, Web2.0 etc. on our daily lives. However, future predictions expect to see communication within factories to be carried out through smart devices such as tablets and voice control (Gorecky et al., 2014; McKinsey, 2015).

Previously technological development has clearly benefitted the society at least in financial term. Between 1993-2007 robots increased GDPs in 17 studied countries by additional 0.4 percentage points. Altogether, robots accounted one-tenth of total GDP during that period and trend is expected to continue (National Science and Technology Council 2016.) Thus, enthusiasm and support from governmental level might have positive impact or at least there is a clear incentive for supportive actions. Such evidences might partially explain the hype around the I4.0 and partially impact how the topics is viewed publicly.

Even though at industry-level the change has not fully started, there seem to be high expectations that manufacturing industry is changing. It is hard to deny that three previous industrial revolution would had not caused radical changes and shaped the ways firms are managed and organized.

2.4 I4.0 and Radical Change

From the perspective of radical change theories (Gersick, 1991), technological innovations like the ones through Industry 4.0, dismantles the structures and processes which prior the new circumstances were linked with winning. In circumstances, these old porcesses do not provide enough competitiveness due to higher costs or weaker business model. Ultimately, those processes and structures might become a burden when demand for redesigning processes and rearranging the structures appears. For example, Tushamn et al. (1986:35-36) state that deeply-rooted culture might prevent organization from registering the threat; ignoring new circumstances or even increasing commitment to existing technologies and business models might cause destruction of the whole firm.

Earlier definition of digitalization suggest that managers might need to have a certain courage to make things differently and change current beliefs. Understanding that structures and processes might become obsolete due to radical change, helps to understands the critique towards DCs (e.g. Winter, 2003); if DCs are grounded on the past structures, it might be difficult to include new requirements within them.

Without transformation, firm's internal dimension consisting of processes and structures will lose its competitive advantage, and/or external dimension lose its functionality to absorb resources from its environment. Longer stable periods also tend to generate greater internal inertia which complicates the change (Gersick, 1991; Tushamn et al., 1986.) Stoddard & Jarvenpaa (1995:81-82) compares radical change to changing engines of a running airplane which might be quite close to truth with digitalization in terms of processes and resources. Thus, willingness for digitalization should be derived from competition and business problems. As Gersick (1991) says, technology does not itself cause the change but need for it.

3. DYNAMIC CAPABILITIES AND AD HOC PROCESSES

3.1 Why Combined Model Outperforms

DCs have been used as a tool to recognizes "best practices" for wealth creation and to explain success of private enterprises during rapid technological change. They are also one way to measure firm-level strategies for maintaining or sustaining competitive advantage. Traditionally, DCs model has been argued to fit especially well to innovation-based competition in so called Schumpeterian world where a new innovation dismantles the structures and processes built around the old technology. Word dynamic refers to market place with a changing nature, and capabilities to management's role at integration of external opportunities with internal skills and resources (Eisenhardt & Martin, 2000; Teese et al. 1997.)

As mentioned in chapter 1, DCs have been criticized for turning effectiveness into rigidity (Schreyögg et al. 2007) and incapability to deal with unexpected and rapid organizational and strategic problems (Ritala et al. 2016). Adner & Helfat (2003:1012) extend the traditional DCs model and include managerial capabilities into consideration. Dynamic managerial capabilities which they define as "the capabilities with which managers build, integrate, and reconfigure organizational resources and competences" suggest that corporate managers and their actions matter.

However, Nickerson et al. (2007) state that quite often managers do not have prior knowledge for the problems and thus problem solving is often more likely based on ad hoc solutions than DCs. Winter (2003:993) defines ad hoc PF/PS and DCs as two different ways for organization to change. Ritala et al. (2016) believe that the outcomes of ad hoc PF/PS can be often decomposed into familiar and unfamiliar problems, and combining ad hoc PF/PS with DCs should increase performance in these cases. Thus, interpreting managerial actions at digitalization and I4.0 with mixed method approach should deliver better overview of the phenomenon than DCs or ad hoc PF/PS would bring solely. Even though digitalization as a topic might be new for managers, it is not purely a rapid and unexpected occasion even though some of its problems are. Thus, some parts of the change can be simplified and prepared in advance through DCs, and some might benefit ad hoc processes.

3.1 Dynamic Capabilities

DCs consist of identifiable and specific routines and processes (Eisenhardt & Martin, 2000) which can be split into three categories: managerial and organizational processes, organization´s current position, and available paths (Teese et al. 1997). Teece & Pisano (1994) define managerial and organizational processes as the ways the activities are done within the organization, paths as available strategic choices, and position as the combinations of current technological and intellectual property asset such as customer base, and relations with suppliers. Furtherly, Wang & Ahmed (2007:35) argue that DC are not per se processes but they are embedded into processes. For example, learning is not a process which can be added into organization because it usually sets certain requirement such as fostering initiative behavior and encouraging employees to reach continuous improvements.

However, DCs scholars also recognizes some of the characteristics of ad hoc process but do not take stand on path dependency. For example, Eisenhardt & Martin (2000) state that in moderate dynamic market place with incremental and predictable change, well-defined processes based on systematic research seem to be more efficient. In dynamic and fast changing environment, quick adaption and creation of new knowledge is more efficient approach. Additionally, Wang & Ahmed (2007:37-38) mention that in DCs, crucial factor during technological change has been firm´s ability to recognize and utilize new information. Bititci et al. (2011) say that managerial processes enhance DCs and determine competitive advantage.

Nevertheless, ad hoc process does not exclude DCs nor say that they are waste of time and money. For example, Winter (2003) notes that learned processes (DCs) might contribute positively to improvisation, or ad hoc problem solving. He also adds that aggressive search of change increases the cost related to DCs and exposes to certain rigid patterns, but DCs can also hedge against the change and obsolescence of current capabilities.

3.2 Ad Hoc Process

In this thesis, ad hoc process consists of problem-finding and problem-solving activities (based on Ritala et al., 2016) PF/PS activities attempt to identify organizational biases, and potentially valuable and largely unseen options (Nickerson et al., 2007.) For example, I4.0 and digitalization of manufacturing operations seem to include novel problems(e.g. Acatech, 2013; Vogel-Heuser & Hess, 2016) and therefore several unseen option can be expected to occur when manager starts digitalization.

According to Nickerson et al. (2007), synthetic search process should be used for problem finding when recognizing inductive, novel problems and working with radical innovations or change. In case of deductive problems or optimization of current processes, one should use analytical search process. Synthetic search process enables to split the findings into unfamiliar and familiar problems from which familiar problems are often within the boundaries of current DCs. Often unfamiliar problems are beyond DCs which causes them to fail bas they cannot cope with the sudden fundamental change (Nickerson et al. 2007; Ritala et al., 2016; Winter, 2003.)

After problem identification, managers preoccupied themselves with search of solutions, and creation of strategies which match with the solutions and vice versa. Based on the complexity, some problems can be solved through independent search processes with minimal organizational control. On the other hand, some problems require knowledge sharing throughout organization and coordinated search (Nickerson et al., 2007.) Ritala et al. (2016) divide problem solving into three categories. First, manager can look at heuristic solutions for complex problems. Second, directional search with hierarchical team can be used for less complex problems. Thirdly, purchased services should be used for non-complex problems. However, the final evaluation and categorization of the problems in chapter 9, do not focus on identifying these sub-categories of unfamiliar problems.

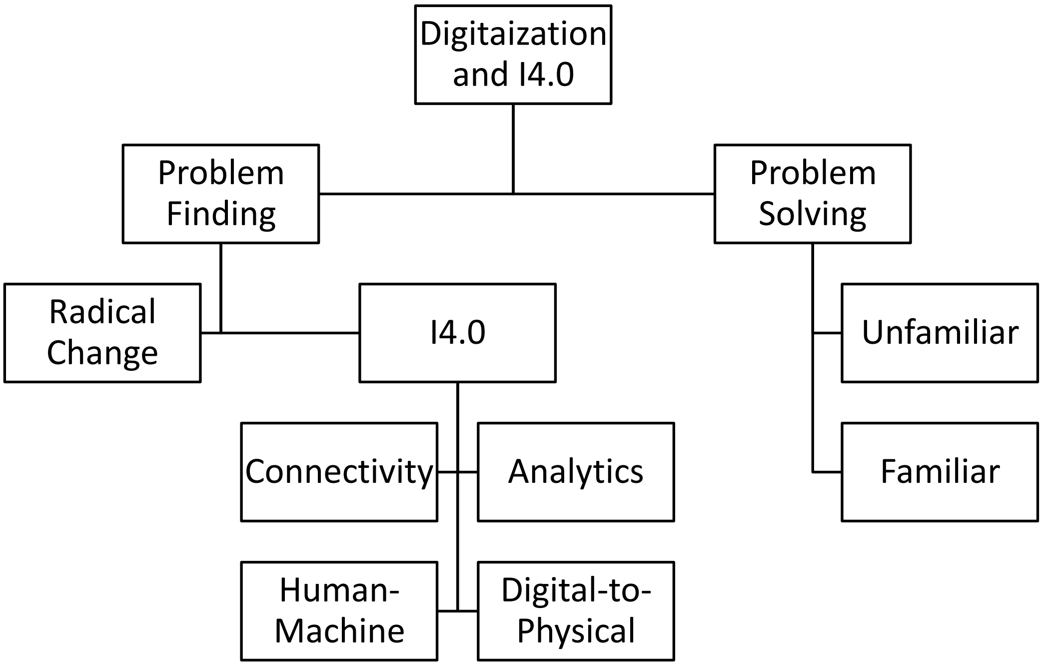
3.3 Framework for the Study

For studying and recognizing problems related to I4.0 and digitalization from the perspective of a manager, framework in table 3.1 has been formulated (based on Nickerson et al., 2007; Ritala et al., 2016.) Problems are identified via synthetic search process. Thus, the focus of the framework lays on finding unique questions and problems.

Problem finding process has two phases: 1) analyzing digitalization through four technology categories introduced in chapter 2.1 (Behrad Bagheri & Kao, 2015:18; McKinsey, 2016; Vogel-Heuser & Hess, 2016), and 2) analyzing radical change in the context of I4.0. Analysis and problem finding for both phases are done through literature review. Findings of phase 1 are also screened and completed against earlier cited problems by four global consultancies. Assumption is that this will enhance the study and combine earlier academic research with more business-related problems. The phase 2 is included in the analysis because based on Greenwood & Hinings (1996:1024) and Stoddard & Jarvenpaa (1995:85), radical change has an impact to social and technical systems of the organization and thus changing even a purely technical process under radical change cannot be done witohut taking into account the social aspect, or employees. Consequently, problem finding in phase one and two might be partially overlapping.

