RESPONDING TO OPPORTUNITIES PROVIDED BY GENERAL PURPOSE TECHNOLOGIES – INDUSTRY 4.0 IN FINLAND

Jyväskylä University
School of Business and Economics

Master's thesis

2017

Cecilia Weinmann
International Business & Entrepreneurship
Supervisor: Mirva Peltoniemi

JYVÄSKYLÄN YLIOPISTO

ABSTRACT

Author Cecilia Weinmann

Tittle of thesis
RESPONDING TO OPPORTUNITIES PROVIDED BY GENERAL PURPOSE TECHNOLOGIES – INDUSTRY 4.0 IN FINLAND

Discipline	**Type of work**
International Business & Entrepreneurship	Master's thesis
Time (month/year)	**Number of pages**
05/2017	**90**

Abstract
Companies are currently facing a technological change that has the potential of disrupting entire industries. Recognizing opportunities provided by Industry 4.0 requires companies to apply vision and foresight and to adapt their strategies in order to face the changing environment. Acting upon these technological opportunities is managerially demanding, but crucial for maintaining companies' future competitiveness. This thesis builds on literature on strategic management and General Purpose Technologies (GPTs) and takes a company-level perspective in answering the question of how such technological opportunities are perceived and responded to by decision-makers.
In order to explore this issue, the strategic approaches to Industry 4.0 of 16 publicly listed companies in Finland were analyzed. For this purpose, in-depth qualitative interviews with managers from the Industrial and the Basic Material sector were conducted and publicly available material in the form of CEO and CIO Interviews, journalistic articles, as well as company press releases were collected and analysed.
The results provide insights into how the characteristics of GPTs influence decision-maker's perceptions and responses and show that the technologies' uncertain development and the generality of purpose result in difficulties in understanding the nature of change and identifying how to turn the potential of the technologies into actual revenue streams. The findings suggest that opportunities provided by GPTs are responded to with new products and services, organizational transformation, new strategies, the adaptation of business models as well as new cooperation with suppliers and customers.
Under the high perceived uncertainty and the complexity of required changes, a more experimental, stepwise approach to the implementation of new GPTs is identified as suitable as it allows balancing disruptive effects and for learning and adaptation to occur, as uncertainties are resolved.

Keywords
Industry 4.0, General Purpose Technologies, Strategy, Technological change

Location
Jyväskylä University School of Business and Economics

CONTENTS

ABSTRACT 2
CONTENTS 3
1 INTRODUCTION 5
1.1 Overview of the research 5
1.2 Need for further research 7
2 THEORETICAL BACKGROUND 9
2.1 Technological change 9
2.1.1 Types of changes 9
2.1.2 General Purpose Technologies 10
2.2 Strategic management of environmental change 13
2.2.1 Strategic adaptation 13
2.2.2 The role of capabilities 14
2.2.3 Technological opportunities and capabilities 15
2.3 Adoption of technologies 16
2.3.1 Technology sourcing options 16
2.3.2 Implementation of technologies 19
2.4 Theoretical synthesis & Framework for the study 21
3 DATA AND RESEARCH METHOD 25
3.1 Research setting: Industry 4.0 25
3.2 Research methods for the collection of data 26
3.3 Data collection 27
3.4 Method of analysis 30
3.5 Reliability and validity 31
4 RESEARCH FINDINGS 34
4.1 General information 34
4.2 Conceptualization and understanding of Industry 4.0 35
4.3 Use of Industry 4.0 technologies 39
4.4 Enablers for the implementation of Industry 4.0 45
4.5 Approaches to the implementation of Industry 4.0 48
4.6 Uncertainties, challenges and risks 54
5 DISCUSSION 62
5.1 Overview 62
5.2 Contributions to literature on strategic management and adoption of technological change 63
5.3 Contributions to literature on General Purpose Technologies 68
6 CONCLUSIONS 72
6.1 Concluding remarks 72
6.2 Managerial implications 73
6.3 Limitations and future research 74

REFERENCES.. 77
APPENDIX 1: OUTLINE OF INTERVIEW QUESTIONS.................................... 83
APPENDIX 2: OVERVIEW OF THE SECONDARY DATA USED IN THE STUDY.. 84
APPENDIX 3: THEMATIC ANALYSIS: CODES, SUB-THEMES, OVERARCHING THEMES... 87

1 INTRODUCTION

1.1 Overview of the research

Change can come in several forms. It can be expected or unexpected and it can be perceived as a threat or an opportunity (Brozovic 2016). Currently, companies are facing a technological change with the potential of disrupting entire industries and changing the ways companies are organized. "A series of disruptive innovations in production and leaps in industrial processes" (Smit, Kreutzer, Moeller, & Carlberg 2016, p. 20) summarized under the term Industry 4.0 are the bases of strategic adaptation for numerous companies. Besides improving efficiency and creating new ways of manufacturing, these technologies have the potential of creating entirely new products and services (Kruppa 2016). These disruptive effects and the wide options for application as well as the technologies' impacts on the growth of the entire economy allow them to be considered as General Purpose Technologies [GPTs]. Such technological prime movers are characterized by technological dynamism and the potential for pervasive use in a wide range of sectors and result in productivity gains and new ways of manufacturing as they evolve and spread throughout the economy (Bresnahan & Tratjenberg 1992; Jovanovic & Rousseau 2005).

Reacting to changes in the environment has been identified as an essential part of strategic management by many researchers. Firms that are able to adapt to changing environments have a greater likelihood of long-term survival and show a better overall performance (Helfat & Winter 2011). Companies can react to change when it becomes apparent, or proactively anticipate change and act upon it before the effects are felt (Ansoff 1979). This action-taking towards change requires capabilities in identifying changes as well as the availability of resources to allow a rapid response to the changing environment (Shimizu & Hitt 2004).

Sensing technological opportunities and responding to them effectively plays a crucial role in a firm's ability to face competition in changing technological landscapes (Srinivasan, Lilien, & Rangaswamy 2002). In order for a company to maintain its position, "managers may use vision and foresight (proaction) during periods of destabilization to transform the organization into a new state of equilibrium" (Hitt, Keats, & DeMarie 1998, p. 25). The options of response are diverse and can include ignoring or monitoring the technology, exploiting it by forming alliances, experimenting with it, or adopting it internally (Srinivasan et al. 2002). Acting upon identified technological opportunities is considered risky because it is unclear beforehand whether the implementation of a new technology will actually bring benefits for the company (ibid.). Since especially radical technological change is often developed outside of the firm, in addition to identifying the opportunity, the integration of external knowledge is an important but challenging factor in successfully managing the technological transition (Tripsas 1997). Dynamic capabilities combined with an effective strategy can enable firms to recognize and seize the "technological and competitive opportunities of the future" (Teece 2012, p. 1396). Failing to develop the necessary capabilities after investing into a new technology in turn is one of the main reasons companies fail in the light of technological change (Tripsas 1997).

Industry 4.0 is a form of change that requires companies to do all that. Industry 4.0 is described as "a leap of faith" (Geissbauer, Vedso, & Schrauf 2016, p. 6), requiring companies to make investments today into an unknown future, as many aspects of the processes and products related to Industry 4.0 are currently still unknown (Geissbauer et al. 2016). "Companies that hold back, waiting to see how it all turns out before investing, will fall behind" (ibid., p. 6). This shows that companies need to proactively respond to this opportunity by implementing an Industry 4.0 strategy and through their actions shape the future products and processes related to this development. However, this also means that these developments are a threat to companies that do not manage to respond and to adapt their strategies accordingly, potentially resulting in drastic changes of the leading positions on the company - as well as the regional level (Rüßmann, Lorenz, Gerbert, Waldner, Justus, Engel, & Harnisch 2015).

This raises the question how companies approach this highly uncertain issue. How do they respond to it and how do they integrate the complex knowledge behind the technologies?

This thesis aims to shed light on how companies in the Finnish market perceive this change, how they approach this issue strategically and how they act upon these opportunities. This allows gaining insights on companies' perceptions and responses to opportunities provided by General Purpose Technologies. By building on the characteristics of such technologies and identifying how they influence decision-makers' perceptions and responses this thesis has the potential of contributing to literature on GPTs, as well as literature on strategic management of technological change.

By analysing the strategic approaches of 16 publicly listed Finnish companies, this thesis attempts to provide an overview of the perceptions and responses to Industry 4.0 in the Finnish context. For the purpose of this study, in-depth interviews with managers from the Industrial and the Basic Material sector were conducted and publicly available material in the form of CEO and CIO Interviews, journalistic articles, as well as company press releases were collected and analysed.

Finland makes an interesting focus of analysis as with its competitive technology industry and high level of skills, as well as a very reform-capable public sector, the country has the prerequisites for success with technologies related to Industry 4.0 (Juhanko et al. 2015). A Global survey on Industry 4.0 conducted by Pricewaterhouse Coopers [PwC] (2016) shows that Finnish companies are highly optimistic about the potential of Industry 4.0, however, the uncertain economic benefits are mentioned as a major reason of constraint (PwC 2016). Additionally, the industry and business environment in Finland with companies focussing more on customized products than mass production for instance, does not allow a direct application of the Industry 4.0 initiative as developed in Germany (Syrjälä 2016). This requires companies to find their own ways of benefitting from these technologies and adapting them to fit their needs (ibid.).

The theoretical framework of this thesis combines Economics and Management literature in order to create an overall picture of the different aspects relevant for this type of technological change. Literature on General Purpose Technologies can be applied to better understand the characteristics and potential impact of current developments with Industry 4.0, and what factors influence the adoption and implementation of such technologies. Literature on strategic management addresses the capabilities needed to recognize opportunities and to respond to environmental change. Literature on technological change and research on previous changes is used in order to create an understanding of the technology sourcing and implementation process.

1.2 Need for further research

Literature on GPTs has focused greatly around the work of Bresnahan and Tratjenberg (1992) who strongly emphasized the need to characterize the notion of technical change underlying an economic phenomenon (ibid., p. 1). Although other authors have dealt with such technologies before, Bresnahan and Tratjenberg (1992), filled the gap in existing analytical models that did not allow to distinguish between "say, the advent of the microprocessor and the introduction of yet another electronic gadget" by introducing the concept of General Purpose Technologies (ibid., p. 1). This work has since been expanded by several authors analyzing the macroeconomic consequences of GPTs and their economic-wide diffusion, the effects of GPTs on international trade and factor markets, the interactions of technology, public policy and facilitating structures or their effects on vertical integration and specialization (e.g. Aghion and Howitt 1998; Helpman 1998; Helpman & Trajtenberg 1994; Jovanovic & Rousseau 2005; Lipsey, Bekar, & Carlaw 1998).

However, the majority of authors operate from a macroeconomic perspective and analyze the GPT-driven economic growth and other related factors. This illustrates that although literature on General Purpose Technologies has expanded after first being introduced, research from the individual company perspective is scarce. It has been thoroughly analyzed what the characteristics of GPTs mean for the productivity growth in an economy, but what role these factors play for the decision-making in companies has so far not been sufficiently addressed by literature.

Whether or not a new technological development results in actual change depends on the diffusion of the technology, which requires companies to be proactive in their strategic response and implementation of these technologies. For this reason, investigating the adoption decision of companies and ways of perceiving and responding to such opportunities is an important issue to study. Like any other invention, the actual spreading of GPTs can expected to be determined by the demand for them and understanding how the characteristics of GPTs affect decision-makers' perceptions and responses to such opportunities can contribute to literature on GPTs and strategic management.

The technological opportunity under study in this thesis does not simply affect a small number of businesses in a certain industry or only certain business units of a company, but the entire company and a large number of industries globally are affected. Since Industry 4.0 is not solely about one technology and the question of whether or not to adopt it, there is more complex strategic decision-making involved and the process of implementation and knowledge generation is very broad and will likely differ from company to company. The technologies related to Industry 4.0 cannot simply be adopted but require high adaptive efforts and further company-internal research in order to be implemented successfully. This current development with Industry 4.0 therefor offers the chance to study a new form of GPTs and to combine the literature and previous findings on GPTs with strategic and managerial issues.

2 THEORETICAL BACKGROUND

2.1 Technological change

2.1.1 Types of changes

The type of environmental change addressed in this study is technological change. Technological change and differences in firms abilities to adapt to technological change have been a key theme in the development of strategy literature (cf. Aggarwal, Posen & Workiewicz 2016). Recognizing opportunities provided through technological developments requires an understanding of "the capacities of these technologies, their adequacy to each business, the possibility of exploring their benefits and the effort of acquiring a new management mentality" (Carneiro 2006, p. 307). Companies that cannot adapt their organization or cannot realize the opportunities are threatened by the entrance of start-up businesses (Henderson & Clark 1990).