Dividing problems into familiar and unfamiliar phases is founed on unexpectedness and urgency of the problem. Unepxtedness is based on perception of how preparad the industry in general is for the problem, and urgency to time pressure faced to overcome the problem (Ritala et al., 2016.) In a longer run, this approach might reduce the unexpectedness of certain problems, even though Ritala et al. (2016:769) mention that recognizing successful solutions for unfamiliar problems is difficult on firm-level. However, as Eisenhardt & Martin (2000:1117) outlines DCs: "while the evolution of dynamic capabilities occurs along a unique path for any given firm, that path is shaped by well-known learning mechanisms". Thus, this thesis expects that in the I4.0 context, it is possible to find commonalities among potential solutions for unfamiliar problems. Ultimately, classification might provide starting point for developing DCs which will then support the digitalization.

Table 3.1: PF/PS Framework of the Study



4. METHODOLOGY AND RESEARCH DESIGN

4.1 Methodology

This chapter goes through the methodology of the empirical part of this thesis. Purpose is to describe how data has been acquired and analyzed as well as justify why certain experts have been chosen to be part of the study. Additionally, the validity and reliability in business research are introduced and discussed in the end of the chapter.

4.2 Methodology in Empirical part

Expert interviews in the chosen topic are common way to collect data in exploratory research. Generally, interviews are one of the most commonly used methods for gathering data in quantitative research. Interview questions should be related, but not equal to research questions (Eriksson & Kovalainen, 2008; Saunders et al., 2015.) Thus, theme-centered interviews have been chosen as the method for empirical part. Even though Saunders et al. (2015) suggest that somewhat unstructured interviews are common in exploratory interview, still the semi-structured with open-ended questions better outline the topic and keep the focus on digitalization, managing it and radical change. As this thesis is interested in facts and to provide truthful answers for the recognized problems, the interviews represent a positivist approach (Eriksson & Kovalainen, 2008).

Semi-structured interview allows interviewer to lead the dialogue, but does not restrict the width and depth of the answers. Also, the approach does not require any particular order of the questions, and some question might be even excluded depending on the responses. Open-ended questions give more control to participant more over discussed matters and usually generates more detailed responses which suitable for expert interviews. Due to direct contact with the participant, interpretation of data through is tightly interlinked to researcher’s observation and perception which generates unique results and findings (Drew et al., 2014; Eriksson & Kovalainen 2008; Saunders et al., 2015).

The four chosen experts who participated the them-centered interviews have been selected carefully based on their personal status within organizations working with topics in I4.0 or industrial internet and digitalization. The all the organizations of interviewed persons are based in Finland. Additionally, two of the organizations have large global networks. By choosing experts already familiar with digitalization and from different organizations, this thesis hopes to capture the truthful and up-to-date picture of best practices and incoming challenges in digitalization. During the interviews, special attention was paid in order not to mislead interviewees. All interviews were also recorded with the permission of the interviewees to capture truthful message.

Interviews were conducted via one-to-one telephone conversations. The interviews´ lengths varied between 20-45 minutes depending on the interviewee. Per se interviews happened between 26th-30th of June. Further introduction of the interviewees is in chapter 7, and draft for questions in appendix.

4.3 Data Analysis

Qualitative data analysis is sensitive to social interaction and interpretation because the meanings are derived from words, rather than numbers (Saunders et al., 2015). Due to abductive nature, the analysis tightly interlinked with the context and thus study combines both inductive and deductive features in analysis. Interviews should generate data that will help answer to research question through careful analysis. (Eriksson & Kovalainen, 2008.) In this study, the data is used to answer problems related to digitalization, radical change, and I4.0. In addition to what is said, interviewer should be interested in the way things are said during the transcription (Saunders et al., 2015.) As telephone-interviews do not make reading the body language possible so the observations focus on verbal communication.

Saunders et al. (2015) recommend template analysis for its flexible nature when analyzing qualitive data. Template analysis is concerned matching data with patterns and themes and therefore it is suitable when comparing different opinions by experts. Themes and codes are created prior to interview, which in this thesis, means that interviews are related to recognized problems from literature review regarding digitalization of manufacturing firm. According to Saunders et al. (2015), coding is used to match data with right category, meaning that transcribed data is first processed and analyzed, and then matched with right themes. Before the analysis, data interviewer gets familiar with the data which in this study is accomplished through transcription. Based on comparison in codes, themes are refined until satisfactory results are met. In this study, the codes are conducted from the recognized problems in chapter 5.

4.4 Validity and Reliability

Validity is founded on study's ability to have scientific rigor and merit. It is understood as a measurement to indicate how the arguments, results and suggestions match to the chosen subject; in this case I4.0 and digitalization. In the context of reliability, validity is the level of consistency in qualitative research. A study has scientific merit when it utilizes knowledge through reliable scientific sources (Drew et al., 2008.) Qualitative research contains both internal and external aspects. Internal validity captures systematically the accuracy throughout the study; it takes into account differences in the sense that interpretation of the study can be generalized in similar cases i.e. can be argued that event x led to event y. External validity refers to the circumstances under which the results of a study can be transferred to population outside, and that the factors of selected methodology represents the world in which the information is wanted to add (Drew et al., 2008; Farquhar ,2013.) Reliability in qualitative research, also often referred to as dependability, is more linked to the consistency of the procedures of data collecting (Eriksson & Kovalainen, 2008). Validity and reliability of this study are discussed in the last chapter.

5. PROBLEM FINDING

To support problem finding, already cited problems by global consultancies have collected together in table 5.1. On its own, data in table 5.1 have certain limitations for scientific generalizability. For example, data sets differ from each other by country and industry, and thus possible biases are not amended. However, with a careful evaluation the results can be used to improve the theoretical problem finding part. PwC's data includes various firms globally, Deloitte's Swizz manufacturing firms, EY's German manufacturing firms, and BCG's US (marked as US) and German (marked as G) companies with various backgrounds. Theme-finding method has been used to categorize the results by consultancies into one table. Themes do not follow the structure introduced in table 5.1 for study's framework but findings are targeted for appropriate structure throughout the theoretical discussion.

Table 5.1: I4.0-related findings by global consultancies

PwC (2016)	Deloitte (2015)	EY (2016)	BCG (2016)
Current Level of digitalization and I4.0			
Overall high level of digitalization among 33 % of the firms *41 % in vertical value-chain integration.* *34 % in horizontal value-chain integration.* *29 % in digital business models, product and service portfolio 29 %.*	**36 % agree or strongly agree that can feel the impact of I4.0** 20 % do not feel the impact. 30% and 18% have strongly digitalized R&D and services respectively. No digitalization at all in warehousing or administration, 35% each.	**For 35 % and 42 % I4.0 is import or rather important respectively** 80 % expect importance to increase within 5 years. In 42 % of the firms I4.0 is a topic, but in 19 % not a topic at all.	**First concepts developed in 47 % (G) and % 29 % (US) of firms** Fully implemented digitalization: 4 % (G) 3 % (US) Nothing done 18 % (G) and 41 % (US) **Activities already applied in** Logistics & supply chains 19% (G), 14% (US) Predictive maintenance 17% (both)

Perceived potential of I4.0			
In 5 years overall high level of digitalization 72 % of the firms *Vertical value-chain integration; 72%.* *Horizontal value-chain integration; 65 %.* *Digital business models, product and service portfolio 64%.*	**84 % agree or strongly agree that I4.0 can increase competitiveness** High or very high potential expected by over 70 % in R&D, warehousing, and production	**Expected potential in:** *production flexibility by 68%.* *Faster response by 59%.* *Overall efficiency by 46 %* **Only 16 % see new business models** Expected savings gained is 6.8 %	Not mentioned
Challenges			
Lack of clear vision 40 % of respondents. Unclear economic benefits by 38 %. High required investments by 36 %.	**4 % have talents needed for I4.0.** 80 % partially 16 % not have at all.	High investments for 66 %. Lack of qualified staff for 61%. Missing common standards for 55%	**Big or very big:** Lack of qualified employees 38 %. Data security 36 %. High investments 32 %. **Not at all or small:** Insufficient management 38 %. IT 38%.
Analytics, IT, and security			
Operational disruption is threat for 54 % of respondents Risks related to data loss, 40 % Medium or poor skills in IT, 74 %	**42 % do not use or use little analytics.** 29 % use or use a lot. 84 % think digitalization increases cyber risks. 48 % has IT partly ready for I4.0, but 20 % do not.	**Very important factors for business model:** IT, 87 %. Machine-to-machine communication 45 % Cloud computing 43 %	Not mentioned
Investments and required skills			

Average investment is 5 % from revenue Expected repayment within 2 years, 55 %	Not mentioned	Average investment to digitalization 4,8 % per year.	**Skills needed much or rather more in:** Data management by 51 % of all firms. Data security and software, both 50 % **Skills needed much or rather less in:** Manual working 47 % of all Operating machines 33 % of all **Skills gained through:** Education 64 % (G), 48% (US) Retraining 15 % (G), 27 % (US) Hiring 20 % (G) 25 % (US)

Current level of digitalization and I4.0 in table 5.1 describes what the firms have already done or how they feel that digitalization has impacted on them. Perceived potential of I4.0 lists what expectation the participants have towards digitalization and what can be gained through I4.0. Challenges combines the areas where firms expect to face or have come across with challenges due to new requirements. Analytics, IT, and security describes what challenges digitalization is expected to bring in forms of IT security, and how systematically firms are utilizing data with their current business model. Investments and required skills part consist of the expectations towards new skills and resources which I4.0 is expected to require.

5.1 Data, Computational Power, and Connectivity

Data, computational power, and connectivity are in practice referring to situation where sensors embedded in physical goods are interlinked via wired and wireless networks to system, or CPS. These networks distribute large volumes of data to various analysis. Part of the connectivity and data is physical world's, like robots, ability to sense its environment which then enables production machinery and even components to communicate autonomously. Simply, this means that digitalization can increases profitability of manufacturing firm's current processes through higher operational efficiency, productivity, and smaller cost and thus processes become more optimized (McKinsey, 2016; Sanders et al., 2016). However, compared to three previous industrial revolutions with capex-intensive upgrades to steam or automation which accounted 80-90 % of created value, it is expected that only 40-50 % of the incoming value can be created through machinery upgrades. Thus, the rest are generated by data analytics and disruptive technologies (McKinsey, 2016:7). In other words, more accurate forecasts, decreased quality costs, mass customization in scale etc. should account over half of the return on investment.