Most technological changes are said to be incremental, meaning that they constitute a small step building on well-established practices, where companies can rely on their existing (technological) capabilities (Rosenbloom & Christensen 1998, p. 215). In contrast to that, the more challenging form of technological change is discontinuous, disruptive or radical, as it requires substantial adaptation efforts and companies need to find a way to fully exploit the new technology (e.g. Helfat & Winter 2011; Lambe & Spekman 1997). Whether a technology is radical cannot always be decided beforehand and various definitions on radical change exist (Rosenbloom & Christensen 1998). In some cases, a technology is termed radical if it creates new products, making previous ones obsolete (Henderson 1993, p. 252). An innovation is further considered radical if it is "competence-destroying", requiring new skills, abilities and knowledge (Abernathy & Clark 1985; Tushman & Anderson 1986, p. 442). Anderson and Tushman (1990, p. 607) also speak of discontinuities, which are referred to as fundamentally different products or ways of making products with an advantage in cost, quality or performance compared to prior forms. Definitions further range from technological change being radical if it requires the development of new technological capabilities to change being radical if it calls for other new capabilities even if it allows relying on existing technological capabilities (Rosenbloom & Christensen 1998, p. 215).

In any case, radical innovations are considered to "disrupt the established trajectories of technical advance", while "incremental innovations reinforce and extend them" (ibid., p. 220). As concluded by Rosenbloom and Christensen (1998), if a change in strategic direction and the establishment of new systems and value networks become necessary, the change brought by the technology are most likely radical. As this requires more than technological activity and complementary assets have to be implemented, even a simple technology may have radical effects (Rosenbloom & Christensen 1998, p. 233). Drastic innovations result in much larger uncertainties and produce risks that are much more challenging to evaluate (Helpman 1998, p. 3).

In general, literature on strategic management and technological change has identified two explanations for why established firms fail in the light of technological change: a lack of strategic commitment and resistance to invest; and failing to develop new organizational capabilities after investing (Rosenbloom & Christensen 1998). That established firms' ability to cope with radical change is more dependent on strategy-making capacities than technological capabilities, as found by Rosenbloom and Christensen (1998), emphasizes the importance of strategic management in the light of technological change.

2.1.2 General Purpose Technologies

This thesis is concerned with a type of radical technological changed termed General Purpose Technologies (GPTs). This type of change has been addressed by the literature on Economics and Management and are describes as "a handful of technologies" that have an important role in creating technological change across different sectors (Helpman & Trajtenberg 1994, p. 1). GPTs are further used "to describe a new method of producing and inventing that is important enough to have a protracted aggregate impact" (Jovanovic & Rousseau 2005, p. 1182).

Bresnahan & Tratjenberg (1992, p. 1) were the first to speak of General Purpose Technologies as "technological prime-movers", having a substantial impact on the growth of whole economies over a long period of time. "Thus, as the GPT evolves and advances, it spreads throughout the economy, and in doing so it brings about and fosters generalized productivity gains" (Bresnahan & Tratjenberg 1992, pp. 1–2).

Bresnahan and Tratjenberg (1992) identified three distinct features that characterize GPTs and their role as "engines of growth" (ibid, p. 33). These have been picked up and expanded by several other authors.

Pervasiveness

This means that the GPTs are used as inputs by a wide range of sectors and have a wide range of different applications. Such a pervasiveness of GPTs results "from the fact that GPTs perform some generic function (…) that happens to have virtually universal applicability throughout the economy" (Helpman & Trajtenberg 1994, p. 1). The varieties as well as the width of use across the economy are characteristics that evolve over time (Lipsey et al. 1998, p. 40). GPTs therefor often emerge as technologies being specific to a certain sector and then slowly spread throughout the economy. Typically a new GPT has a rather specific use, which then expands as more and more applications are discovered. For this reason a GPT is suitable for several different industries and it can either be used with little adaptation, or investments can be made in its adaptation to a specific product or a specific use (Helpman 1998, p. 12).

Potential for Improvement & high technological dynamism

This refers to the aspect that GPTs should develop and advance over time. Innovational efforts and learning effects will over time increase the performance of the GPT (Bresnahan & Tratjenberg 1992).

As stated above, when general purpose technologies first appear, they are considered to be rather crude, evolving into more complex technologies being widely used in different applications. "Over time the technology is improved, its costs of operation in existing uses falls, its value is improved by the invention of technologies that support it, and its range of use widens while the variety of its uses increases" (Lipsey et al. 1998, p. 39). For this reason, a new GPT has implicit in it "a major research program for improvements, adaptations, and modifications" (ibid.). This has also been termed as "technological dynamism", where innovational efforts and learning effects increase the efficiency of the generic function of the GPT (Bresnahan & Tratjenberg 1992, p. 5). According to Lipsey et al. (1998, p. 39), in the case of GPTs, this evolutionary process means that "the processes of technological change and diffusion are intermingled in time, space, and function".

Presence of innovational complementarity

Innovational complementarity means that the introduction of the GPT enables the invention and production of new products and processes. Due to the working of these innovational complementarities, GPTs have been termed as "prime-movers" (Bresnahan & Tratjenberg 1992, p. 1), meaning that R&D productivity increases as a consequence of the GPT. As Brynjolfsson & Hitt (2000, p. 24) argue, "such technologies are economically beneficial mostly because they facilitate complementary innovations". This means that the economic contributions of GPTs go far beyond the return expected from the capital investments made into the technologies (Brynjolfsson & Hitt 2000). This is explained by the fact that in the short-run, returns represent the direct effects of the technology investments, whereas the long-run returns represent the effects of the technologies combined with related investments in organizational change.

The benefits of the technologies can hence not be fully grasped unless related technologies, capital goods and other factors that cooperate with the new technology are altered (Lipsey et al. 1998, p. 42). "The consequent changes will typically take the form of new factors of production, new products, and new production functions" (ibid., p. 42). Brynjolfsson & Hitt (2000, p. 45) conclude that complementary factors such as new business processes, new skills, and new organizational and industry structures are the actual drivers behind the contribution of GPTs.

This characteristic of complementarity can be considered a result of the prior two characteristics as GPTs provide inputs that fulfill various uses and are likely to be at the center of technology systems, being linked to many other technologies. Generally it can be said that the more pervasive a technology is, the more complementarities it is expected to have with others (Lipsey et al. 1998, p. 43). "For this reason innovations in GPTs will typically induce major structural changes in many, sometimes even the great majority of, other technologies" (ibid., p. 43). For this reason, GPTs are described as having a tree-like structure where one GPT can result in many new technologies that themselves can become GPTs (ibid., p. 44).

In summary, an innovation can be termed a GPT if it has the potential to be used across different sectors and changes the way of operating within those sectors. Rather than offering complete and finished solutions, GPTs are seen as enablers which create new opportunities (Bresnahan & Tratjenberg 1992).

Steam engines, electricity, Information Technology or Information and Communications Technology (ICT) are often described as examples for GPTs (e.g. Helpman & Trajtenberg 1994; Helpman & Trajtenberg 1996; Jovanovic & Rousseau 2005). As these technologies fulfill all of the features characterizing GPTs, they are not considered as traditional capital investments (cf. Brynjolfsson & Hitt 2000, p. 24).

The characteristics of GPTs have an influence on their diffusion. GPTs have been found to be slower to implement into wide use at first as they are subject to network effects. In their study on the diffusion of Electricity and Information Technology, Jovanovic & Rousseau (2005) illustrate that the initial slowness of implementation of these technologies was linked to the fact that the full positive effects and a cost reduction in the use of the technologies was achieved only when the number of users was large. It can therefor be argued that the adoption of GPTs is only beneficial if a large amount of other players on the market do so too. In general, GPTs have been found to have two types of externalities: vertical, between the GPT and each application sector and horizontal, across different application sectors (Bresnahan & Tratjenberg 1992, p. 10). Vertical externalities, which link payoffs between complementary assets are a consequence of innovational complementarity. Horizontal externalities link the interest of actors in different application sectors and result from the general purpose of the technologies (ibid., p. 18).

That the implementation of GPTs requires the development of complementary skills and capital goods is a further factor affecting the speed of diffusion (Hall & Khan 2003). In some cases, the slowness of the implementation has been found to result from a need to re-organize the whole manufacturing facility (ibid., p. 8). In the case of IT, the changes formed a complete departure from previous practices (Brynjolfsson, Renshaw, & Van Alstyne 1997, p. 37).

From an economic perspective, GPTs have been found to evolve in two phases. The first phase is termed as the "time to sow" (Helpman & Trajtenberg 1994), where output and productivity are negative. In this phase resources are devoted to the development of the required complementary inputs that are necessary in order to take advantage of the GPT. Only during the second phase when enough complementary inputs exist does the GPT show its benefits, resulting in higher outputs, real wages and profits (Helpman & Trajtenberg 1994, p. 2). This illustrates the fact that "general purpose technologies do not come ready to use off the shelf" (Aghion & Howitt 1998, p. 121), but instead require new intermediate developments before being implemented. As Bresnahan & Tratjenberg (1992, p. 3) conclude, "looked from the vantage point of the evolution of GPT's, growth is seen to depend critically on the industrial organization details of a handful of markets, namely, those associated with the GPT".

2.2 Strategic management of environmental change

2.2.1 Strategic adaptation

The broader field of this study lies in literature on strategic management, which is described as a constant process of reacting to change by developing suitable strategies (Chakravarthy 1982). "The primary purpose of strategic management is adaptation, i.e., to fit the firm more particularly for existence under the conditions of its changing environment" (ibid., p. 35). Adapting and adjusting the organization to environmental change is a highly complex, dynamic process and includes countless decisions and behaviours throughout the organization (Miles, Snow, Meyer, & Coleman 1978, p. 547). Related to this is Strategic flexibility which is defined by Zhou & Wu (2010) as the competency to deal with change and to create strategic responses. Such strategic responses and adaptations of strategy can be rather reactive, put into place when change becomes apparent or proactive, anticipating change.

In general three levels of adaptation differing depending on a firm's openness to environmental change have been identified: defensive, reactive, and proactive (Chakravarthy 1982; Miles et al. 1978). A defensive firm is described as "unstable" and least open to environmental change as it is buffering itself from it. In terms of technology, these firms hardly make any change, which has an effect on profitability in the long run (Chakravarthy 1982, p. 36). The lack of a clear strategy, a mismatch between organizational structures and processes and the chosen strategy, or a failure to change the strategy with changing environments are factors leading to a lack of response to environmental changes (Miles et al. 1978).

Compared to this, reactive companies are said to pay attention to changes around them and are willing to react to them (Chakravarthy 1982). Like defensive companies, reactive ones respond to change only after its impact has become apparent. But the delay in reaction is likely to be shorter and the reactive organization is, in contrast to the defensive one, willing to react and to implement strategic moves to improve the situation (Ansoff 1979, p. 181). The responses are however limited through "the historical strategic culture and the historical perception of the environment" (ibid., p. 181). In addition, the response may be initiated too late and closing the gap between strategic thrust and the capability becomes challenging (ibid., p. 180).

A proactive company, in turn, is one that has foreseen change beforehand and is therefore highly prepared for it (Chakravarthy 1982). These companies are described as being on the look for new opportunities, which besides reacting to upcoming change may even take actions to implement change themselves. Strategic choices of such companies may go beyond their existing technological capabilities and they are equipped to respond to changes in the future (Miles et al. 1978). Such anticipating companies therefor respond before and not after the impact of the change is felt (Ansoff 1979, p. 181). In this case a company has the ability to effectively use its resources in order to make use of innovations (Lengnick-Hall & Beck 2005). In contrast to a mere reaction to environmental changes a proactive company has the "ability to model, shape and transform its environment" (Brozovic 2016, p. 6). A disadvantage of such an approach is that actions are based on incomplete information, which will only improve over time (Ansoff 1979, p. 181).

Strategic choices and adaptive behaviour of an organization are considered to be reflections of its top management and their perception (Miles et al. 1978). This emphasizes the role that decision-makers perceptions of the change play for responses to the change in question as "the choices which top managers make are the critical determinants of organizational structure and process" (ibid., p. 548). Effective organizational adaptation therefor depends on decision-maker's abilities to envision and implement changes and a "new organizational form" (ibid., p. 561).

2.2.2 The role of capabilities

Strategic management literature has put substantial focus on capabilities to explain differences in firm's abilities to respond to environmental change and the resulting opportunities. According to Teece, Pisano and Shuen (1990), "capabilities are a set of differentiated skills, complementary assets, and routines that provide the basis for a firm's competitive capacities" (p. 28). The term capabilities therefore "emphasizes the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organizational skills, resources, and functional competences towards changing environment" (Teece & Pisano 1994, p.1). It has been emphasized that these capabilities need to change with time in order to remain useful to the company (McEvily, Eisenhardt, & Prescott 2004) and managing the evolution of capabilities over time is seen as a prerequisite in organizational survival (Leonard-Barton 1992, p. 112).