Unfortunately, technologies and solutions representing I4.0 are currently high-end equipment and require high financial investments (Sanders et al., 2016). McKinsey (2016:7) expects the overall change to be rather slow due to long investment cycles of manufacturing sector which also turns the firms conservative and cautious with their decisions. Conservatism towards digitalization has been also documented, for example, among German small- and medium-size enterprises (SMEs) (Sanders et al., 2016:813). In table 5.1, PwC (2016) reports that unclear economic benefits (38 % of respondents mentioned), high required investments (36 %), and lack of a clear digital operations vision are biggest the challenges for building digital capabilities. Also, BCG (2016) and EY (2016) report that expensive investments are top concerns for 32 % and 66 % of respondents respectively. On the other hand, more than half of the firms expect the investments to pay back within two years (PwC, 2016) and generate savings of around seven percent on average based on all answer or maximum 10 percent by two-thirds of the respondents (EY, 2016). Reported annual investments in I4.0 technologies are around 5 % of annual revenue (EY, 2016; PwC, 2016). Thus, firms seem to put their effort on new technologies.

Expectations towards digitalization are clearly high. However, discussed studies and reports suggest that firms are conservative and cautious with their digitalization investments. Missing common standards, mentioned also by EY (2016), might be one source of hesitance as the choice of technology or solutions is not clearly defined by the markets. For example, the uncertainty of future development might turn first mover advantage into disadvantage if wrong format is selected. Thus, proposed first problems concern investments, potential benefits, and examples to compare what has already happened in manufacturing industry.

Problem 1: How to capture economic value of I4.0 and does digitalization bring value?

Problem 2: What other firms have done with digitalization and how one should react to it?

5.2 Analytics and Intelligence

Earlier industrial revolution focused on automating simple and repetitive tasks. However, recent development in AI with predefined tasks, or machine learning, and data analytics have been benefitting the automation and of knowledge work (Ford, 2016; McKinsey, 2016.) Analyzing and distributing large quantities of up-to-date information can be recognized as one of the major advantages of systematic use of data, despite if the application is called AI, CPS, data analytics tool, machine learning etc. However, advanced use of data still requires human intervention and lack of necessary skills seem to be problem for most of the firms covered in table 5.1.

In table 5.1, PwC (2016) reports that 74 % of the firms believe that they own medium or poor capabilities in mature data analytics. Also, among studied Swizz manufacturing firms, more than two-fifth state that they do not use or use only little analytics. On the other hand, 29 percent state to use extensively. These results indicate that firms' preparedness for digitalization varies a lot; some firms simply are in better shape with data utilization and some have not even started yet. Most likely embedding data analytics in current processes or creating new structures does not necessary bring more value. For example, Stoddard & Jarvenpaa (1995) state that redesigned processes do not result planned outcomes if proper training is not executed. In their study, some of the followed firms cancelled the supportive training due to high costs and therefore poor success was obtained with new business processes. Especially new responsibility allocated to operators through elimination of some supervisor roles increased gap between old and new skills.

Before furtherly analyzing the required skills, a following problem is stated regarding use of data.

Problem 3: Data analytics and how to start

As said, utilizing data more systematically means that new skills are required. Therefore, it is not surprise that three consultancies in table 5.1 highlight the need of new skills and qualifications. In BCG's (2016) survey, the lack of qualified employees is the biggest challenge as 38 % of firms agree that. Half of respondent also estimate employees to need new qualifications in data management, cyber security, and software developments. More alarming, Deloitte (2015) states that in Switzerland only 4 % of studied firms have required employees, four-fifth of firms perceive that they own required skills only in certain areas, and 16 percent completely lack the skills. Among studied German industrial firms, 61 percent do not have enough of qualified employees (EY, 2016).

However, data analytics is not the only are which will require new skills. Increased level of automation and development of AI will accelerate the current transformation which turns employees from generalists into specialists. Transformation will cause need for different sets of skills than earlier (Trkman, 2010:129.) Even though most of the skills, as mentioned, are regarding to data and working human-machine cooperation, 20 % of firms in BCG's (2016) survey are expecting to see peak in qualifications of machine operating. On the other hand, one-third believes that less or much less qualifications are needed with machine operating. Thus, the requirements might be linked with the special characteristics of the firm and its production or firms are confused with the future which table 5.1 also supports.

Generally, expectations that machine operating will move towards data management and human-machine teams, discussed in chapter 5.3, is most likely close to common view. For example, Frey & Osborne (2017) believe that 47 % of 702 detailed occupations in USA are at risk to be automated which, unlike the last two industrial revolution, has a negative correlation between compensation and education level. It simply indicates discontinuity between 3rd and expected 4th industrial revolutions as PC, IT, and automation benefitted skilled labor through higher demand for more cognitive tasks like administrative tasks and machine operator. When earlier physical activities like lifting were automated and human oversaw controlling the machine leasing to increased productivity and allows higher wages, now less supervisor for robots are needed.

Especially vulnerable occupations among logistic and transportation, bulk office workers, and labor in production. Probability for computerization of all manufacturing occupations is solely over 70 percent and for instance 97 % for electromechanical equipment assembler (Frey & Osborne, 2017.) Possibility of polarization of labor markets, highly-skilled jobs hierarchically above the machines and low-skilled jobs requiring social intelligence and creativity, has been expressed as future development (Ford, 2016; Frey & Osborne, 2017). Thus, demand of skills might grow especially fast for certain occupations, creating bottle-neck in digitalization which might be one reason why firms in table 5.1 are worried about lacking the necessary skills. On the other hand, employees with obsolescent skills must be re-educated or let go.

Based on previous discussion about new skill requirements due to data analytics and increased intelligence in factories, following problem is represented.

Problem 4: How to acquire necessary skills and what kind of skills are needed at future factory?

In chapter 2.1, CPS was defined (through Behrad Bagheri & Kao, 2015:18; Sanders et al., 2016; Vogel-Heuser & Hess, 2016) as the distribution center of data of the factory processes and more practical manifestation of digitalization than I4.0 as a term. One the most well-known multi-purpose CPS might to be currently IBM´s Watson (Lewis, 2016.) With term multi-purpose, this study refers to adaptability of the system and ability to be used with various tasks.

What makes such a cognitive computer system so special are, inter alia, its adaptability, ability to learn as it goes, and connectivity. For example, Watson has been used in legislation and law cases, medical research, and Industry 4.0 applications. However, Watson is still narrow AI meaning that it has to be dedicated for certain tasks, it does not have general intelligence, it only replicates or outperform human performance in dedicated tasks, and it is totally indistinguishable from human operator Technically it is utilizing various technologies i.e. machine learning, data mining, neural networks etc. from which some were discussed in the beginning of this chapter (Ford, 2016; Lewis, 2016; The Economist, 2015.)

However, CPS is widely discussed as chapter 2 showed and general term for machine intelligence in industrial environment. Thus, understanding better the potential and use in practice, following problem is proposed to understand the potential.

Problem 5: What CPS such as IBM's Watson means and what is its future?

5.3 Human-Machine Cooperation

As mentioned earlier, interaction between humans and machines has increased a lot through personal smart devices, such as smart phones. However, at firm-level solutions, such as smart glasses, seem to be somewhat rare or just under piloting. Generally, new technologies and systems must be adopted by the users to utilize the expected benefits. For example, a CPS not used properly, does not account the benefits calculated prior the investment decision. Academics and consultancies also highlights the need for effective communication between human, machine and system when discussing about I4.0 solutions (Ghazizadeh et al., 2012; Heiner et al., 2014; McKinsey, 2016; Venkatesh et al., 2003.)

Even though development and new work methods will turn human operator from supervisor into active member of human-machine team, progress does not indicate that human would be less important in manufacturing operations. In fact, maintaining human involvement in production has been observed to increase overall performance as it minimizes downtime and thus improve process flow when results are compared with pure automation. Similar development has been earlier observed in chess: in 1997 Deep Blue, a supercomputer by IBM, managed to win World Chess Champion. Instead of chess being dominated by even more powerful computers nowadays, the best chess players are actually human-machine pairs who can compensate each other´s weaknesses (Brynjolfsson & McAfee, 2012:28-29, Endsley, 1999, Madhavan et al., 2007.) Generally, higher level of automation is needed or should be used when the task exceeds human skills, for example heavy lifting and processing large quantities of data. Decision about automation level and tasks should target to maximize productivity (Ghazizadeh et al., 2012.)

In table 5.1, Deloitte (2015) report that in Switzerland one-third of studied firms have strongly digitalized their R&D activities and only 18 percent their services. However, 35 % have not done any digitalization in warehousing nor administration which both Ford (2016) identifies as suitable areas for digitalization. However, 70 % of studied Swizz firms recognize R&D, warehousing, and production as potential target for high-level digitalization. Thus, digitalization of potential tasks has not implemented yet, even though the potential has been recognized.

In general, Ghazizadeh et al. (2012) divide the degree of human-machine relationship into two levels: a) acceptance and b) adoption. From these, adoption goes further indicating deeper trust, utilizing the full potential when acceptance might for example, mean bare minimum use. Endsley (1999:462) splits the taxonomy of degree of automation into four functions: *monitoring* processes and collecting data, *generating* processing options, *selecting* the optimal or locally optimal option, and *implementing* the option. The degree of automation as table 5.2 shows, can vary between totally manual system up to pure automation depending who oversees each of the four functions. Ghazizadeh et al. (2012) believe that surprises caused by higher level of automation will be far more usual in future: jobs with less formal training like drives or machines operators are riskier compared to pilots, who along with extensive training also keep track of the accidents with a view to prevent such cases in the future.

Table 5.2: Degree of Automation and Related Human-Computer Cooperation (Endsley, 1999:465, Parasuraman et al. 2000:287)

	1. No Assistance by computers
Low Level	2. Computer help with selected actions but human control required
	3. Automated physical implementation of the options
	4. Both human and computer generates options but human controls the selection
	5. Computer offers options which can be selected or one can use his/her own option
	6. Human uses veto for choices by computer
	7. Only limited set of option is represented by computer in which operator may select
	8. Informs human only when asked
High Level	9. Computer generates options, selects one, and implements it. Human interferes only when needed
	10. Fully automated. Human processing is not needed

Higher level of automation does not automatically mean better performance. Endsley (1999:463) suggests that intermediate level of automation with human operator deliver in some cases higher efficiency. Situation is like comparing self-driven car to blind spot detector, lane change assist, and other driving monitors which fundamentally has different level of automation. Monitoring systems are meant to cooperate with human and ultimate intervene in case of a human error, when with self-driven cars human is the one to interfere. For example, disregard of human operator has led to death of the driver when self-driven car has failed, and driver has not been monitoring the traffic together with the system (Yadron & Tynan 2016.) Example indicates that operator´s disregard can block reaching the optimal performance. However, excluding human would lead to lower performance (Endsley, 1999).