Dynamic capabilities are defined as those routines that allow a company to adapt to changes and achieve competitive advantage by effectively using resources (Eisenhardt & Martin 2000). Dynamic capabilities literature extends the literature on the Resource based view of the firm by focusing on situations of change in dynamic environments (ibid.). As the Resource based view builds on resources in the form of organizational, physical, or human assets used in implementing strategies, dynamic capabilities refer to effective processes and routines, which allow adapting existing resources to changes, as well as creating new resources (ibid.). For this reason a strong connection exists between dynamic capabilities and the ability to recognize opportunities (Teece 2012). As dynamic capabilities can be used "to match or even to create market change" (Eisenhardt & Martin 2000, p. 1107), they are necessary in adaptive, as well as proactive actions of companies. According to Aragón-Correa and Sharma (2000), a proactive environmental strategy can be developed into a dynamic capability. Zhou and Wu (2010) further identify strategic flexibility as a form of a dynamic capability, which helps firms in making a stronger use of their technological capabilities and allowing companies to explore new opportunities that go beyond their existing technological and organizational borders.

2.2.3 Technological opportunities and capabilities

"While readiness to invest is necessary, it is not a sufficient basis for the successful exploitation of radically new technology; the innovator must also succeed in creating a new set of capabilities" (Rosenbloom & Christensen 1998, p. 220). A technological change has an influence on companies' capabilities as it results in new forms of organizational activity, new ways of creating values and requires building up new knowledge (Lavie 2006). The challenges that a new technology brings for companies may result in a capability gap, which refers to the difference between the capabilities possessed by a company and the optimal configuration of capabilities in the light of the new technology (ibid.). Successfully implementing a new technology therefore requires companies to adapt existing capabilities or to develop new ones (ibid.).

Capabilities in terms of technological opportunities can broadly be divided into those capabilities necessary for acting upon opportunities and those related to actual technological know-how and implementation (Srinivasan et al. 2002; Teece & Pisano 1994; Woiceshyn & Daellenbach 2005).

Teece (2012) emphasizes the role of the top management team in sustaining dynamic capabilities through entrepreneurial and leadership skills. The author states that in the light of technological change dynamic capabilities can be divided into three forms: Opportunity sensing and identification capabilities, capabilities for seizing the opportunity by mobilizing resources, as well as transformational capabilities.

Capabilities for sensing opportunities play an especially critical role when it comes to opportunities that are more challenging to identify. Identifying such opportunities requires making investments into research as well as scanning, learning and interpretative activities (Teece 2009).

Having identified a technological opportunity, it can be seized by introducing new products, processes, or services (ibid., p. 17). This involves "maintaining and improving technological competences and complementary assets and then, when the opportunity is ripe, investing heavily in the particular technologies" (ibid., p. 18). Besides selecting the timing, amount, and target for investment, the organization needs to create a business model defining the commercialization strategy and priorities for investment (ibid., p. 18). Teece (2009, p. 19) emphasizes that success depends as much on organizational innovation and the creation of new business models, as it does on the selection of the technology itself. Aligning the business models with the technology is said to be "a much overlooked component of strategic management" (ibid., p. 19).

Similarly to this, Srinivasan et al. (2002) examine the "technological opportunism capability" (ibid., p. 1) of the firm and state that a technologically opportunistic firm "senses and responds proactively to capitalize on (or counter) these technology opportunities (or threats)" (ibid., p. 49). Technology-response capabilities in turn refer to the ability to adapt the strategy accordingly in order to exploit the opportunity (ibid.). The findings of the study conducted by Srinivasan et al. (2002) show that a firm's focus on the future and the development of capabilities matching this future, the efforts of the top management towards implementing responsiveness and advocating new technologies, as well as the organizational culture all influence a firm's technological opportunism.

Dynamic capabilities further have an impact on a company's capability to adopt and integrate technology (Woiceshyn & Daellenbach 2005). Woiceshyn and Daellenbach (2005), emphasize the importance of "integrative capabilities", which are defined as "the dynamic interaction between knowledge systems and adoption processes" (ibid., p. 325). The dynamic interaction of these two elements of knowledge system and adoption process need to be aligned as a set of capabilities in a way that is difficult for others to copy (ibid.). According to the authors, integrative capabilities include external as well as internal integrative capabilities. While external integration refers to recognizing and evaluating external opportunities with regard to existing capabilities, internal integration refers to the implementation of the new technology and the related knowledge, as well as adjusting it to the company specific use (Woiceshyn & Daellenbach 2005). Similarly, Tripsas (1997) identifies external integrative capabilities as key contributors to dynamic technical capabilities. He defines external integrative capabilities as the ability to "identify and integrate external knowledge" (Tripsas 1997, p. 351), which includes internally investing in new technologies and developing absorptive capacities, as well as an creating an infrastructure that allows for the transferral of knowledge.

Leonard-Barton (1998, p. 46) emphasizes the importance of considering the link between strategy and technological capabilities. According to the author, this link can be violated on two ends. Either the strategy of an organization does not take technological elements into account and the actual strategic intent may be unclear or not existent, or a company fosters technologies, which do not have strategic relevance in supporting the organizations core capabilities or competitive advantage. Only if the strategic goals are clear, the technological capabilities required to achieve it can be identified (Leonard-Barton 1998, p. 48).

Having identified the technological capabilities required in supporting the strategy, companies can evaluate their existing capabilities to see whether the necessary knowledge, managerial systems, physical systems, and other factors such as supporting norms are already existent within the organization or whether the possessed knowledge is incomplete or not up to date (ibid.). The more current and complete knowledge and capabilities exist within an organization in terms of a specific technology, the more "familiar" (ibid., p. 51) the technology is.

2.3 Adoption of technologies

2.3.1 Technology sourcing options

As mentioned in the previous chapter, the existing capabilities and know-how have an effect on how familiar a certain technology is for a company (cf. Leonard-Barton 1998). For this reason, the knowledge and capabilities already existent within an organization as well as the capability gaps identified influence the chosen form of sourcing new technologies.

Contrasting the dimensions of strategic importance of a certain technology for the company and the familiarity with this technology results in "four potential technology-sourcing situations": Outsourcing, internal R&D, external acquisition or not investing (Leonard-Barton 1998, p. 51). For obvious reasons, hardly any investments will be made into technologies with little strategic importance and a low familiarity within the company. Technologies that have a higher familiarity within the firm but that are of low strategic importance are characterized as candidates to be outsourced to other firms. Technologies with a high strategic importance and high familiarity, which are important for a firm's core capabilities, are technologies that companies will want to invest in further in order to enhance these capabilities. These are categorized as candidates for internal R&D (Leonard-Barton 1998).

In the case of high strategic importance of a technology, but a lack of familiarity due to a lack of- or incompletion of internal knowledge, the resulting capability gap provides the need for external acquisition of the technology and the related capabilities. Consequently, if strategically important technological expertise is non-existent or insufficient within the company, technologies are acquired from the outside (Leonard-Barton 1998). McEvily et al. (2004) use the term acquisition to describe "the process by which firms develop new scientific and technological competencies, and renew old ones" (p. 714). According to the authors this can be done by acquiring other companies, collaborating with them, assimilating and absorbing technological knowledge from others, as well as through learning processes such as experimentation.

Leonard-Barton (1998) argues that the use of options for accessing external technologies differ in the level of commitment as well as their potential of acquiring new technology capabilities. The options move from more short-term and low-cost options such as licensing and R&D contracts over increasing commitment options in the form of co-development and licensing, to high degrees of commitment in options such as Joint Ventures and Mergers and Acquisitions. The potential for the creation of capabilities thereby increases with the level of commitment. Options such as observation and licensing will most likely not result in the creation of new capabilities for the company. The options with increasing commitment in turn, can give access to expertise, know-how, as well as supporting physical systems. Co-development and licensing for instance can result in the transferal of capabilities. The creation of new core capabilities, however, is expected to happen only through joint ventures or mergers and acquisitions. In some cases companies may combine different options by beginning with a low commitment option and moving to higher commitment options when uncertainty is reduced (Leonard-Barton 2011). With the initial appearance of a new technology, companies may be rather uncertain of how this technology will affect their industry and they will not be willing to make such high commitments (Lambe & Spekman 1997).

In addition to the uncertainty regarding the technology, Lambe and Spekman (1997) identify urgency of implementation as a factor influencing the use of such external acquisition. Alliances are said to be preferred in situations of high urgency and uncertainty as they may allow a more rapid access to new technologies with lower investments compared to mergers and acquisitions, and therefore firms can avoid putting a lot of money into a technology with high uncertainties regarding its actual breakthrough. With less time to market pressure and resolved uncertainties, companies may prefer the other options of mergers and acquisitions or even internal development (Lambe & Spekman 1997). An overview of the different options and their potential for creating new capabilities and level of commitment can be seen in Figure 1.

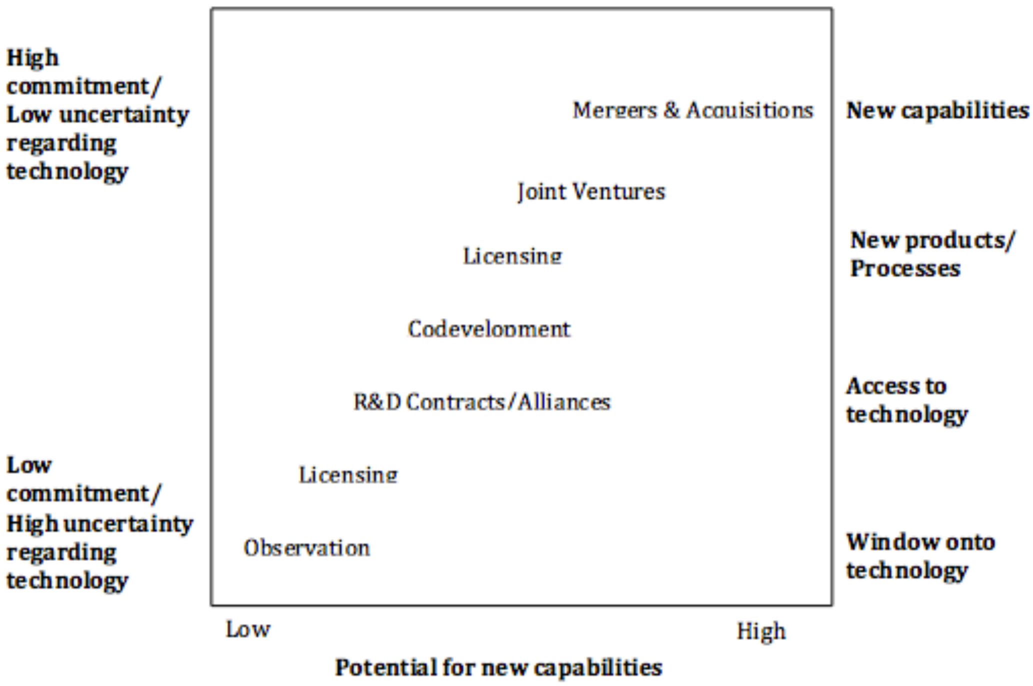

Fig. 1 Options for creating capabilities and implementing technologies (Adapted from Leonard-Barton 1998, p. 51)

Besides the urgency, strategic importance, familiarity of the technology and the related capabilities and uncertainty regarding it, previous experience in implementing technologies as well as the firm size have been identified as factors influencing the form of chosen implementation (Hung & Tang 2008).

Previous experience affects the chosen form of implementation in that way that firms may prefer to use approaches they have used before in order to benefit from the experience they have with certain forms of collaboration (Hung & Tang 2008). Firm size is said to have an affect on the chosen form of acquisition as this is linked to a firm's existing financial resources and the availability of qualified employees. Therefore, with increasing size companies will more likely choose an alternative with higher resource commitment (ibid.).

Overall, the main strategic decision in terms of technology sourcing seems to be whether to internally develop the new technologies and the capabilities related to it, or to choose a form of external sourcing in order to get access to the new technologies and capabilities in some form. When technological complexity is high and the technology requires a high level of expertise, developing the technologies and related capabilities internally may be challenging and therefore acquiring these externally may be more attractive.

2.3.2 Implementation of technologies

It has been argued that when it comes to new technologies, the actual innovation does not necessarily lie in the invention of the technology, but in the implementation of it (Leonard-Barton 1988). For any technology sourcing option, implementation is not a straight-forward process, but more of an extension of the technology's invention process (ibid.). As misalignments between the technology and the organization's business environment occur, adaptations of the technology and the organization have been found to be crucial. According to Leonard-Barton (1988), "instead of a preprogrammed plan, implementation is a dynamic process of mutual adaptation between the technology and its environment" (p. 252). The author suggests that the technology, the business environment, or both mutually, need to be adapted in order to fully grasp the benefits of the technology. As new technologies may not necessarily fit the needs of the organization as they are, implementing companies need to adapt the technology to fit their needs. On the other hand the author argues that new technological developments transform the structures and practices of the environment they are implemented in, which results in an adaptation of the organization.

Mutual adaptation therefor is an ongoing, two-way process supported by continuous technological and organizational change, where a change on one side may trigger a change on the other (Leonard-Barton 1988). This has been found to include the creation and transferal of knowledge between different parties and practices where people responsible for the technologies need to understand the business side and business people in turn need an understanding of the technology (Garrety et al. 2001).

Such an approach of mutually reinforcing practices can be considered especially relevant in the case of GPTs, where the need to develop complementary factors is emphasized. Milgrom & Roberts (1990) study modern manufacturing technologies and argue that they require to be adopted as part of a cluster of mutually reinforcing organizational changes. Their implementations "are not a matter of small adjustments made independently at each of several margins, but rather have involved substantial and closely coordinated changes in a whole range of firm's activities" (Milgrom & Roberts 1990, p. 513). Although the changes can be implemented over time, a complete transformation is necessary in order to grasp the full benefits (ibid.).

Brynjolfsson & Hitt (2000) further show that information technology led to a number of changes in work organization and firm strategy. According to the authors some companies make the mistake of assuming "that technology's effects are independent of the organizational structure in which it is embedded" (Brynjolfsson & Hitt 2000, p. 3). The authors illustrate how companies successfully transformed themselves and combined IT with various changes in their work practice, products and services, strategy, as well as supplier and customer relationships. Managers must therefor plan a strategy that coordinates the interactions among all the components of a business system. "Success often depends on coordinating the right technology, the right product mix, and dozens of the right strategic and structural issues all at once" (Brynjolfsson et al. 1997, p. 38).

Brynjolfsson et al. (1997) argue that in order to plan the implementation of technologies, the pace of the change (gradual or rapid), as well as the nature of the change (incremental, radical) need to be considered. According to the authors, radical change should rather "be spread over several episodic steps" (ibid., p. 46), as this can prevent the change process from becoming too disruptive and confusing as well as too expensive. In other cases, however, change should be implemented all at once in order not to risk wasting resources and organizational exposure. The authors identify three factors that may be used to assess the appropriate pace of change: "task interdependence, organizational receptiveness to change, and external pressure".

Task interdependence refers to the modularity and serial nature of different steps. Only if organizational processes can be logically divided, does it make sense to approach implementation in several steps (Brynjolfsson et al. 1997).

The second factor regarding the organization's culture influences the form of implementation based on the openness to change. An episodic step-wise approach to change needs to be supported by a culture that is used to experimentation and risk taking. "The advantage of a supportive culture and episodic change is that they permit phased adaptation to unfamiliar practices" and such an approach to change can therefor also promote experimentation (ibid., p. 46). Nevertheless, experimentation is said to be unlikely to occur if the organizational culture sanctions failed experiments.

As a third factor of influence, the authors identify external pressure. High external pressure is said to prevent the application of episodic change, as companies need to act fast. Low external pressure in turn provides more time for the adaptation (Brynjolfsson et al. 1997).

Leonard-Barton (1988, p. 252) found that such a stepwise process of mutual adaptation can be controlled through large and small cycles. What the author terms as "cycles of adaptation", describe the process of adapting the technology to the environment and/or altering the environment to make better use of the technology. In the case of a mutual adaptation, the technology is reinvented and the organization is adapted at the same time. In the model of adaptation cycles the author distinguishes between small and large cycles of adaptation, which differ depending on the magnitude of the changes made. Large cycle adaptations result in drastic change, affecting several factors in the organization and leading to new strategy formulation and strategic change within the organization. Such adaptation cycles therefor allow to actively link the implementation of the technology to the strategy. Small-cycle adaptations appear in all cases of technology implementation. Nevertheless, variations occur due to differences in the adaptability of certain technologies or organizations. "Therefore, in some cases technical changes predominate; in others organizational changes do" (Leonard-Barton 1988, p. 261).

2.4 Theoretical synthesis & Framework for the study

This chapter covered different theoretical backgrounds on General Purpose Technologies and strategic management as well as the sourcing and implementation of technologies, that can all be considered relevant in understanding companies' responses to a certain type of technological opportunities.

The characteristics of General Purpose Technologies distinguish them from other technological changes. Due to their protracted aggregate impact (Jovanovic & Rousseau 2005), investing into GPTs cannot be compared to traditional capital investments. The characteristics of this type of technologies can be expected to influence the perceptions and responses of decision-makers in the light of new GPT-opportunities. Figure 2 provides an overview of the characteristics presented in chapter 2.1.2 and their effects that may influence perceptions and responses.

With their first introduction, the impacts of GPTs are challenging to foresee. Considering existing GPTs from today's perspective their evolution and diffusion seems inevitable (Lipsey et al. 1998). However, at the first introduction of the technology, whether it will be a modest advance, a GPT or something in between these two extremes is challenging to estimate (ibid., p. 48). An explanation behind the challenge of making estimations can be found in the fact that the emerging complementarities are challenging to predict (ibid.). As all the characterizing features of general purpose technologies are time dependent, it is only logical that being able to identify a GPT is also time dependent (ibid., p. 49). For this reason, different perceptions of the future development of the technologies and their meaning for specific industries may exist throughout the process.

The evolvement of the technologies in two phases where output and productivity initially fall before complementary investments allow exploiting the benefits (Helpman & Trajtenberg 1994), may make investments into the technologies seem unattractive for companies that are rather concerned with the short-run. Decision-makers therefor face high uncertainties regarding returns on investments, as the development of the GPTs are uncertain, and after the first phase the productivity gains of the technologies will most likely not yet be visible. This slow development of the visible advantage of GPTs may initially provide reason for doubt regarding their usefulness. At the same time, however, proactive approaches would seem to be required in order to push the development of the technologies and the complementary factors forward. As the actual impact and applications of GPTs will only show throughout time, companies will need to respond despite the uncertainties regarding the technology's development.

Early commitment is further made necessary due to the network externalities GPTs are subject to. In the presence of network externalities, companies that get a head start will tend to stay ahead of competition and it will be challenging for others to catch up (cf. Teece 2009, p. 18).

As old technologies and skills become obsolete in the light of new GPTs, it may be perceived more as a threat than an opportunity by some decision-makers. Companies that thrived in the prior situation may feel threatened by the appearance of such disruptive technologies. As it has been found that established companies that rely on routines, assets, and strategies that were developed for dealing with existing environments are disadvantaged in adopting radical and competency-destroying innovations (Henderson & Clark 1990; Tushman & Anderson 1986), GPTs with their far-reaching impact certainly will be perceived as challenging by incumbent companies. The capability gap can hence be expected to be large in the case of new GPTs.

As GPTs affect the entire economy, not responding at all will most likely not be an option even if the change is perceived as a threat rather than an opportunity. Literature on technological diffusion shows that, "at any point in time the choice being made is not a choice between adopting and not adopting but a choice between adopting now or deferring the decision until later" (Hall & Khan 2003, p. 1). Therefor decision-makers will have to weigh the benefits of getting a head start against the uncertainties of the future developments of the GPT.

While the generality of purpose of these technologies allows them to be used for a wide range of applications, identifying the possible applications within a company's business context may pose some challenges. Opportunities provided by GPTs may not openly present themselves to companies, as they are not ready for use and implementation just like that, but require research programs to develop the technologies as well as the supporting factors. As the use of the technologies may initially focus on one sector, it will require capabilities in sensing opportunities to recognize how the generic function can be developed further and how it can be benefitted from in a specific industry and in company-own business processes.

As the innovational complementarity of GPTs makes it more profitable for the user sectors to innovate and to improve their own technologies (Rosenberg & Trajtenberg 2004, p. 65), the rise of a new GPT can be expected to be responded to by increased innovational efforts. Since GPTs provide inputs (Lipsey et al. 1998, p. 43) and enablers for new opportunities (Bresnahan & Tratjenberg 1992), companies may initiate research programs and implement strategies on how the generic function can be exploited in the context of their business. Identifying strategic goals regarding the use of the GPT can allow decision-makers to evaluate the existing capabilities in order to identify supporting factors that need to be developed in order to exploit the full potential of the technologies (cf. Leonard-Barton 1988).

The fact that new general purpose technologies require the creation of complementary assets in the form of new business processes, new skills, and new organizational and industry structures in order to fully seize the opportunities provided by GPTs (cf. Brynjolfsson & Hitt 2000, p. 45) will likely reflect in decision-makers' responses to such opportunities. As Brynjolfsson and Hitt (2000, p. 24) argue in regards of Information Technology and Computers, the business value results less from the computational capability but rather from the "ability of managers to invent new processes, procedures and organizational structures that leverage this capability". Seizing GPT-opportunities therefor requires "recognizing complements among technology, practice and strategy" (Brynjolfsson et al. 1997, p. 37). As investments into previous GPTs without organizational change, or only incremental or partial implementation of organizational change have been found to result in productivity losses as the benefits of the technology are outweighed by conflicting organizational practices (Brynjolfsson et al. 1997), decision-makers have to initiate overall change in the light of GPTs and combine new business processes, adaptations of the technology and the leveraging of complementary factors. For this reason a mutually adaptive approach as introduced in the previous chapter can expected to be a suitable response for implementing GPTs. As GPTs evolve over time, implementation cannot be predictable and preprogrammed (cf. Leonard-Barton 1988) but rather needs to evolve with the technologies.

As stated earlier, the potential for improvement and the need for innovational complementarities result in the diffusion and the process of technological change being intermingled (Lipsey et al. 1998, p. 39). Implementing these technologies in a stepwise process would allow to continuously develop the technology further and to identify and implement supporting factors while resolving uncertainties and creating learning effects. Since the different applications and the technological progress are factors that can only evolve over time, a stepwise implementation can get the process started. While the overall long-term impact of GPTs can be considered disruptive, the broad requirements and influences on critical aspects of the entire company- and industry structure may lead to a more cautious approach in their implementation.

The potentially high capability gap in the case of GPTs certainly influences the familiarity of the technologies, as less current and complete knowledge exists within organizations (cf. Leonard-Barton 1998, p. 51). This can be expected to reflect on the chosen forms of technology sourcing options. As mentioned above, the uncertainty regarding the technologies and how they will develop can be considered to be rather high in the beginning. At the same time, the necessity to absorb new capabilities from others and to create an understanding of the technologies can also be considered high. For this reason it can be expected that general purpose technologies are responded to by some form of external acquisition of the new technology, which then has to be combined with further internal development programs in order to improve and adapt the technologies to new uses, and to develop complementary assets. Due to the initial uncertainty, companies may start with a more low commitment option and move to options with more commitment as uncertainty decreases (cf. Leonard-Barton 2011).

As a further factor, the vertical and horizontal externalities inherent in GPTs require increased cooperation of different actors in order to jointly create the new structures needed to fully benefit from GPTs. As the horizontal externalities lead to an interdependency of different actors, decision-makers in different companies may need to work together in order to push the process of complementary innovations and technological improvement forward. This shows that cooperating with others will not only be necessary for the sourcing of the technology but is required throughout the process of implementation and utilization of the technologies. Without cooperation between various actors the required technological progress and complementarities and therefor the benefits of the technologies will be challenging to achieve. Joining forces of different actors will therefor have a positive impact on the diffusion of the technologies and in exploiting their full potential.