On the other hand, joint human-computer option generation messes up the decision-making process, resulting higher insecurity by operator over his choices i.e. when machine propose another option from scratch. Thus, worse performance is linked with joint human-computer option generation than either computer or human deciding solely alone (Endsley, 1999:488-489.) Madhavan et al. (2007) highlight the significance of operator’s self-confidence, higher self-confidence improves process performance if operator is cognitively capable for selecting heuristic solution. For example, a doctor should know approximately the size of the dose which system then adjusts for patient to prevent mistakes. Ford (2016) also emphasizes the potential of human-machine cooperation to increase significantly performance through cooperation of two “experts”, instead of rivalry.

Endsley (1999:488-489) suggests that under normal operating conditions, automation benefits the performance the most when human operator oversaw generating options and selecting one, leaving automation in charge of implementation. This holds up in the higher and medium levels of automation. Even though the findings are rather old, they are in align with observation by Ford (2016) expect now automation is shifted to higher levels to oversee more cognitive tasks. Based on Ford (2016), it can be assumed that CPS will operate in the automation levels of 7-9 [table 5.2], causing humans to interfere when the system does not deliver the best performance or task is still cognitively too challenging or includes moral choices. The full automation is not desired even the case of CPS: As Endsley´s (1999:489) states, implementing without operator is detrimental for system´s recovery if automation fails. Factory or work shift without employees can easily turn out to be disaster if system fails due to cyber-attack or error, for instance. On the other hand, the lower levels of automation do not utilize the full potential of the digitalization.

Even though previous discussion provides some ideas human-machine cooperation, there are too many generalizations. This, more evidences and examples through empirical problem solving can benefit managerial decision with human-machine cooperation and therefore following problems is stated.

Problem 6: What does human-machine cooperation require?

5.4 Digital-to-Physical Conversion

Recent technological development has made acquiring and using advanced robotics cheaper. Absorbing data from physical world, interpreting it for human operator and machine, and then adjusting data based on response is base for I4.0 (McKinsey, 2016.) Thus, it is not surprise that Kuka, a German manufacturer of industrial robots, declares: “It is a fact that no robot today has any future unless it is capable of being integrated into complex, networked production systems on the basis of standardized mainstream technologies.” (Kuka, 2017:34-35). Acatech (2013:24-26) states that the software used in digital factory or CPS should support orchestration in areas such as “safety and security, confidence, reliability, usage, operator model convergence, real-time analysis and forecasting”. Orchestration, or reference architecture seamlessly interlinks processes and service over the supply chain to operation management i.e. data flows from customers and suppliers via CPS to production and then back. According to Baxter et al. (2011) and Mumford (2006), the system design should rest on principle that technology does not dominate design. Because CPS will increasingly interlink humans, machines, and environment, the design should understand the social and technical influence on the functionality of the system which means that system can meet its requirements but fail to deliver expected support for real work if it is too complicated to use or understand

For linking physical world into cyber space, Behrad Bagheri & Kao (2015) introduce a 5-level structure of CPS. First part is smart connection which combines data from various sources such as ERP, MES, SCM and CMM. Smart connection requires two fundamental structures: seamless flow, and suitable sensors for data collection from physical world. The second level, data-to-information conversion, brings self-awareness for machines by analyzing the meaningful data. As third comes cyber level which is the heart of the system, acting as the central information hub and connecting physical and cyber environments. Fourth level, cognition level, visualizes up-to-date information to human operator. The highest level, configuration level, is the preventive and corrective level with combines artificial intelligence and human cognition to cyber level, sending orders to cyber level. In practice, the seamless flow has been demonstrated by converting speech into written Chinese symbols through a robotic arm, and answering to complex, riddle-like question in TV-show Jeopardy in which IBM’s Watson managed to win the best human player in TV-show’s history (Ford, 2016; Lewis, 2016; The Economist,2015). Previous introduction of digital-to-physical conversion includes several viewpoints and obviously needs some further discussion.

At least in simulated environment Watson and CPS have demonstrated significant results. Based on earlier 5-level model, it is quite clear that connectivity does not itself bring desired cost savings. When interlinking various sources of data to CPS for analysis, one might face the fact “garbage in, garbage out”, meaning that input data which is not meaningful, valid, and high-quality does not result remarkable output. Thus, large investments to CPS is useless if the sensors and data acquisition lacks behind.

In table 5.1, EY (2016) states that very important technologies for business models among German firms are: IT solutions (for 87 % of respondents), machine-to-machine communication (45 %), and cloud computing (43 %). Also, cyber-security and lack of standards and technical specifications are among the issues recognized in table 5.1 and by academics (e.g. Acatech, 2013; Drath, & Horch, 2014; Vogel-Heuser & Hess, 2016). For example, more than one-third of surveyed US and German firms identified data security as major problem. Corresponding Swizz results show 84 % believing that I4.0 will increase cyber-risks. Even though some digitalization solutions are already in use, interlinking various systems efficiently and securely raise problems. According to McKinsey (2016:43-47) the threat of cyber risks increases when more computers, robots and other devices are online. Increasing number of interlinked machines increases the overall complexity of the system which causes that entirely reliable and secure system is unlikely. Thus, possibility of increased computer vulnerability or “security holes” is more likely.

Digital-to-physical conversation seem to include several aspects. Even though they are mostly technical, managers should understand the basic principles in order to connect business and technology profitable and safely. Therefore, following problems is expressed

Problem 7: What aspects digital-to-physical conversion in digitalization of manufacturing firm include?

Problem 8: How to ensure cyber-security

6. RADICAL CHANGE

Gersick (1991); Stoddard & Jarvenpaa (1995), and Tushman et al. (1986) recommend executing radical and incremental change with different kind of tactics, at least partially. Table 6.1 lists the common characteristics of radical and incremental change tactics. Generally, radical change tactics emphasize excluding past stakeholders for building new processes, when incremental tactics emphasize including stakeholders in order to improve current processes. However, none of the three studied firms (by Stoddard & Jarvenpaa, 1995) used solely either radical or incremental tactics: radical tactics dominated the design phase but incremental tactics came along or took over in implementation.

Table 6.1: Tactics for Organizational Change (Stoddard & Jarvenpaa, 1995:86)

Category	Incremental change tactics	Radical change tactics
Management	Internal Leadership from existing management	External leadership from outside of the organization
	Broad organization-wide communication	Selected and focused communication; face-to-face and 1-to-1
People	Adapting change according to people	People must qualify for new organization
	Change comes from motivation to self-improvement	Organization must believe cognitively for change and might need to face a crisis.
Process	flexible milestones	firm milestones
	Broad participation of current stakeholders	Excluding current process owners

On the other hand, Liker et al. (1987) observed that the changing the technology and organizational culture at the same time might cause psychological costs which results weaker outcomes than expected. This is tightly interlinked to digitalization and I4.0 which not only change the technology which is utilized for production, but the change will also reshape the way of work. For example, human cooperation with robots will most likely increase. Therefore, further discussion about radial change in the context of I4.0 is required to better answer for research question.

6.1 Radical Change Tactics

Tushman et al. (1986:35-42) state that organizations tend to fall in crisis before reacting properly. Replacing management and excluding the current process owners and thus releasing organization from the past commitments, have been observed to increase survival rate through radical change. According to Tushman et al. (1996:18), incremental change is easier for the organization because uncertainty is on tolerable level and overall system adapts faster the minor adjustments than to whole new design.

Tushman et al. (1996:18) separates cultural inertia i.e. how thing have done earlier from the structural inertia which consist of organizational characteristics such as structure, processes, size, systems etc. They see that cultural inertia impacts on every level of the organization, when structure-based inertia might have even department specific variation. According to Tripsas & Gavetti (2000:1147) especially difficult for managers of established firms is to overcome cultural inertia because interpersonal cognitive adaptability might differ between organizational levels. For example, Louis Gerstner managed to overcome IBM’s predicament after he was hired by recognizing that in addition to new strategy, the firm needed a new culture and way of work to overcome the cultural inertia and follow the change through. Overall, cultural inertia and creating new business models have been recognized to be more difficult for managers to overcome than encouraging to develop new technologies or finetuning organizational structures and processes. For example, Tripsas & Gavetti (2000:1158) state that systematic behavior for recognizing technological innovations at Polaroid in 1990’s, resulted the necessary technologies for digital photography. However, top management’s incapability to think beyond its traditional razor-razorblade business model (selling cameras and films separately) and agree firm's future led to major crisis (Tripsas & Gavetti, 2000:1158.)

However, there is a reason why especially structural inertia exists: it is a source of profitability during equilibriums. As discussed earlier, incremental change happens within the limits of current structures and business models. Thus, only minor adjustments exist with a view to maximize the short-term profitability and competitiveness in relatively stable environment. Process-wise, incremental change aims to decrease the fluctuation and increase predictability of outcomes. However, incremental change is not a key to long-term success: firm operating in competitive environment will face the radical change eventually. (Benner et al., 2003, Tushman et al., 1996).

Also, executives might have very different idea about usability of new technology compared to factory floor operators or middle management. Rapid technology-based change, like I4.0, has been recognized to be less fatal for firms when structures and culture are tuned to identify and utilize incoming opportunities. Processes to identify opportunities can be split into development and selection of new technologies, and processes and capabilities to utilize technologies under new business models (Reijers et al., 2004; Liker et al., 1987.) Therefore, at lower levels of organizational hierarchy early isolation should be pursued. Cognitive, motivational, and obligational barriers causing internal inertia should be minimized or removed to successfully reshape the organization (Stoddard & Jarvenpaa, 1995:81-82; Tripsas & Gavetti, 2000.)

People must qualify for change statement is tightly interlinked to no-layoffs-promise; clear correlation between broken promises and amount of criticism by employees has been observed. Criticism under broken promises derives from employee's perception that he did not receive the outcome which was promised or deserved. The feeling is based on lost outcome or absence of perceived fair policies and it can strengthen if interpersonal injustice by subordinate or supervisor is witnessed (Liker et al., 1987; Kickul et al., 2002:472.) Along with keeping adaptable employees along, maintaining and communicating selected approach for change has been recognized as vital part for minimizing the critique. Kickul et al. (2002:473-478) state that involving the employees early in the discussion prevents formation of job dissatisfaction, intentions to leave the firm, lower job performance, and lower solidarity towards colleagues. In practice, this could mean consulting operators prior the change, communicating in person to employees why change happens and how it realistically affects one's work, and following the change trough. However, this approach clearly relies on more incremental than radical tactics.