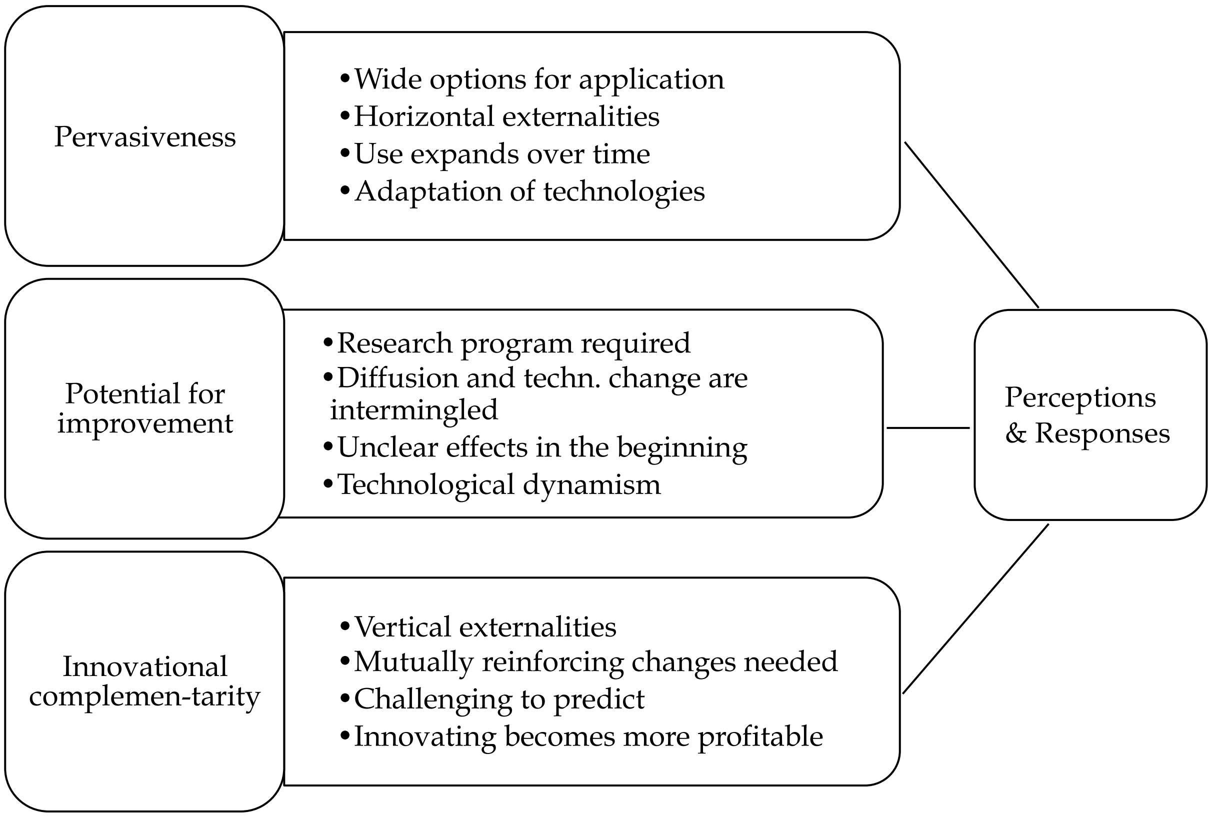

Fig. 2: Characteristics of GPTs (Own illustration based on Bresnahan & Tratjenberg 1992; Helpman 1998; Helpman & Trajtenberg 1994)

3 DATA AND RESEARCH METHOD

3.1 Research setting: Industry 4.0

The term Industry 4.0 has its origins in the strategic initiative *Industrie 4.0* implemented by the German government, but has ever since spread internationally as a term describing the transformation of industrial companies globally (Bundesministerium für Bildung und Forschung [BMBF] n.d.; Pwc 2016).

The term "is *conceptual* in that it sets out a way of understanding an observed phenomenon" (Smit et al. 2016, p. 20) and does therefor not refer to one specific technology but rather comprises several different technological trends, such as Internet of things, Internet of Services, cyber-physical systems, cloud computing, smart sensors, 3-D printing, or big data, which allow digitalizing production processes and vertically and horizontally integrating value chains (cf. Gartner 2015; PwC 2016; Smit et al. 2016). Especially the term Internet of Things is often used as a synonym for Industry 4.0. However, instead of the Internet of Things being a synonym for Industry 4.0, Industry 4.0 is the application of Internet of Things to the world of manufacturing (Smit et al. 2016, p. 22). The Industrial Internet is a further term that is often used as describing similar phenomena as those included in Industry 4.0 (Smit et al. 2016).

Although there exist several related terms such as digitalization, Internet of Things or Industrial Internet, the term Industry 4.0 was chosen for this thesis as it on the one hand allows to include a broader group of current trends, which through their interplay result in smarter operations and production processes, and on the other hand is more specific to the industrial sector than alternative terms such as digitalization, which refers to "the digitization of everything that can be digitized" (IGI Global, n.d.). The same argument applies to the term Industrial Internet, which includes roughly the same processes as Industry 4.0, but similarly as digitalization, goes beyond the industrial sector (Bledowski 2015).

Overall, Industry 4.0 comprises technological developments enabled by the Internet allowing "communication between humans as well as machines in Cyber-Physical-Systems (CPS) throughout large networks" (Brettel, Friedrichsen, Keller, & Rosenberg 2014, p. 37). This advanced digitalization through internet- and future oriented technologies is said to result in more efficient manufacturing and processes in which products themselves can control the production process and tailored individual production becomes as feasible as mass production (Lasi et al. 2014). Combining several break-through digital technology innovations allows integrating the physical and virtual world and "bringing the fungibility and speed of software to large-scale manufacturing" (Geissbauer, Vedso, & Schrauf 2016, p. 3). The core concept of Industry 4.0 therefor is "to connect embedded systems and smart production facilities to generate a digital convergence between industry, business and internal functions and processes" (Gartner 2015). As a result of these developments, a shift from product orientation towards service orientation is expected to happen also in rather traditional industries (Lasi et al. 2014). “These developments make the distinction between industry and services less relevant as digital technologies are connected with industrial products and services into hybrid products which are neither goods nor services exclusively” (Smit et al. 2016, p. 20).

“In order to recognize and realize the potential hidden in Industrie 4.0, completely new strategies and thought patterns will be necessary” (Kruppa 2016). A successful adaptation does therefore not solely include developing and incorporating these technological innovations, but additionally organizational structures and business models have to undergo change in order to fit the new environment.

The addition 4.0 indicates that these developments represent the Forth Industrial Revolution in the form of cyber physical systems (McKinsey & Company 2015). This argumentation is based on the scope and transformative effects of the related technologies (Schwab 2016). Other sources in turn argue that it rather represents an expansion of Automation or Digitalization as the Third Industrial Revolution (c.f. Drath & Horch 2014; McKinsey & Company 2015). Either way, as Industry 4.0 affects a large number of players from different sectors globally, enables the creation of new products and services, requires new structures and business models and the technologies advance over time, it can be argued that the technologies represent General Purpose Technologies.

Successfully transforming the manufacturing industry is of very high importance in Finland. The development of the country’s industrial sector has been rather weak and investments as well as productivity have been in decline (Ailisto et al., 2015). “The disruption is a threat to those who stick to the old operating ways for too long, while it is an opportunity for those who utilise the new technology, offering products and services that interest customers, methods that increase performance and new profit-making business solutions and models” (ibid., p. 7).

3.2 Research methods for the collection of data

The aim of this study is to get an in-depth understanding of how companies in Finland respond to Industry 4.0. Creating an understanding of a rather novel concept calls for the use of qualitative methods. For this reason the primary data for this thesis was collected through individual in-depth interviews with company decision-makers.

The purpose of qualitative interviews is to produce empirical material for the research by focussing on issues related to the topic under study and the research questions (Eriksson & Kovalainen 2008). As Industry 4.0 is a rather new and hardly researched topic that may be approached very differently from company to company, using interviews allowed gaining in-depth insights on the issue from different companies’ perspectives.

A specific challenge related to qualitative interviews is the formulation of good questions that result in the creation of material relevant for the study without the interview questions equalling the research questions (Glesne 1999, p. 69 as cited by Eriksson & Kovalainen 2008, p. 80). As stated by Eriksson and Kovalainen (2008, p. 79), interview questions should provide material that allows answering the research question through analysing the material.

The form of interviews used in this research are guided, semi-structured interviews using an outline of questions, but leaving some freedom in the order of questions and the exact wording used (cf. Eriksson & Kovalainen 2008, p. 82). The advantage of this form of interview is that it results in a more informal and conversational tone while ensuring that the collected material is nonetheless systematic and comprehensive (ibid.). During the interviews a framework of open-ended questions was used, which allowed asking follow-up questions depending on the answers given by participants. The use of this method therefor allowed creating an overview of different company representative's opinions and perceptions and the aspects that are considered to be important in relation to Industry 4.0.

Compared to structured interviews, a semi-structured form can be somewhat challenging as the researcher needs to ensure that all topics from the outline are sufficiently covered in every interview and the respondent should be encouraged to give in-depth answers (Eriksson & Kovalainen 2008). At the same time, enough freedom for participants to bring up topics they consider important has to be given. This more open nature of the interviews, where different participants interpret questions differently and may set a different focus, can make the analysis and comparison of the material more challenging (ibid., p. 82). Nevertheless a semi-structured form of interview is suitable for this study as it allowed capturing the different perceptions and viewpoints on the rather new concept of Industry 4.0, while ensuring that similar issues where addressed in every interview, creating an overview of Industry 4.0 in Finland.

Secondary data refers to already existing data in textual or other form that has not been produced for the purpose of the study by the researcher (ibid., p. 78). The secondary data for this study was collected through a web-based approach focussing on the identification of journalistic material and company publications on the topic. "The usefulness and relevance of textual data in qualitative business research is traditionally based on the idea of transparency", meaning that they are considered to represent the subject under study (ibid., p. 90).

3.3 Data collection

For the purpose of this study, data on the perceptions and strategies regarding Industry 4.0 of 16 companies listen on the Helsinki Stock Exchange was collected. The selection of companies was narrowed down to those companies whose Industry is categorized as Industrials or Basic material in the main list, as these are the companies that are mostly affected by changes brought through Industry 4.0.

Primary Data was collected through in-depth interviews with company representatives and a technology expert.

Due to the need of the participants to have knowledge about the company strategy and activities and planned actions in terms of Industry 4.0, the company representatives were all active members of the organization and part of the top management team. Positions of interview partners include Chief Information Officer, Vice Presidents in areas such as Technology or Digitalization, or Director of Engineered Solutions. Additionally to company representatives, one interview was conducted with a Technology expert participating in national studies on the issue. This interview was conducted in order to gain better understanding of the technologies, their general emphasis in Finland, as well as to discuss the issues addressed in company interviews on a more general level. The companies represented by the interview participants operate in areas such as basic resources and engineering; Technology and services, manufacture of machinery and equipment, engineering and research. An overview of the interview dates, participants and the companies can be found in Figure 3.

	Industry	Participant position	Date
Company 1	Basic resources, engineering	Director – Digitalization strategy	23.01.17
Company 2	Industrial machinery	Vice President - Digitalization	30.01.17
Company 3	Technology and services	Vice President - Technology	01.02.17
Company 4	Manufacture of machinery and equipment	Director – Engineered Solutions	09.02.17
Company 5/Expert	Technical Research Institute	Principal Scientist	10.02.17
Company 6	Engineering	Chief Information Officer	14.02.17

Fig. 3: Overview of Interview Participants and Interview Details

The interviews were conducted over a period of five weeks during January and February 2017. Leaving at least several days of time between interviews allowed reflecting on their contents and adapting the interview questions based on the experience gained. All of the interviews were conducted via Skype and lasted 20-45 minutes, with the majority of interviews lasting at least 30 minutes. The semi-structured interviews were conducted using a Framework of in-depth questions. The interview framework (see Appendix 1) consisted of three main parts. In the first part the focus was on the respondents' and the represented company's opinions on Industry 4.0. General issues regarding Industry 4.0, the strategic meaning of it for the company as well as the effects for the company and the future development of Industry 4.0 were discussed here. The second set of questions dealt with issues regarding the technological know-how, the creation of new know-how and the implementation of the technologies. The third part covered questions on the strengths and weaknesses of the company in terms of these developments, the perceived risks and alternatives for Industry 4.0., as well as other challenges with the issue. In a last part participants were asked to contribute anything else they considered relevant. In order to ensure that participants understood what the questions are about and all participants had an understanding of what the interviewer means by industry 4.0, the interview started with a short clarification of the study and the concept Industry 4.0.

Apart from the first question, which was used as an introduction to the subject, formulation and order of questions varied somewhat depending on the issues addressed by the participants and the different sets of questions were therefor often mixed throughout the interviews. During the interviews some freedom for participants to focus on aspects they considered most important was left. Due to the high expertise of the interview participants, many questions did not have to be asked directly, but interview participants would often answer several questions simply by opening up on the subject. This allowed gaining an in-depth and broad impression of issues regarding Industry 4.0 within the different companies.

Transcribed interview material resulted in 36 pages of data. Respecting the confidentiality wishes of the interview partners and the strategically sensitive issues discussed in the interviews, names of participants and companies are not published in the study.

The data in the form of interview transcripts was complemented with secondary data from public sources, such as journalistic material, mainly in the form of CIO or CEO interviews, journalistic articles and official company press releases. In order to ensure that the findings are up to date, only sources from 2015 or later were accepted. The collection of data from publicly available sources was initiated after the first interviews had been conducted. The criteria for the selection was that the sources needed to cover Industry 4.0 or certain technologies related to this concept. Search words included Industrial Internet, Internet of Things, Industry 4.0, Industrial Digitalisation and similar related terms in English as well as in Finnish. The sources further needed to deal with a certain company and illustrate aspects of their approach to Industry 4.0. This ensured that the collected data presents actual actions and perceptions regarding technologies related to Industry 4.0, instead of hypothetical approaches and suggestions.

The search for publicly available sources resulted in 19 different data sources, which cover 11 different companies. As the companies included in the primary data, the secondary data covers companies that are listed in the Helsinki stock exchange as operating in the basic materials or Industrial sector. More specifically the companies represent Industries such as Engineering & services, Industrial machinery, pulp and energy, paper and automation, heavy equipment, construction services, building and industrial services as well as forest industry. An overview of the secondary material used, as well as the companies represented by it can be found in Appendix 3.

3.4 Method of analysis

The research method used in this study is a qualitative descriptive method in the form of thematic analysis.

Thematic analysis allows identifying, analysing, and reporting patterns or themes within data by organizing and describing the data in detail (Braun & Clarke 2006, p. 6). The process is based on identifying themes through closely reading and re-reading and familiarizing oneself with the data and encoding important aspects (Fereday 2006). Good codes should capture the qualitative richness of the data without interpreting the data at this stage (Fereday 2006).

A theme grasps contents from the data that are of importance in relation to the research question and tries to provide an overview of patterned responses (Braun & Clarke 2006). Although in many cases certain themes are very apparent and can be found in several different data sets, the process of identifying themes is somewhat dependant on the researcher's judgement as he or she evaluates the importance of certain themes within the data (ibid., p. 10).

In this study an inductive, data-driven approach was used in which the themes are closely linked to the data and emerge from the data. Inductive research is explorative in nature and allows gaining new insights from empirical data (Fereday 2006). Nevertheless, it is important to note that "data are not coded in an epistemological vacuum" (Braun & Clarke 2006, p. 12) as it is impossible to entirely free oneself from the theoretical framework of the study and the framework itself is also based on assumptions of the nature of data (ibid., p. 9). As the interview questions for this research were somewhat based on the initial theoretical framework, this may have influenced the emergence of certain themes throughout the interviews and within the analysis.

The overarching themes are kept very broad and reflect the main points discussed in the interviews and the secondary data. The sub-themes then represent the different issues addressed regarding an overarching theme. In order to ensure transparency in the emergence of the themes from the data, all steps were closely documented and an overview of codes, sub-themes and themes is given in Appendix 3.

The thematic analysis was further based on a semantic approach, in which the themes are identified solely on the explicit meanings of the data and aspects beyond what was said in the interviews or written in the journalistic material was not considered in the analysis (cf. Braun & Clarke 2006, p. 13).

Due to the descriptive aspect of thematic analysis, this method is suitable for answering research questions that aim at describing a certain phenomenon (Fereday 2006). The broadness of the topping of this thesis and the diversity of information gathered through interviews and public sources, calls for a method that allows creating an overview of the situation.

Based on Braun and Clarke (2006) the identification, coding and analysing of themes was done in six nonlinear steps that involve moving back and forth whenever needed.

After the data set was gathered the first step was to familiarize with the data. Audio-recorded interviews were transcribed and translated from Finnish to English and the transcripts were then checked back against the audio recordings in order to ensure accuracy in terms of transcription and translation. Collected journalistic material and company statements were reviewed and those not relevant for the context of the study were excluded from the data set. The secondary data was then transferred into word files, which allowed them to be printed and analysed in the same way as the primary data.

After reading and familiarizing with the data, the second step involved creating initial codes that cover all the information given in the data sets. Altogether 74 initial codes were derived by reading and re-reading the collected data and by highlighting potential patterns. Overlapping codes and codes with the same meaning were later summarized, and this resulted in 84 codes as the basis for generating themes. In a next step related codes were categorized and combined as sub-themes. This process initially resulted in 12 sub-themes providing an overview of the codes.

In a fourth step the sub-themes were verified by going through the data and evaluating whether enough specific data existed to support these themes, whether the themes accurately represented the content of the data set and whether the codes had been allocated to each theme correctly and formed a coherent pattern. This process resulted in regrouping codes and combining closely intertwined themes as well as separating issues in themes of their own, which left the analysis with 18 sub-themes in total.

A next step included defining and naming the themes and creating five large overarching themes that summarized the sub-themes. The overarching- and sub-themes were named in a way to give the reader an immediate impression of the content of the theme (cf. Braun & Clarke 2006). These steps were very iterative and deriving the final set of overarching themes and subthemes involved a lot of going back and forth between the data and the codes and themes.

The final step was writing the analysis on the basis of the identified themes and using evidence for the themes in the form of data extracts.

3.5 Reliability and validity

The objectivity of qualitative research can be evaluated based on the reliability and validity of the observations (Eriksson & Kovalainen 2008, p. 291; Kirk & Miller 1986, p. 13). Using evaluation criteria increases transparency and assures readers of the work's scientific nature, quality and trustworthiness (Eriksson & Kovalainen 2008, p. 290).

Reliability refers to "the extent to which a measure, procedure or instrument yields the same result on repeated trials" (Eriksson & Kovalainen 2008, p. 292). Validity in turn refers to the extent to which the instrument measures what it was intended to measure and the extent to which the conclusions provided by the study accurately describe or explain the phenomena under study (Kirk & Miller 1986, p. 7).

These criteria can be challenging to establish in qualitative research, however, a detailed description of the research process and how the results and final conclusions were generated can ensure reliability of the study (Eriksson & Kovalainen 2008). The researcher must therefor closely describe how the conclusions were derived. In this study the findings are supported with a large amount of direct quotations in order to illustrate their reliability. The process of conducting the analysis of the findings closely followed the stepwise approach described by Braun and Clarke (2006), and although thematic analysis is always somewhat subject to the researcher's interpretations, the close documentation of the use of the steps and the derivation of themes, allows readers to understand and reproduce the process.

Nevertheless, reliability may have been compromised in some aspects due to the nature of qualitative research and the limited number of interviews.

As the findings reflect the issues relevant to decision-makers at the time of the study, the opinions on the topic of the issue under study may change with increased experience and learning effects. The results regarding for instance uncertainties are somewhat tied to this point in time as they describe the issues considered to be relevant at this time. For this reason reliability in terms of consistency of results over time may be somewhat jeopardized due to the nature of the issue under study. Nevertheless reliability in the short-run can be assumed. Especially the secondary data, which was also analyzed using the thematic analysis, is very likely to result in similar findings if conducted again using the same steps of analysis.

This research describes the perceptions and responses of different decision-makers representing the companies they work for. The participants in this study were therefor interviewed as decision-makers within companies and not as private persons. However, it may be possible that opinions given in interviews do not always reflect participant's opinions as decision-makers and representatives of companies, but rather their own personal opinion. However, it could be argued that this personal opinion is likely to influence and reflect in their opinions as decision-makers in the company.

The purpose of this study was to identify perceptions and responses on a more general level and therefor some aspects that were evaluated as insignificant for the outcome of the study were left out of the research. Due to the qualitative nature and the somewhat strategically sensitive issue under study it is possible that not all relevant issues were brought up within interviews or in the secondary data. Nevertheless the depth of the interviews and the existence of secondary data may allow assuming that the most relevant aspects were addressed.

The reliability of this study may further have been influenced by the use of semi-structured, open-ended interview questions. Using open-ended and semi-structured questions may lead to subjective interpretations of questions and to the choice of different focuses depending on the interviewee (cf. Eriksson & Kovalainen 2008, p. 82). Because the interview material and parts of the secondary data are originally in Finnish and were translated by the researcher, the possibility that minimal aspects are lost in the translations cannot be ruled out. It was, however, paid close attention to detailed translations that capture the original meaning as accurately as possible. With the permission of participants, a recorder was used throughout the interviews to ensure that no information is lost between the time of the interview and the transcription.

Validity and the accuracy of the perceptions and responses regarding the technologies can be considered high due to the careful selection of interview participants and secondary data material. All of the participants are part of the higher management of the companies they represent and their input and knowledge on the issue can be considered very significant. As the secondary data also focuses on opinions of decision-makers within companies it can be expected to accurately illustrate what decision-makers make of the issue. A further factor supporting the validity of findings is that interviewees participated voluntarily and were interested in the subject under study. The structure of the interview and the nature of the questions allowed participants to express their own opinions and to guide the interview towards aspects they themselves considered most relevant. It was paid close attention to avoid suggestive questions and to keep the role of the researcher neutral.

Nevertheless some aspects of the findings may have to be treated with caution as opinions and plans of the best way to proceed with the issue under study may not necessarily always reflect actual actions taken.

That the interview material was complemented with secondary data on the subject increases validity and coherent results throughout the interviews and the secondary data further support that the findings are valid and accurately represent the issue under study.

A further aspect that has been identified as influencing validity is the size of the sample and saturation of data (Guest, Bunce, & Johnson 2006). This issue was addressed by complementing the more limited interview data with secondary data. Secondary data could be collected up to a point where repetition of information became high and it was assumed that no substantially new information would appear from collecting further data.

4 RESEARCH FINDINGS

4.1 General information

This section is structured according to the five overarching themes derived through the thematic analysis of the data. While the overarching themes were kept rather general, the sub-themes provide an overview of the individual responses and opinions related to the large overarching themes. The interviews and the publicly available data sources addressed very diverse aspects of Industry 4.0 and the themes cover the *Conceptualization and understanding of Industry 4.0*, the *use of Industry 4.0, Enablers for the implementation of Industry 4.0, Approaches to the implementation of Industry 4.0* as well as the *uncertainties, challenges and risks.* In the following these themes will be closely described and the sub-themes that emerged within over-arching themes will be outlined in order to create an impression of what factors companies considered being important in terms of responding to Industry 4.0. An overview of the codes, sub themes and overarching themes that have been identified throughout the analysis process is given in Appendix 3.

The findings are equally based on the interview data as well as the data collected from publicly available sources. The opinions given in the findings reflect the empirical data and are underlined with relevant quotations from the data. In order to ensure the confidentiality of the interview participants no information that could identify the participants or the company they represent are given in the case of interview material. Direct quotations from the primary as well as the secondary data are assigned to company numbers, which can be found in Figure 2 and Appendix 2. Extracts from the primary interview data and the secondary publicly available material that was originally in Finnish has been translated into English.

As mentioned in chapter 3.1, Industry 4.0 is considered as a concept including several different technological developments. For this reason all issues regarding a technology or process that can be seen as an element of Industry 4.0 according to the description of the concept given in chapter 3.1, were considered as relevant for the findings regardless of the wording used by the informants.

4.2 Conceptualization and understanding of Industry 4.0

The overarching theme on *Conceptualization and understanding of Industry 4.0* includes four sub-themes covering the *Terminology*, the *Impact of Industry 4.0., Making-sense of Industry 4.0* as well as *Industry 4.0 strategies.* These four issues were grouped as an overarching theme because they all deal with the way industry 4.0 as a concept is perceived and conceptualized by the companies: what the term itself is considered to refer to and what alternative wording is used, the perceived impact of the concept and how it is evaluated, as well as how companies incorporate Industry 4.0 and related technologies into their strategies.

Terminology

In terms of *terminology* it showed throughout the data that various terms are used for the same developments. In some cases the same terms were interpreted differently and in other cases different terms were treated as synonyms. The terminology used for the same concept ranges from digitalization, over Industrial Internet or Internet of Things to Industry 4.0. Although all interview participants stated to be familiar with the term Industry 4.0 and to have an understanding of the concept, this was not always the term the related developments were referred to inside the company. In some cases the preferred term was Digitalization due to the broadness and all-encompassing character of the term including all relevant technologies that relate to digitalizing the processes.

> "I'll open up a bit on the terminology we use. My own role as digitalization manager includes very broadly, of course, all of these technologies and also the related business side and so on. In the firm we speak very broadly about digitalization, which for us also includes many other processes and new digital services and so on…so it is a specification thing what Industry 4.0 means to whom in different circumstances." (Company 2)

Some participants evaluated Industry 4.0 as being solely a term used for the German industry sector, but meaning the same as Internet of Things. In one interview the participant referred to Industry 4.0, Internet of Things and digitalization as synonyms, with different regional origins.

> "We don't in that sense speak about Industry 4.0 because Industry 4.0 is an invention of the German Industry sector. So for us it is more IoT, so Internet of Things. But they are the same things, Industry 4.0 or IoT…so in that sense it doesn't matter." (Company 4)

While Industry 4.0 was considered the German term for the technologies, Internet of Things was considered to be a synonym that was developed in the US.

> "Industry 4.0 is not such a known term in Finland – it is more known abroad. (…) And IoT again seems to be from the US side. I myself like to talk about digitalization. Things are digitalizing." (Company 4)

Despite the awareness that Industry 4.0 is originally a term invented for the German industry sector, some participants reported that the term was used in their organization because it summarizes all relevant technologies. In this case the Internet of Things was considered as one component of Industry 4.0 instead of a synonym for the term.

> "We in our company speak about Industry 4.0 (…) For me Industry 4.0 is this umbrella term under which almost any technology can be put. It includes 3-D printing, analytics, cloud services, industrial internet and IoT." (Company 6)

Impact of Industry 4.0

The sub-theme *Impact of Industry 4.0* summarizes all issues addressed regarding the effects Industry 4.0 has on the company- and the industry level and their future developments. The primary as well as the secondary data showed very differing perceptions on how radical the impact of industry 4.0 is considered to be. One company representative emphasized the fact that Industry 4.0 and the related digitalization is made up of so many different technologies and developments with different effects that it includes both incremental and radical aspects.

> "There are elements which are in a way incremental, they are the usual developments and then there are those perhaps more radical elements related to renewing business operations." (Company 2)

In evaluating the effects for the own industry, perceptions further ranged from Industry 4.0 as a disruption or a revolution and Industry 4.0 as an expansion or an evolution. Whether Industry 4.0 can be seen as revolutionary was evaluated differently depending on the prior experience with technology, automation and renewal of the company as well as the industry operated in.