6.2 Incremental Tactics

Radical change does not always cause mutation in the environment, basis of competition, or functionality of current business model. If change only dismantles current business processes but does not threat the whole strategy, total cognitive change in the culture or business model can be highly dysfunctional. Thus, organization must be able to recognize and separate change that requires only the development of new technical skills from the one that asks for adoption of a different strategic beliefs (Tripsas & Gavetti, 2000:1159.) There are some evidences which suggest that digitalization requires only updating tools and processing. For example, most likely manufacturing firm continues producing goods but the processes are just controlled by CPS. Also, among surveyed German firm in table 5.1 only 16 % see new business models raising through digitalization

However, there are even more evidences suggesting that digitalization requires new strategies and "hard" radical change. Throughout the surveys in table 5.1 firms are worrying about lack of necessary skills in digitalization and new work methods. This indicates strongly that new way of thinking and acting is required. Also, McKinsey (2016) states the I4.0 technologies enables in the futures firms to mass customize its products and thus increase responsiveness and maintain economies of scale, this includes utilization of new technologies and business models. Additionally, already discussed human-machine cooperation suggests that way of work and firms' culture must be modernized and thus digitalization will not be just process optimization within current business model. To clarify radical change, following problems and aspect is included in the consideration.

Problem 9: What kind of change tactics I4.0 requires?

7. EMPRICAL ANALYSIS

There are four experts who participated in this study. Even though the interviewees were chosen based on their occupation, answers and opinions do not represent the official statements of the organizations the experts belong to.

7.1 Description of the Chosen Interviewees

Mr. Ylönen of Tekes, a senior technology adviser of big data, analytics, and AI. Tekes is a Finnish publicly funded expert organization for financing research, development and innovation. Annually Tekes finances around 1500 business research projects. Mr. Ylönen faces industrial internet, or I4.0 in three different ways. Firstly, Tekes funds Finnish startups and many of them are developing solutions related to industrial internet of things. Secondly, he is in charge of big data, analytics, and AI at Tekes' industrial internet team. Thirdly, he co-runs a funding campaign for AI which is tightly interlinked to industrial internet of things.

Mr. Niku of PwC Finland, a senior manager of digital transformation. PwC Finland is part of PwC's global professional services network with more than 223 000 people in 157 countries. Mr. Niku described that PwC has systematically promoted I4.0 globally during last two years. He oversees coordination and development of that project in Finland. All the cases which his team works with, are related to digitalization of different industries.

Mr. Leinonen of ABB, a local business unit manager of robotics. ABB is one of the world leading manufacturers of industrial robots and robot systems. It operates in 53 countries and over 100 locations globally. Mr. Leinonen described that many I4.0 applications are interlinked to manufacturing industry, and from that perspective, he faces the phenomenon often.

Dr. Kuivanen of VTT, a business development manager. VTT, or Technical Research Centre of Finland is one of the leading research and technology organizations in Europe. VTT focuses on providing expert services for both private and public sectors through its own research and know-how. Mr.Kuivanen mentioned that digitalization itself is part of all the activities which VTT takes part of nowadays.

7.2 Current Status of I4.0 and How Firms Have Reacted to It in Finland

Generally, the awareness of phenomenon has been, based on the interviews, increasing steadily during last two years. According to Dr. Kuivanen of VTT, especially smaller Finnish firms are still quite skeptical about the concrete benefits of I4.0. On the other hand, larger firms have been using some digitalization technologies in their products nearly 30 years. For example, during the last 10 years, firms have been equipped their systems and products with proper connectivity capabilities, said Dr. Kuivanen. Mr. Niku of PwC also mentioned that large firms have been actively promoting I4.0 and digitalization for a few years in Finland but now they are actually starting to implement these technologies. However, in his opinion, SMEs have also gradually awakened but they are facing bigger challenges with digitalization than larger firms, mostly due to fewer resources. In Finland digitalization relates especially products, services, and business models instead of digitalizing the factories. Usually digitalization of factories occurs when companies are planning to establish a new plant or running down an old one.

According to Mr. Leinonen of ABB, awareness of I4.0 has increased during last couple of years and ABB has been actively taken part of the discussion. Nevertheless, awareness varies a lot depending on the industry and size of the firm. Personal courage and ability to keep abreast of the latest development contribute a lot, he mentioned. Mr. Ylönen of Tekes stated that manufacturing industry is behind the other industries in data utilization. He reckoned that even though manufacturing firms are collecting data, they are exploiting perhaps couple of percent of it. On the other hand, online firms have their data already in right format for analysis, compared to industrial machines which need various sensors to collect data. Finnish firms have overall tackled the challenges regrettably slow. He hoped that high hype around AI would trigger further progress in Finland.

7.3 How to Capture Economic Value of I4.0 and Does Digitalization Bring Value?

All interviewees agreed that digitalization and I4.0 can really boost firms' competitiveness but digitalization must be tightly interlinked to business and cannot itself be the purpose of action. For example, Dr. Kuivanen stated that at first firm must recognize if digitalization creates value for the firm and its customer, "nowadays it usually does."

Dr. Kuivanen has seen some cases where the firm has managed to decrease unit price by 50-90 % through systematic automation and use of robotics when comparing to previous, rather manual processes. He reckoned that generally savings can be 20-90 percent of the unit price but potential cost benefit decreases if processes are already efficient and somewhat automatized. ABB has been able to improve the productivity at one of its factories by 60 % through automatization, said Mr.Leinonen. Lower, 40 percent improvements have been also reached. However, Mr. Leinonen emphasized that ideally product should be designed from scratch for automated production in order to reach optimal benefits. Mr. Niku of PwC said that generalizing potential benefits is difficult as one should understand the case and firm's situation before further evaluation. Generally, he said, SMEs can reach better competitiveness against larger firms as they usually have smaller commitments for past structures and thus ability to leapfrog into higher levels of automatization.

Dr. Kuivanen expressed his trust on firms' ability to make decision on digitalization. In practice, productivity has increased through more efficient technologies and better materials for a long time. At the same time digitalization forces to reshape the nature of factory work but it is the only way to stay competitive, he mentioned. Mr. Niku also agreed that increasing the level of automation improves productivity and decreases firm's dependency on labor costs. Digitalization produces more transparent processes which allows to integrate whole supply chain and distribute accurate real-time information.

7.4 How to Start Data Analytics and Digitalization

Mr. Ylönen said that in many cases firm has acquired some data and then hires someone to do data mining and find interesting patterns or correlations. This, he said, has proven to be wrong approach. Firstly, one should define what is the business problem and then identify necessary data to solve the problem. After data is collected, the problem is then tried to solve with data analytics and AI. He reckoned that even some of the projects financed by Tekes have failed because firms have spent their time and money for acquiring and cleaning data which has caused a failure to generate any valuable output. He said that also Gartner, a technology researcher, has mentioned the problem of skipping customer's need when firms are starting to utilize their data.

Dr. Kuivanen told that current discussion oversimplifies digitalization by suggesting that adding sensors and finding interesting patterns from data is enough. In reality, the actual benefit of digitalization should be rather concretized through case or pilot. Digitalization is a gradual process and usually firm starts from situation of holding unused data sets. Current data should be learnt to utilize before adding new sensors into machines. New sensor should then produce data which can be used to generate more value for customers.

Mr. Niku expressed that Finnish SMEs in manufacturing industry are looking for assistance to understand how digitalization will impact on their business and how one should respond to digitalization. Thus, assistance is needed in rather strategic questions. Mr. Niku also suggested that starting with planning and strategy is advantageous approach. When it comes to digitalization and vertical integration, or integrating systems from factory floor up to ERP, the potential benefits and actual need for change should be clear to justify the investments. Another option which has been used is to start with pilot. Eventually in the scaling phase, new business model or process should anyhow match with firm's strategy and be profitable enough, he mentioned.

To increase flexibility, processes should be designed for rapid changes in production. For example, decreasing set up times, and improving communication between machines and operators. Internal processes should be also aligned with new work methods. Increased responsibility and demand for more advanced problem-solving might require decentralized leadership, contributions to life-long learning, and suitable multidimensional KPIs which focus on process efficiency, instead of produced quantities. Solutions for previous might include lean methods such as best practice network within the organization, and possibilities for e-learning (Acatech, 2013:55-57; McKinsey, 2016.)

7.5 What CPS such as IBM's Watson Means and What is Its Future?

Dr. Kuivanen said that IBM's Watson and similar systems are not yet close to real-life applicability in factories. For example, Watson has been used for developing machine learning and AI but full utilization per se is in the future. However, machine learning has been already deployed in practice. He mentioned that even machines do not have to repeat same mistakes again if they know what went wrong on first time. Watson and other CPSs might be needed to control in larger scale the future production systems and processes, said Dr. Kuivanen. How far in the future, depends in his opinion how fast the other areas such as machine learning and AI will develop.

Interestingly, Mr. Ylönen believed that IBM's Watson will lose the battle of AI platforms. He stated that Google's TensorFlow and similar AI platforms by Amazon, Baidu, and Facebook are based on open-source licenses and therefore free to use, whereas IBM is expecting to get paid for its services. In startup environment where he works, startups are systematically choosing open-source platforms with Nvidia GPU compatibility. These startups are the most probable source of radical innovations in area of AI. For example, he estimated that around 90 percent of 45 firms which applied for Tekes' AI project were using open-source platforms. Furtherly, Mr. Ylönen did not expect to see any global standards for CPSs nor single large player. Mostly likely there will be rather fragmented markets for sensors, cloud services, data processing services etc.

Mr. Niku agreed that AI and cogitative machines can most likely help to optimize production processes and decrease lot size down to single production while maintaining economies of scale. Even though systems like IBM's Watson, Siemens'

Mindsphere etc. are existing, he assumed that due to long investment cycles it will take some time before seeing these system in extensive use. On the other hand, he said, radical change in operational environment or visionary firm can be sources of faster piloting of those technologies. Mr. Leinonen said that ABB itself has a cooperation agreement with IBM's Watson. He believed that Watson will generally help to optimize processes through better utilization of data and enable ABB to develop more efficient production lines. Naturally, optimizing supply chain thoroughly will help to decrease waste, he said.