In one case Industry 4.0 and its effects for the own industry were compared to the effects of digitalization on consumer industries. In this case Industry 4.0 was seen as an expansion or an evolution compared the to the more drastic effects digitalization has on the consumer industry. This was because Industry 4.0 was seen rather as part of a development that has been going on for a longer time already.

> "If in consumer industries and stores we are talking about these kinds of disruptions and about this that things change entirely and a revolution is happening, then in this industry we are speaking more of an expansion.

> Automation has been for a long time this kind of local thing inside our production and now it can be even more optimized. (Company 1)

Companies that considered Industry 4.0 to be the next big step in the process of automatizing factories had seen the digitalization of manufacturing and other processes coming already for the past 30-40 years.

> "I myself see the development of the Industrial internet more as an evolution than a revolution. The enabler of this development is industrial automation, which has started moving to the digital age already in the 1980s." (Company 10)

In contrast to this, Industry 4.0 was evaluated as a disruption when considered from the technology side and the progressiveness of the industry operated in. In that case the developments were perceived as more sudden and as initiating more rapid changes within the industry operated in.

> "But we are in this disruption of course. The industries we are in – if we consider it from a pure technology perspective - are not the most progressive (…) and customers are in such industries where renewal has maybe traditionally not been done among the first. But it is coming in a way and new operation modes are coming, which will likely change our operations and our industry faster than before." (Company 2)

Another company representative considered the developments to be more of an interplay of different technologies resulting in a megatrend. This interplay of technologies was referred to as "smart solution concepts, which then combine to megatrends" (Company 6).
Despite these differences in the perception of Industry 4.0 and its revolutionary character, all of the companies included in the analysis considered Industry 4.0 and the related technologies as an opportunity if responded to rapidly enough and it was stated that "the potential is huge." (Company 7)

> "I do think that it is an opportunity. At least if we continue to push things forward and invest and not just lean back. Then it would clearly become a threat." (Company 1)

Making sense of Industry 4.0

The different evaluations of the actual impact of Industry 4.0 and the broadness of the technologies included was expressed as providing difficulties in truly *making-sense of Industry 4.0*. As company representatives expressed some confusion on what Industry 4.0 or the related technologies actually are and showed uncertainty of what to make of these developments these issues were grouped separately as a subtheme of their own.

It was expressed by company representatives that the lack of a clear definition and the existence of several related terms results in confusion on what Industry 4.0 and other related terms and concepts actually comprise.

> “At least the market we are following is predominated by this kind of a bluff or at least very diverse perceptions of what this Industry 4.0, or digitalization, or digital transformation, or Internet of Things actually is.” (Company 1)

> “Maybe from my own perspective having worked on this during the past three years then this IoT is such a big…such a big cloud that no one can really say what it actually is and everything somehow relates to it or nothing relates to it.” (Company 4)

Some companies faced the difficulty of understanding what kinds of changes Industry 4.0 actually brings. Companies that have been working on automation for a long time already and have continuously updated their processes, showed some confusion about the transformative effects of the technologies.

> “Many – us too – have censored and measured things for a long time and it raises the question of what is actually different with this now. So if it is not analogue it’s digital - but maybe the transformative effect is not understood. So that things are actually changing.” (Company 6)

In regards of such an uncertainty of the actual novelty and impact of Industry 4.0, the existence of a certain denial within companies was mentioned to exist.

> “People can be found that feel that well does this bring anything new or different. So people who still are in this kind of a denial mode can be found.” (Company 6)

Connected to that, some participants also showed skepticism on the actual value industry 4.0 can bring and it was stated that “Industry 4.0 is not the answer to everything” (Company 1). In these cases the question that was raised was whether the effects are truly that impactful, or whether too much hope is put into this transformation in some cases.

> “Maybe there has also been going on some illusion – so it feels like digitalization can be extended to all sides and it solves all problems but probably no one actually believes this in the end.” (Company 5/Technology Expert)

Industry 4.0 strategies

Despite existing difficulties in making sense of Industry 4.0, companies recognized the potential of Industry 4.0 technologies and considered the concept to be a clear prerequisite in maintaining future profitability and competitiveness. Several companies included in the study have put Industry 4.0 and related technologies in a more or less prominent position in their agenda and some companies explicitly expressed that their strategies take Industry 4.0 and the related developments into account.

One company representative for instance stated that the company has developed a technology strategy as well as a business strategy related to the use of the technologies.

> "We have a couple of years ago developed this kind of a technology strategy related to Industry 4.0 and about a year ago we developed a business strategy and are continuing to clarify things a bit. We understand that digitalization is a central component of our future competitiveness and… and I can say this for all of the Industry 4.0 areas." (Company 1)

For other companies specific technologies or aspects of Industry 4.0 were selected and emphasized strategically. Putting the technologies to the core of the company strategy was considered important "because it is a prerequisite in succeeding in competition (…) [as] otherwise one cannot keep up with the development of the market." (Company 7)

> "In our strategy we have these smart solutions (…) and we do this operational efficiency work and there Industry 4.0 is very much present." (Company 6)

> "This concept has a very strong meaning for us and for our future (…) so based on this we will hopefully create some kind of revenue in the future. Digitalization is an important part of our strategy and Internet of Things and Industry 4.0 are our cornerstones." (Company 4)

A part of the strategy creation process was to identify the different ways of how the technologies could be benefitted and applied within the company. Company representatives emphasized the importance of finding out how they can benefit from the technologies within their organizations.

4.3 Use of Industry 4.0 technologies

This overarching theme deals with issues regarding how the technologies and concepts behind industry 4.0 are used by the companies, and the benefits they are considered to bring. Three broad issues regarding how Industry 4.0 and the related technologies can be used appeared in the data: Using Industry 4.0 technologies for the *improvement of efficiency*, using Industry 4.0 technologies for the *development of new business- and revenue models,* as well as for *improving safety and reducing risks*.

Improve efficiency

The basic application of Industry 4.0 technologies was considered to be their use in improving efficiency of existing operations. By connecting parts and machines and allowing them to communicate and interact, production systems were said to function more rapidly and with higher productivity, and customization was said to become more affordable through smart systems that allow more flexibility.

> "Because of the Industrial Internet, the smartness of products and their environments moves outside of the machines and devices. Industrial Internet enables the strengthening and improvement of current business operation processes." (Company 8)

Implementing technologies that allowed connecting different machines and equipment into smarter processes was expressed as improving company's operations by reducing losses.

> "If we get these processes to communicate along the way we can minimize for instance losses and improve the functioning of the processes." (Company 3)

The data also showed that solutions connected to the Internet are used for optimizing the use of different resources such as the energy consumption.

> „IoT-solutions are used in the energy branch for collecting and analysing data in real time in order to be able to produce energy more accurately, distribute and use it more efficiently and to use resources more economically and environmentally friendly." (Company 16)

Improving efficiency through new technologies was not only considered to apply on the inside of the own company, but was especially seen as an important factor in helping customers to improve their operations. As most of the companies included in the sample deliver systems to other industrial companies, a strong focus was put on the possibilities for increasing productivity for the customer. Being among the first to offer innovative integrated solutions to customers was considered crucial for the organization's competitiveness.

> "It applies on different dimensions: the internal efficiency and what we can develop for our own operations and productions and services and then also how we can help customers to improve their business." (Company 2)

> "We see improving customer experience and improving their cost-efficiency as the means of digitalization – this is an on-going development." (Company 13)

Whether on the customer's side or the own company-internal processes, the reduction of losses and costly interruptions in production due to machine breakdowns was said to be avoided through the interplay of new technologies. Several sources mentioned that the use of Industry 4.0 technologies transforms the way of operating from a mere reaction to incidents, to foreseeing problems and understanding their origins and potential effects before they actually occur.

> "Combining machine learning with these other technologies and cognitive processing of data allows moving from a reactive and predictive form of operating to this cognitive form of operating. So it's not just about what will happen next but what the effects will be." (Company 4)

In these cases the different systems and technologies are connected to networks, clouds or satellites that gather and transmit different kinds of data and information, which is then used to work on services and estimate maintenance needs. Company representatives stated that they receive "the needed information for maintenance and production development" (Company 7) from different devices connected to the network, which then allows them to improve customer service and "in the best case faulty situations can be avoided through predictive maintenance." (Company 7)

> „Over satellites we get the information on how the equipment is operated. Utilization rate and failures can be followed more easily. The need for maintenance could not be predicted this accurately in the past. Now we are able to better see into the equipment and plan the maintenance in advance." (Company 9)

The machines and equipment produced by the companies was said to "include a monitoring of operative actions: where is the equipment moving, does it need vehicle transport to reach its goal, what is the output and fuel consumption" (Company 11) and other information that allows to collect data in a cloud from where it can be accessed by customers in order to gain information on the state of the equipment. Other companies applied smart solutions "in developing maintenance services, evaluating the performance of equipment and processes, simulations and critical analyses" (Company 15). Such an approach allows companies to become more predictive in their maintenance services.

> "Continuous collection of data supports proactive maintenance and brings information to the system that can be used in simulating the expected behaviour of the equipment. With the help of these technologies it is possible to target and to optimize predictive maintenance or to make

> investments, with which one can influence the realisation or the monitoring of a development." (Company 15)

Improve safety and reduce risks

In addition to increased efficiency, several sources also emphasized the role of the technologies in reducing risks and improving the safety for the work force. "With the help of the Industrial Internet, industrial companies can truly improve the safety, reliability and usability of their equipment." (Company 7)

This increased safety was said to result from the fact that information concerning the machines can now be obtained through data sent by the machine, instead of requiring the workforce to physically monitor the equipment. Evaluating the data was said to provide more specific knowledge on the functioning of the equipment and in preventing potentially harmful situations for the workforce or the environment.

> "Typically people are no longer needed in dangerous places close to the machine, instead the information needed is received through data sent by the machine. Safety is also increased if we know where the machines are and what they are doing and whether they are causing problems or danger to their environment." (Company 9)

Using predictive maintenance and recognizing defects before they actually occur, was further said to improve safety and lower risks resulting from faulty equipment. Companies working with mobile equipment stated that such a predictive approach now allows timing the maintenance of equipment to a certain location. The danger of a sudden breakdown far away from any repair possibilities is thereby reduced.

> "It results in cost-efficiency that the cargo can be scheduled according to the maintenance and that the maintenance stop can be scheduled for a specific harbor. It is also a question of managing risks. Risks are reduced if defects can be detected before the ship leaves the harbor." (Company 17)

Development of new business- revenue models

Besides the possibility of improving efficiency of the existing processes and operations, several sources expressed the resulting opportunity of *developing new revenue models* by creating entirely new products and services and innovative approaches. Most companies considered this to be the most important factor of Industry 4.0 but also the one that requires the most efforts in succeeding.

In most cases the opportunity to create new products and services was said to result from the access to data that could not be benefitted before and novel ways of evaluating data and connecting data from different sources.

> "So what this digital disruption means for us is that we have a lot of unused data (…) and we are trying to build things in a way that we have better access to all the data (…) and can benefit from the knowledge that collects." (Company 2)

Such knowledge was said to be "connected in an exponential way in order to generate new business models" (Company 8).
Participants further stated that using technologies and concepts such as the Industrial Internet allowed them to create additional value and to create novel sources of income. The share of additional value solutions in the revenue was said to increase from year to year and to change the competitive field.

In several cases new business and revenue models related to selling services in addition to physical goods. Company representatives stated that combining "smart systems, documentation- and industrial Internet applications to a unique service concept" (Company 14) provided new possibilities for growth and an access to providing business development activities.

> "The more interesting aspect for us is besides on the one hand developing and improving existing services and products by using digitalization, on the other hand we intend to create entirely new services through data analytics and cloud technologies."(Company 2)

Companies recognized that offering new services to their customers would allow them create more long-term relationships. The use of available data and the knowledge gained through this was said to allow the companies to offer consulting services in addition to merely selling products. This change was considered to result in a shift in the nature of business operations from a transactional business operation to a long-lasting relationship-type business operation where "instead of selling products, a focus is put on consultative selling and it is looked for the best solution in developing the customers' production process." (Company 7)

As a further reason behind the possibility to offer new services, company representatives mentioned the decreasing role of physical location. Several companies stated that the possibilities brought through the technologies related to Industry 4.0, provided more flexibility for offering services as the location of the company now plays less of a role.

> "This knowledge can be connected from many new sources, which can be projected more efficiently. And then related to this is this opportunity that we can do things independently of our location and faster and better and of course this means changes and improvements." (Company 1)

Through a transformation in the way of operating and organizing, it was recognized that the geographical distance of the Finnish market no longer provides such large challenges in serving the customer. By making use of distant monitoring and the predictive maintenance connected to that, companies face the possibility to provide services independently of the distance between them and their customers. It was expressed that until now companies were rather inflexible in their cost structures and business models as they were tied to a certain location. "Now digitalization is breaking the physical dependency while at the same time also changing the business logic and organizational structure" (Company 9), which was said to open up the value chain and offering the possibility to develop new operation models.