7.6 How to Acquire Necessary Skills and What Kind of Skills Will be Needed

Dr. Kuivanen suggested that one source to acquire new skills is cooperation with startups. Startups are often looking for new markets, and for more established firms the cooperation or using services by startup can be a first step to recognize new opportunities. However, eventually firm should rely on hiring new or training old current employees in order to build more durable skills. Generally, for smaller firms one of the largest challenges is lack of skillful employees and fewer resources compared to larger firms. In Finland, the transformation of Nokia has increased the availability of ICT skills. However, those skills are not always completely suitable for manufacturing industry without some additional skills and know-how. He also supposed that in the future, operators must understand more systematically how systems and processes are arranged at higher levels to identify why something works or fails

According to Mr. Leinonen, operators should have somewhat know-how in programming and especially willingness to learn. Understanding basics in machine, electrical, and automation engineering would be beneficial. Still, machine and system manufacturers are always trying to develop user interfaces which are easy to use, meaning that operator will check error message and perhaps make some adjustments to the system. For example, even more complicated systems such mobile phones are made easy to use, he said. What was also mentioned is that firms simply must accept that machines are increasingly entering to manufacturing industry, and machines and humans will be working together. Mr. Niku mentioned that even though automatization increases the requirements, from firm's perspective hiring new employees or designing necessary training program is quite straightforward task once the change has been planned. However, changing organization culture has been observed to be more difficult task. Agile and lean methods, and more collaborative way of work can be quite difficult to adapt with limited previous experience, he mentioned.

Acatech (2013:52-57) recommends not only to place efforts in technological development, but also in training and continuing professional development. The academy questions the advantage of traditional standardized education and (along with McKinsey, 2016) suggests firms and industry to increase cooperation with academic and vocational training providers to impact in education themes and what is studied. In practice, Mr. Ylönen explained, from Tekes' perspective joint projects should include enough players throughout the value chain, and both larger and smaller firms in order to create opportunities for international business which is the main target of Tekes. For example, software supplier might need university´s help to produce more competitive algorithm which Finnish firm then can use in its business. Usually larger firms have better understanding over the opportunities in the markets which smaller, agile firms can utilize to create or produce something innovative, he said. Mr. Ylönen described that universities are willing to study anything which has scientific merit and can generate scientific publications but research problem should be a one without proper commercial solution. Also, roles during the project should be carefully defined. This means excluding researches from operative tasks and letting them focus on questions which firm cannot solve by itself.

Another aspect on learning, stated by Huy (1999:331), is that individual learn first by thinking and then acting. There are several studies (e.g. Tzafestas et al., 2006:360; Precup et al., 2011; Jara et al., 2011) suggesting that virtual training laboratories such as training through virtual reality games deliver good results compared to physical lectures or online courses. Especially this holds when acquiring new mid- and high-level skills. Approach has also received positive reviews from undergraduate engineer students participating the training. Fundamentally, training is playing significant role in radical change as business process redesign without proper training has been observed to increase resistance towards change and estimated to impact negatively on the achieved benefits (Stoddard & Jarvenpaa, 1995.)

7.7 Human-Machine Cooperation

Employee should generally understand that digitalization is not about competition with machines but new way of working, said Mr.Leinonen. Also, Mr. Ylönen highlighted that in the future human operator will be working together with robots instead of controlling machine. He also mentioned that current development and trend is the first time when human brain and cognition are tried to substitute with machines. For example, previously automation has focused on physical task such as carrying or lifting. However, Mr. Ylönen said, purpose is not to remove humans but support our strengths and help to reach better performance. He said that development will create new kinds of occupations and already now there are occupations in Finland which oversee training of machines. He believed that even employees in factory floor are expected have skills to train machines independently.

In practice, the degree of use of automation can be directly determined through a) operator's intention to use the system, and b) perceived personal capability to use the system. To achieve the advantages of human-machine cooperation both components should maximize. First, perceived personal capability is affecting to intention of use. Lack of needed resources such as time and expertise, have negative impact to perceived capability in addition to demographic characteristics such as age and gender**, s**o that younger generations and males, on average, have fewer difficulties with new systems. Secondly, intention to use the system increases when system is perceived as easy to use, perceived personal capability is high, system is suitable for its task and attitude to new system is positive. Also, level of use increases when considered applicability of the system for the designated task is high which itself is influenced by socially formed imaged, basing on design, context of the task, and the level of automation (Ghazizadeh et al., 2012:42; Lee et al., 2010:1753; Mathieson et al., 2001; Venkatesh et al., 2003:467.)

Negative image which the was also mentioned during interviews, raises from employees feeling that automation will have a negative impulse for his future in the firm. Negative image towards new work methods results stronger negative emotion towards the change (Liker et al., 1987.) Previous findings match with opinions by Mr.Niku regarding to difficulty of changing organization culture towards new work methods. To increase level of use and arouse positive images on human-machine cooperation or CPS, Lee et al. (2010) suggest engaging operators starting from the designing of new processes and methods. Also, excluding incapable employees according to radical change tactics in table 5.1 should be an option.

Also, Madhavan et al. (2007) state that trust is a critical factor in human-machine relationship. Humans tend to treat and interpret machines as another human, and thus, apply methods in human-human interaction to human-machine interaction. Merriam-Webster dictionary (2017a) defines trust as "assured reliance on the character, ability, strength, or truth of someone or something", or system's ability to fulfill its duty. Empirical findings by Madhavan et al. (2007) suggest that humans tend to trust on machines more than to other humans. However, they also suggest that such trust might influence to evaluation and turns operator into a passive observer, increasing risks and decreasing the attention paid for the process. Humans are also more sensitive to mistake made by machines which might be caused by the fact that human advisors are perceived more "familiar". This might be the reason why humans seem to react socially similar ways to machines but still perception of advices by human-human and human-machines relationships varies. Overall, imperfect human advisor is easier to accept than imperfect machine (Madhavan et al., 2007.) Nudges, behavior change support systems, have also observed to improve work results. For example, incentives framed as punishment ("losing" the bonus if target is not reached) enhanced productivity by 1 percent when presented passively next to work stations (Hossain & List, 2012) Oinas-Kukkonen (2013) states that information technology always influences user's attitude and opinion, sometimes unintentionally. Thus, the system and training content might have larger impact to work motivation and change than expected.

7.8 Aspects for Digital-to-Physical Conversion and Data Quality

When transferring data from between system components, one should be sure that data from the sensor is valid, said Dr. Kuivanen. For example, system can check that the value is logical and coherent compared to previously measured values. Generally, the data chain includes too many stages for a single good model or answer. However, the system should have ability for learning from data to prevent cumulation of false information. Mr.Niku emphasized that connecting Watson into system or digitalizing only some tools is not enough because all parts should be integrated with each other. In his opinion, the biggest challenges have been with manufacturing execution systems which, so far, have had the weakest connectivity. Thus, lack of standards creates some issues with digitalization. Another thing which he mentioned is that firms should consider sharing some of their information with other players in the industry. Especially it could be valid when the service or ecosystem is produced jointly. He also believed applications for delivering information via augmented reality glasses or mobile devices to become more popular in manufacturing environments. Mr. Leinonen explained that quality inspections should ensure that final goods within the specification, robots are able to monitor their movements and thus avoid collisions, and robots can be connected into system with different connection devices which per se is not a new thing.

Even though robots and automation will be increasingly participating to data collection, option generation and implementation phases (McKinsey, 2016; Acatech, 2013:6-7), Mr. Ylönen viewed the current process of distributing information quite easy from the perceptive of organizing the task and network. Generally, sensors are collecting data during the process which is then is typically sent to cloud for computing. However, incoming trend of edge computing requires further research for solving issues like cyber security, he mentioned. According to Gorecky et al. (2014), operator´s access to easily understandable visualizations of data, for example, through virtual reality or augmented reality is vital. Also, a system or information which restrict operator´s control, such as self-driven cars, are less likely accepted unless effective communication. For example, car is accepted to intervene because it saves lives or prevents a collision

7.9 Cyber Security and Other Risks

Interviewees confirmed that cyber-risk indeed is among topics which concern managers when talking about I4.0, industrial internet or digitalization. Dr. Kuivanen mentioned that especially large firms which control their processes over wireless networks and distribute large quantities of data into cloud service are concerned about the threat of someone stealing or misusing their data. Mr. Niku also mentioned that using cloud services raises the question of the ownership of data. Mr. Ylönen stated that AI and cyber security are areas which one must master or otherwise digitalization is not possible. For example, some consumer devices such as web cameras are often unprotected. This vulnerability in these devices has been already exploited by hackers but one cannot exclude similar threats in industrial environments, said Mr. Ylönen. He mentioned that risk of distributing false information to sensors must be also considered, in addition to threat of losing some valuable data. According to Mr. Ylönen, current trend of moving towards edge computing, or computing the data near its source will generate new kind of cyber security issues. Each device processing data will need corresponding information security as cloud has nowadays. Required solution is technically more complicated due to decentralized infrastructure. Another risk is related to deep learning and AI; those technologies are still “black boxes” and researches do not understand how algorithm in practice learn and how answer is produced.

Generally, various types of attacks such as blocking the system via denial-of-service attack, false data injections, replay attacks to catch data, and covert attacks via “hidden” channel are all possible in digitalized industrial environments. System-wise the threats can be modeled by simulating exogenous inputs that would put system’s stability in danger. In addition to revealing system vulneraries and analyzing the impact of cyber-attack, revealing and locating attacks independently can be done. However, from the perspective of the defender, this approach requires notably more effort to analyze system and defend it due to complexity of computing environment (Mo et al., 2012; Pasqualetti et al., 2013; Pasqualetti et al., 2015.) Thus, securing the future industrial infrastructures requires more research.

Dr. Kuivanen said that VTT has a rather large team developing and testing solutions for cyber security which VTT also offers for its customers. He also stated that several firms provide services to ensure systems’ security and that starting point for cyber security analysis should be recognition of possible threats. This approach match with McKinsey’s (2016: 43-47) recommendation to identify firm’s key asset and then prioritize the security around them. In addition to protected networks within factories, Mr. Leinonen pointed out that industrial robots are per se protected with suitable software. Also, cyber security should not be viewed through a single machine or layer, but analyzed as a network. For example, he clarified, what devices can do and how the network topology is organized. He also mentioned that processes including industrial robots lifting heavy objectives must be possible to terminate safely in case error. Furthermore, cyber security practices by human operators, also mentioned by Mr. Leinonen, might decrease the reliability of the system. For example, industrial virus called Stuxnet infected Iranian nuclear power plant most likely via defected USB device which was plugged into network by an employee (F-secure, 2010).

7.10 Managing Digitalization

According to Mr. Ylönen, managers should understand that AI and its opportunities are not science fiction but present. It is simply based on mathematics and smart algorithms. Even though AI is heavily hyped, managers should realistically evaluate where digitalization and AI can or should be used within the business. Unfortunately, several managers in Finland do not understand that. Ultimately, table 5.1 suggest, a new management might be needed to digitalize the business.

Mr.Leinonen listed that three barriers for digitalization are lack of automation know-how, lack of capital to invest, and lack of trust on firm's future or unlike survival. Banks might also perceive the firm unreliable if it has not done any investments for a long time. Finnish firms should also consider their competitive advantage, said Mr.Ylönen. AI needs data to learn and Finland has firms with unique data in forestry and machine building industries. Firms should realize where they can realistically win the competition especially now when AI is taking its first steps.

8. INDUSTRY 4.0 AND RADICAL CHANGE TACTICS

This chapter concludes theoretical research on radical change and with the information gained from empirical part, recommends suitable action to implement digitalization strategies before conclusion.

8.1 Management Component

Empirical part mentioned that there is a certain lack of recognizing the potential of digitalization. According to Stoddard & Jarvenpaa (1995), replacing top management with externally recruited managers has observed to lead more than three times higher success rates in execution of frame-braking change compared to firms keeping the old management. Researches also suggest that only in 6 out of 40 studied CEOs can design and implement radical change. However, redundant CEOs have been observed to achieved rather successful career in other organizations, indicating that per se they are not bad managers (Stoddard & Jarvenpaa, 1995; Tushman et al., 1986:35–42; Tushman et al., 1996.)

Thus, even successful managers can in long run become “myopic” for incoming change. Therefore, a new executive can be an efficient vehicle to implement the radical change as she can bring in different skills and fresh perspectives, and have no commitments to past structures. Tushman et al. (1986:40-41) declare: “Direct personal involvement of senior management seems to be critical to implement these system-wide changes” which holds in both planning and implementation phase. The most efficient managers can also foresee the incoming radical change and prepare the organization for it which, however, is not very common. For example, Polaroid managed to overcome the cultural inertia with new CEO and top management team. New management could associate with the “right” view of middle management, implanted the radical change and thus solved the problem which caused the crisis (Tripsas & Gavetti, 2000.)

Tripsas & Gavetti (2000) found that current management can only build new capabilities only within the boundaries of their current beliefs. However, sometimes current managers can push the radical change through but during the process the might look for external help. Gersick (1991) observed that over half of the teams were looking for an outside “trusted advisor” to check external requirements, help with decision making, and push change forward. Stoddard & Jarvenpaa (1995) observed that all three studied firms utilized external help (consultants) to support strategic choices in the beginning, to audit the process during the implementation, and at one the firms, consultants played major role during the whole change. According to Yaniv (2004:1), individuals try to improve their judgment accuracy, and they have got high expectations towards outside advices. Also seeking justification for one´s choices, sharing responsibility of the results, and to match with the external expectations have been reordered as reasons for trusted advisors. Outside advises have been proved to improve the results in a long run Yaniv (2004:1).

8.2 People Component

To support the radical change, no-layoffs-promise should not be guaranteed. Such promise violates the basic principle of radical change as people should qualify themselves for the new, instead of building new structures around them. This approach might include layoffs to signal that resistance is not tolerated (Stoddard & Jarvenpaa (1995:81-82). Radical change usually leads to redistribution of power and resources and therefore challenges the basic assumptions which employees have. However, Employees have been reported to be less forgiving when the loss is tangible or easier to quantify (Gersick, 1991, Huy, 1999:332; Kickul et al., 2002.)

Too rapid and “harsh” change can have a negative impact to employees. On the other hand, employees’ negative attitudes may have an impact to organizational efficiency (Gersick, 1991; Huy, 1999, Kickul et al., 2002:471.) For manager, it is vital to understand that major uncertainty is linked with the radical change because consequences are hard to evaluate beforehand for employees which might be source of inertia (Huy, 1999:330.)

8.3 Process Component

Incremental change activities should be separated from activities dedicated to radical change i.e. developing new technologies, changing organizational culture, and planning new business models (Benner et al., 2003:238-239; Tushman et al., 1996; and Tushman et al., 2010). Incremental change is the most effective when planning take places in the unit which owns the process. While the process units oversee optimization, the senior teams above those units should have cognitive processes to support forward-looking innovation and backward-looking experiential learning. To reach this state organization must be ambidextrous. (Benner et al., 2003:238-239; Tushman et al., 1996:8-27.) However, as discussed in chapter 3, those systematic processes should be exposed to careful evaluation before implementing them so that wasting resources in unnecessary DCs can be avoided. Thus, ambidextrous can be also viewed to refer not locking firm with rigid DCs.

When a new technology or innovation is recognized and it is utilized through suitable business model, the future activities should focus on improving the process i.e. incremental change. On the business function level, successful firms split the functions into smaller units but scale when possible. For example, shared R&D, finance, and purchasing but separated product divisions. Even though soft social control is exercised by splitting units into somewhat loose incremental change and radical change teams, the senior team should be able to pursue hard social control also. Ambidexterity can be also implemented by separating radical planning through joint-ventures, alliances, acquisition or formally linking interdepended functional units. Ambidexterity suits especially well to technological change; in 1960-1970s firm were operating with transistor technologies were unable to cope with innovation while being locked with maintaining profitability through old technologies (Benner et al., 2003:238-239; Tushman et al., 1996:8-27.)

One trigger to stop the inertia of equilibrium seem to be milestones. Project groups with live a short life spam, from hours to months, usually execute major transition on halfway of the project´s deadline sometimes even unconsciously in order to reach the target. Among organizations such deadline can be 5-year plans or investment time of a venture capital fund (Gersick, 1991.) However, Tushman et al. (1986:35-42) observed that for older organization and long-lived executive teams it is harder to break equilibrium even with milestones. Gersick (1991) noticed that CEOs of startups created artificial milestones for strategic planning and then evaluated the plan after six months before crafting the next plan. Same pattern was repeated even though they were aware of problems with current plan. Another CEO described how they overcome product failures with similar unofficial offsite session (Gersick, 1991). The beginning of the change might appear disorganized but according to Gersick (1991) there is an observed moment during the radical change when system and process transition shifts from chaos towards clarity. For example, new small piece of information may provide another way to look at situation and “things fall into place” which from its parts matches with ad hoc process.

9. CONCLUSION

This thesis studies digitalization in manufacturing industry. To achieve an understanding on digitalization both empirical and theoretical part are included. The main research question of the study was "*What are the typical managerial problems related to I4.0 and digitalization of a manufacturing firm?*" Two sub-question to further clarify understanding on selected topic and with selected methodology were "*Which of the problems should be solved with DCs and which with ad hoc processes?*" and "*How well ad hoc processes help to understand digitalization-related problems in the context of I4.0?*"

Empirical part of this thesis shows that I4.0 is a hot topic among the manufacturing firms. However, capabilities and awareness vary a lot between firms and managers. Empirical part and its findings also confirm Heiner et al. (2014) statement regarding to definition of I4.0; various concepts and technologies complicate or rule out clear classification in individual cases. Thus, instead of dealing I4.0 and digitalization as one big event, managers should be able to recognize beneficial technologies and business models for real business problems from the wide range of solutions. This approach was also recommended throughout the empirical part.

It is difficult to estimate if digitalization of manufacturing sector will shape our society and way of work like steam power, electricity, and IT did. Some academics predict (e.g. Frey & Osborne, 2017; Ford, 2016) that up to 47 % of occupations in USA might become obsolete due to digitalization. On the other hand, obstructing I4.0 might from employer's perspective cause higher dependency on labor cost, weaker productivity, and less efficient processes than competitors have and therefore decrease firm's competitiveness. Ultimately, if the change is delayed systematically on national level, it can jeopardize the competitiveness of the nation. Thus, it is unlikely that any country or firm can afford to overlook digitalization.

In Chapter 1.3, the target of this study was defined to clarify understanding on digitalization and offer tools for managerial decision making. To achieve that, chapters 9.1, 9.11 and 9.12 go through main findings and circumstances which seem to occur during digitalization process. Managerial implications of this study are discussed in chapter 9.2, and limitations of this study for generalizability are analyzed in chapter 9.3. As mentioned earlier, I4.0 seems to be somewhat fragmented area of research. Also, ad hoc process seems to require more research. Therefore, recommendations for future research are suggested in chapter 9.4

9.1 Main Findings

As mentioned earlier, I4.0 and overall digitalization of the manufacturing sector are highly hyped and rather new phenomena (Heiner et al., 2014). In the past, dynamic capabilities framework has been used to explain why some firms manage to go through successfully such a big change and some of them not (Eisenhardt & Martin, 2000; Teese et al. 1997). Based on, inter alia, Winter, 2003 and Ritala et al., 2016, this study strengthens DCs model with ad hoc process model in order to recognize which part of the successful digitization might be explained through DCs and when the success can be derived from successful reaction to spontaneously appearing, unfamiliar problems.

Table 9.1 categorize the recognized managerial problems which occur during digitalization per familiarity of the problem. The table helps to define for which I4.0-related problems managers and organization should develop systematic skills, or DCs, and which problems are most likely too complex, case-specific, and fast emerging that it would be economically smart to spend resources to systematically solve all possible aspects beforehand (Nickerson et al., 2007; Ritala et al., 2016). Instead, managers should utilize ad hoc process when one of these unfamiliar problems emerge. As mentioned earlier, Ritala et al. (2016) suggest that manager 1) can look at heuristic solutions for complex problems, 2) use directional search with hierarchical team for less complex problems, and 3) purchase solutions as a service for non-complex problems.

Combining ad hoc processes and DCs seem to be a practical way to define problems in general level. Ritala et al. (2016) mention that approach might be also functional in firm specific cases. Winter (2003) criticizes that DCs can lead to costly structures which can be also subsidized with ad hoc process. Ritala et al. (2016) note that DCs might ease cognitive pressure which managers and organization would phase if, for example, whole R&D department would work with ad hoc process rather than somewhat systematic research methods and structures. Thus. in some cases, excluding DCs might be even dysfunctional. On the other hand, some of the problems in table 9.1 such as cyber-security has too many aspects to develop solution for all possible digitalization-related cyber-security challenges prior the beginning of digitalization. Based on this study, ad hoc process model seems to help in understanding firm's success through radical change and designing the implementation.

Table 9.1: Categorized Familiar and Unfamiliar Problems

Familiar Problems	Unfamiliar Problems
• Problem 2: What other firms have done with digitalization and how one should react to it? • Problem 4: How to acquire necessary skills and what kind f skills are needed at future factory? • Problem 6: What does human-machine cooperation require? • Problem 9: What kind of change tactics I4.0 requires?	• Problem 1: How to capture economic value of I4.0 and does digitalization bring value? • Problem 3: Data analytics and how to start • Problem 5: What CPS such as IBM's Watson means and what is its future? • Problem 7: What aspects digital-to-physical conversion in digitalization of manufacturing firm include? • Problem 8: How to ensure cyber-security

9.1.1 Familiar Problems

Starting with problem 9 about change tactics. Based on empirical and theoretical parts, radical change tactics seems to overall fit better with digitalization. Mr. Niku mentioned that changing organizational culture and work methods have been difficult tasks and that digitalization should match with firm's overall strategy. In theoretical part, changing organizational culture was mentioned to be one the most difficult areas of change and therefore it requires "hard" change tactics (Stoddard & Jarvenpaa, 1995; Tushman et al., 1996).

Even though Tushman et al. (1986) suggest that organization might need to face crisis to recognize a problem, nothing prevents firms to prepare itself beforehand for new circumstances. Benner et al. (2003:238-239) and Tushman et al. (1996:8-27) recommend organization to develop separated structures for incremental and radical change. Based on Nickerson et al., 2007 and Winter, 2003, both of these functional units should use mixture of DCs and ad hoc processes to solve problems and increase flexibility. For example, even though one team would be hierarchically above the other overseeing forward-looking innovations, both teams can divide their problems into familiar and unfamiliar sub-problems once they appear. Similarly, Mr. Niku suggested that in digitalization might require more systematic use of agile or lean methods.

Therefore, this thesis repeats three "last choices" to launch the radical change (based on table 6.1 and other sources). Firstly, replacing management might sometimes be a prerequisite to start radical change (Tripsas & Gavetti, 2000; Tushman et al., 1986). Secondly, no-lay-offs promises should be avoided and employees must qualify themselves for the new structures or business model Thirdly, in order to minimize inertia, strategic planning should be done with a small number of participants (Stoddard & Jarvenpaa, 1995.)

Problem 2 is categorized as familiar problem because studying competitors' behavior and reacting to it, is rather straightforward process. In empirical part of this study, referred firms as well as some of the competitors consist Finnish manufacturing firms. However, especially SMEs were mentioned by Mr. Leinonen to be dependent on the courage and curiosity of one or few employees. Even though manufacturing industry has reacted to digitalization slower than many other industry (Mr. Ylönen), identifying potential technologies and business models should be possible through available information and assistance by governmental organizations for example. Based on empirical part, this thesis suggests that firstly, both SMEs and large enterprises should participate in industrial cooperation and be willing to share some of their own data. This might provide opportunities to understand markets better and get at innovative technologies. Secondly, formal processes and training opportunities combined with systematic cooperation can help managers to identify change drivers (Acatech, 2013). Thirdly, managers should understand and signal to organization that digitalization is not science fiction, but reality.

In problem 5, planning the training program is direct task for the firm once the change has been designed, according to Mr. Niku. On the other hand, cancelling or skipping the whole training program can result poor success and implementation of new structures (Stoddard & Jarvenpaa, 1995). In the future, workers are expected to understand higher levels of the system topology as well to identify why something works or fails. System-wise, easy to use interfaces are the most likely the primary target and thus using those systems should be smart phone-like, rather “easy” experience. However, this requires managers ability to understand the potential of digitalization and lead the change. Acatech (2013) recommend employers to provide tools for life-long learning.

Human-machine cooperation, or problem 6 is categorized as familiar problem. In empirical part, human-machine team was defined as a standard in the future. Also, Endsley (1999) and empirical part are suggesting that automation only enhances human’s skills and involving human control is still compulsory from the perspective of system’s stability. To achieve the calculated benefits, operator’s intention to use and perception of personal capabilities to use the system should on high-level as defined in chapter 7.7 (Madhavan et al., 2007; Venkatesh et al., 2003:467). For example, including the final user in design phase of the new system has positive impact to final level of use (Lee et al., 2010.) Future development might also create new occupations which oversee training the robots (Mr. Ylönen) which creates a demand for new kind of skills.

9.1.2 Unfamiliar Problems

To solve problem 1, empirical part suggest that one should first define what is the business problem and then evaluate if digitalization makes financially sense. However, both empirical and theoretical parts propose that in most of the cases, digitalization makes sense for the manufacturing firm. As Mr. Leinonen said:

"Theoretically, everything can be automatized but after a certain point it is not financially wise anymore." All interviewees generally agreed that potential benefits and problem itself should be clear before digitalizing. Therefore, this thesis suggest that digitalization should be targeted to solve problems with 1) firm's production or increase efficiency, and 2) customer's problem which might eventually generate new business models.

Similarly, data analytics, or problem 3 should not skip customer's need when firm is evaluating the systematic use of data as mentioned Mr.Ylönen. Both data analytics and digitalization should include a clear vision where firm's competitive advantage lays or where the probability of winning is the most probable. For example, Finnish forestry industry has unique data from forestry processes (M. Niku & Mr. Ylönen). Even though exploiting current data was identified as a good starting point in empirical part, that stage might be too company and case specific for DCs.

Problem 8, or cyber-security seems to be one the most complex topics of digitalization. Even though empirical part suggests that securing production systems and facilities under current circumstances is a clear task, new trends such as edge computing might complicate security practices of firms with all sizes. In empirical part, various network topologies, and different digitalization levels and solutions cause that developing or recommending a single good solution is almost impossible. Dr. Kuivanen also mentioned that various security services already exist in the market. In addition to current industrial environment, Pasqualetti et al. (2013) and Pasqualetti et al. (2015) suggest that securing CPS requires advanced skills in modeling which are most likely beyond the scope of SMEs. Thus, data security is an unfamiliar problem.

Problem 5, or CPS is most likely an unfamiliar problem. According to empirical findings, CPS seems to be a future solution and large-scale use of such systems was argued to take years. However, technologies like machine learning and AI are getting closer to break through in manufacturing industry which was assumed in empirical part to eventually define the evolution of CPSs. Even though definition for CPS structure already exist (Behrad Bagheri & Kao, 2015), conservatism and long investment horizon might push out the mobilization of CPS as well as whole digitalization. Also, dominance of one platform or standardized system was questioned in empirical part. Thus, selecting the suitable system, even in the future, seem to base on ad hoc processes and recognition firm's and its customer's needs when selecting the solutions.

For problems 7, empirical part suggests that digital-to-physical conversion and its implication are quite logical processes. Various data tools and methods can be used between the system parts to measure and ensure that information is logical and coherent. However. possible future technologies and trends can create new kinds of challenges which requires more research and state-of-the-art solutions. Empirical part also propose that old manufacturing execution systems have had limitation with their compatibility with newer system. Systems, required solutions, and needs in data conversion varies between firms. For example, some firms are just starting data analytics, and other might be already piloting applications for augmented reality. Therefore digital-to-physical conversion is unfamiliar problem and DCs would be waste of resources. However, this thesis suggest that management should have general understanding on the topic.

9.2 Managerial Implications

This thesis gives managers and manufacturing firms information on how to prepare for digitalization. Theoretical and empirical parts prove that expectations a towards I4.0 are high as well as achievable benefits. Until certain extent, this thesis separates individual technologies from the whole highly hyped I4.0 context and concretize the ideas. Radical change, I4.0, DCs, and ad hoc processes have been studied somewhat broadly (i.a. Ritala et al., 2016; Stoddard & Jarvenpaa,1995; Tushman et al., 1996; Vogel-Heuser & Hess, 2016). Nevertheless, this thesis makes an attempt to clarify interlinks between these concepts.

Firstly, this thesis classifies digitalization as a radical change. Literature review on radical change tactics are screened with special characteristics of digitalization so that managers are cognitively prepared to lead the change.

Secondly, this study clarifies how essential it is that managers understand the potential of digitalization and see behind I4.0 hype, and that mentioned technologies and solutions are not science fiction but reality. Thirdly, this study highlights the significance and importance of digitization and interlinking it with real life business.

Finally, as table 9.1 shows, mangers do not necessary have to solve all the digitalization related problems through ad hoc processes but for some general problems, firms can systemically create competencies i.e. dynamic capabilities and share best practices with each other.

9.3 Limitations

In chapter 4.5, this study listed and explained how validity and reliability have been ensured and improved. The chapter also discuss in depth the procedures of data collecting and ways to improve qualitative study's generalizability.

To improve the reliability and validity of this thesis, the used publications have been carefully selected to the research questions. Instead of inference-based observation, this study acquires its data through questions in person, rather than by interpreting the results from interviewee's behavior. To transcribe more reliable, an electronic recording device has been used during the interviews. Due to nature of qualitative research methods, carefully selected questions have been asked to assure the trustworthiness of a study. Aim of the study supports the generalization of interpretation; excessive generalization of single events should be avoided. Expert interviews should be a good method to gain general data which benefits this study.

Based on Eriksson & Kovalainen, 2008, following limitations should be noticed with generalizability of the empirical part and this study. Firstly, the selected group of individuals for the interviews consist of persons who have already gained experience on I4.0. Therefore, the results of empirical part reflect a perception of a group which has already engaged with the phenomenon, instead of managers from the firms who are starting to digitalize.

Secondly, all the interviewees come from Finland, and thus their opinions might be strongly affected by national characteristics in digitalization. Therefore, generalizability from country to another in all discussed topics might not be possible. Also, comparisons between different countries has not involved in empirical nor theoretical part.

Thirdly, absence of different organizational hierarchies is potential source of bias in this study. The interviewed group consist of experts most likely cooperating with the management of manufacturing firms. Thus, the perception of workers towards digitalization topics does not emerge is this thesis, even though some of the discussed topics such as human-machine cooperation could benefit from it.

9.4 Future Research

I4.0 and ad hoc processes are still relatively new topics. Thus, both topics could benefit from additional research, especially in managerial field. Four emerging topics are listed below.

Firstly, ad hoc process research would gain from practical case study which focus on identifying and categorizing solved familiar and unfamiliar problem, and their relations to DCs and ad hoc PF/PS activities.

Secondly, study on digitalization process should be carried out in order to verify whether the characteristics of digitalization problems in table 9.1 are practical.

Thirdly, gathering more information from current level of awareness among manufacturing industry managers and workers on digitalization could offer additional understanding about managerial capabilities required to digitalize the firm. For example, how much management should have general understanding about digitalization.

Fourthly, as empirical part showed, there are still several more technical sub-topics in I4.0 which would need further in-depth research. For example, edge computing, cyber-security, CPS and AI platforms for industrial environment, and possibility of common standardization of industrial technologies., how much system and training content might impact to work motivation and change towards digitalization

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APPENDIX

Appendix 1. The interview questions

- How does I4.0 appears in your daily work?
- How prepared firms are in general for digitalization and I4.0?
- What does the firm expect from your organization through cooperation?
- What are the biggest advantages or threats of I4.0 for manufacturing firm
- How would you describe the meaning of Cyber-physical system such as IBM´s Watson or Siemens' MindSphere to I4.0
- What is the first phase when firm wants to digitalize manufacturing operation?
- How capable or prepaid managers are for digitalization?
- What kind of new skills are required or training should be provided for operators/workers with the new system and processes in order to stabilize the new state?
- In your opinion, what is the usual bottleneck when digitalizing manufacturing operations