Connected to this, it was stated that updates and improvements to customers' equipment could also be made from afar by benefitting from cloud solutions.

> "We do not need to fly our experts all over the world, but can bring the expertise to one central monitoring room (…) based on the analysis we can give recommendations to our customers regarding the settings or the maintenance of the engine. Sometimes we generate a new setting data file, which the customer can load and install. An increasing number of distant monitoring devices are using two-way data streams and they can also be optimized in the future. " (Company 17)

Distant analysis services were seen as a way to create new revenue streams from offering customers an increase in efficiency and productivity through Industry 4.0 technologies.

> "In the last years we have complemented our offerings by distant analysis services, which improve the productivity and efficiency of processes as well as the quality of the end product. We are developing new solutions all the time and the starting point for the developments is always improving our customers' performance. (Company 10)

While for some companies the opportunities for new revenue streams were said to be the biggest focus and these aspects were actively pushed forwards, others were a bit more hesitant about creating new business and revenue models. Offering new contents was considered an important aspect in "growing products' and services' competitiveness" (Company 1), however, the creation of new revenue models was not always considered necessary for this. In such a case the focus was considered to be more on improving existing operations, although openness for new opportunities that may appear over time was expressed to exist.

> "At this moment we see it as most important to create additional value to our existing business operations but we have also spoken about and decided to keep our eyes open if with the help of this something new can be found – then this is welcomed by us." (Company 3)

4.4 Enablers for the implementation of Industry 4.0

Companies realized that successfully making use of industry 4.0 requires organizational change and the development of new know-how and capabilities. Several companies included in the study identified factors that needed to be developed as a basis for being able to realize opportunities regarding industry 4.0.

> "I do think that at this point it already shows that with the traditional operation mode and the traditional capabilities we will not make it in this competition. It does also demand from us a substantial internal change." (Company 1)

> "There are certain strategy areas that have been planned out quite far ahead or many years ahead and especially certain kinds of enablers will be realized and taken into use. They are the biggest focuses so that we can at all start to build up a new business operation." (Company 2)

These enablers were seen as issues of top priority that need to be solved or developed before any further steps in terms of implementing industry 4.0 could be taken. It was stated that a short cut to the exploitation of the technologies does not exist and "certain basic capabilities have to exist before one can start developing new business models or –innovations" (Company 9).

Depending on the company and the existing capabilities, know-how and experiences, different enablers were identified as a requirement for Industry 4.0 and these were grouped in the sub-themes of *technological enablers*, *organizational and human factors* and *comprehensive understanding and know-how*.

Technological factors

Several companies placed a lot of focus on the technological capabilities as a basis for Industry 4.0. In these cases technologies and the related capabilities were considered as being the key to a successful approach to Industry 4.0.
While some focused on specific technologies and tried to create know-how for them, others considered the basic capability for the Industrial Internet to be "that devices are connected to the system and to one another and they collect data for analysis for the company" (Company 9).

> "All capabilities have to be improved. For us maybe the biggest ones are IoT technologies, big data and then cloud computing." (Company 4)

Also those companies that buy technologies from an external provider considered it necessary to have an overall understanding of their development process and the maturity of different technologies in order to create products and services from them.

> “And of course we have to understand how technologies are developed, although – as I said – we ourselves do not develop these technologies that much but we have to understand what for instance the maturity of a certain augmented reality in our kind of environment and our customers’ environments is (…) this we have to understand, this kind of perspective has to exist, although the core for us is not the technology development, many others can do this a lot better.” (Company 2)

Organizational and human factors

For other companies the focus was less on the technological side but rather on people, organizational capabilities and the organizational culture as a basis for successful implementation. Company representatives emphasized that in many cases it is not about the technology itself but about the people in the organization as it “is not just a technology problem but a substantial change in the entire operation of the company” (Company 9). Making the right decisions and changing the internal processes in order to benefit from the technologies was said to require people and know-how.

> „The future is not born without its makers. Recognizing and developing new opportunities requires know-how and creativity. (…) I dare to say that Industrial Internet is not a technology question, but to a greater extent a question of people and know-how.“ (Company 10)

> „It’s not usually the technology that is the problem with this. The first thing is the believe and the courage to start trying out some new things and then combining these kind of technology trends with business cases...these things have been done in quite traditional ways (...) But it does depend on people and not the technology. (...) So technology is – in my opinion – not the biggest obstacle here. “ (Company 6)

For one company the prerequisite was developing a service ability that was considered necessary to benefit from the technologies. It was emphasized that being prepared to actually offer the services that the technologies would enable is the most important aspect before thinking about actually implementing the technologies for use.

> “I think additional value creation through digitalization requires for our service ability to be intact. With this we still have got a lot of work to do…in that way that we are able to provide a customer with exactly the spare part needed reliably and in a rapid enough delivery time. And this is the first priority before we start for example thinking about machine learning analytics from which we would then get these advanced maintenance information.” (Company 1)

For another company the basis for moving forward with Industry 4.0 was considered to lie in the development of risk-taking capabilities. Together with the risk-taking capabilities, renewing the organizational culture was seen as an important aspect. Lowering risks for employees in trying out different approaches was seen as a necessary change in order to develop innovative products and services with new technologies.

> "The question is what kinds of risk taking capabilities do we have in starting to try out something new. Either the creation of new services or developing improvements to our products and services in a new way (…) A central element here is the speed with which we can renew things, how rapidly we can create a new culture in which we give people the opportunity to try out new things without this fear of failure and we could actually create new services and also realize more crazy ideas through that." (Company 2)

Not all companies did, however, see the need to make changes to their own organization. In that case the need to create enablers and adapt the organization to the changes brought by Industry 4.0 was seen more as a duty of the customers.

> "Right now we would see it that way that this adaptation needs to happen on the customer's side." (Company 3)

Comprehensive understanding and know-how

Several companies also saw the need to focus on both, technological and organizational enablers from the beginning on. A necessary basis for Industry 4.0 was considered to be an overall understanding of the technologies as well as the environment they are used in and to identify supporting organizational factors. A comprehensive, or hybrid know-how in which knowledge and skills from different areas are combined was considered to be an important basis for Industry 4.0. This overall know-how was expressed as a necessity in order to gain an understanding of the problems that are trying to be solved as well as understanding the technological side in order to successfully connect them and to adapt both to the changes.

> "In order to be able to take things forward it takes these normal human relation capabilities so that you can convincingly sell your thing. (…) But then this hybrid know-how - so you have to have an understanding of the industry and of the technologies. So this has to be combined with the technological opportunities and IT…being between borders is at its best in this situation. (…) So it's difficult to take Industry 4.0 technologies forward if the problems or things that are tried to be solved are not at all understood." (Company 6)

> “And then of course a comprehensive know-how is needed. We can under no circumstances say that we are good at anything. We have to develop everything.” (Company 4)

> “IoT demands new kinds of capabilities and skills from companies, independently of the business field. Important are among others an understanding of the overall architecture and the service architecture, capabilities in analysing and handling data, skills in managing ecosystems and partnership networks and getting them to work together, and of course data security.” (Company 12)

One company representative emphasized the importance of first understanding the value creation and how revenues can be made through this and to then combine this with the technological side and the processes.

> “It has to be thought about what kind of value is created with this and the revenue perspective has to be considered and then you have to look at processes and technologies.” (Company 6)

Not all companies, however, felt the need to make changes to their organizational structure or culture from the beginning on. In that case the focus was put on the technologies as first-stage enablers, although it was expressed that organizational changes will most likely follow later on.

> “We are still in such an early stage that we are more working on the technologies and have not that much encountered the fact that people and our way of organizing have to change. But I do have recognized something like that in our organization (…) there is this old-fashioned thinking about what the benefits might be and how to move forward with this.” (Company 3)

4.5 Approaches to the implementation of Industry 4.0

The overarching theme of *Approaches to the implementation of Industry 4.0* comprises all factors that relate to the actual implementation of the technologies. Within this overarching theme three sub-themes emerged: *Advance in experimental, small steps, Creating an ecosystem,* and *selection and adaptation of technologies.* All of these subthemes represent different actions and approaches taken or planned to be taken by the companies in order to create products and services that make use of Industry 4.0 technologies.

Advance in experimental, small steps

This sub-theme is concerned with a type of approach used by several companies to develop the know-how and capabilities for the technologies and integrating them into processes: *Advance in experimental, small steps.*

Approaching the issue in small steps was seen as a safe way to get things started and to continuously gain experience on different possibilities in order to create an understanding of the bigger picture of Industry 4.0 over time. "Rapidly testing and trying out new thoughts and ideas" was considered "essential for the creation of new innovations" (Company 9).

> "I do think the best way to advance is through testing and to rapidly get experience on what works and what doesn't. We have of course - to some degree - thought about the whole architecture and how this is developed and so on but the starting point has been of that kind that we get this rapid experience through which we can then learn and understand more." (Company 1)

This kind of an approach helped companies to offer increased additional value to their customers from the beginning on and to step-by-step build up the entire Industry 4.0 architecture. Projects "should be taken forward with agile, small steps while understanding the needs and feedback of users" (Company 8).

One company representative mentioned that they use proof of concepts in order to realize certain ideas and to demonstrate how they work.

> "We have done a couple of these so called proof of concepts here. So basically we are taking little steps in developing the products and that way we can rapidly create some small increased value for the customers and the market and through that we start building the whole service concept. We don't take these large leaps but develop it little by little." (Company 4)

It was further mentioned that taking small steps along the way allows to involve people better and to give them the necessary time to get used to the changes.

> "Include people in early stages and give them time to adjust…Not the old rural community way of 'Let's wait until the spring, it will happen', but give people a week or two to internalise the change. Take small steps, but more often." (Company 8)

Starting with small things and developing the capabilities throughout the process, was said to enable industry 4.0 processes to grow over time and to be linked to the normal business operations. The strategy program of the company was said to create a new focus and openness to change and by building on the capabilities that have been developed throughout the past years Industry 4.0 steadily expands within the company.

> "We do believe that we have a good basis regarding this industrial automation and we have built these capabilities for many years and this then expands with the strength of the business. And then we have also had this company-wide strategy program which has tried to create this new openness and new focus." (Company 1)

Advancing in smaller steps was further seen as important due to the difficulty of making reliable long-term plans. One company representative emphasized the importance of continuously adapting such plans along the way. While a long-term roadmap was seen as important in order to plan how technologies can be benefitted and how implementation as a whole should be approached, it was stated that "technology develops and the market develops and the world changes so fast nowadays, so it has to be modified based on changes in the long run all the time" (Company 4).

Although an experimental approach was seen as a good way to start the process, the need to move on to the business side at some point was emphasized in order not to get stuck in the technology-testing phase. While testing and experimenting with the technology was considered an important aspect, a focus was put on the problems that are trying to be solved.

> "A lot of new technology is on the offer and we are testing and looking at the ways of how to benefit from them but we should not stay in this everlasting test phase, we should more courageously move forward to developing the business side and approach the issues more from the customer's perspective or customer's challenges (…) the approach should be more from the outside to the inside and if we solely approach it from the technology side we might forever be experimenting and in the end won't be able to entirely benefit from it and seize all the developments economically." (Company 2)

Creating an Ecosystem

Truly understanding the customers' problems and creating an overall understanding of the technology- as well as the business side in terms of Industry 4.0 were seen as very important factors for successful implementation of Industry 4.0. In order to create this kind of an overall understanding, companies considered cooperation with customers and different partners to be an important aspect. For these reasons the issues regarding different forms of cooperation are gathered under the sub-theme of *creating an ecosystem.*

For some companies this meant changing the way they create new products from isolated development in R&D to opening up and getting feedback from customers throughout the development process. This also meant getting little things done in a shorter period of time in order to receive feedback and to then continue development based on the input received. Several companies considered the role of the customer to be very important with Industry 4.0 technologies.

> „Not everything needs to be – and is not reasonable to be - done on your own (…) this work [creation of Industrial internet solutions] is naturally done in cooperation with customers and mutual trust cannot be compromised." (Company 10)

Getting something "ready in three weeks or even three months" in order to "show it to the users, take note of the feedback and make changes accordingly" (Company 8) was seen as the way to go with industry 4.0 solutions. Instead of developing solutions in isolation, opening up for external feedback was expressed as a crucial aspect in the creation of new solutions.

> "We should dare to try out more – do little experiments in different connections and not solely, like it used to be for a long time, develop something new inside R&D for three years and then bring it out to show the customers and put all eggs in one basket because this is the one thing we have developed and then it just has to be good. In traditional product development this is of course the way to do it but with these digital services we need a lot of feedback from customers in a very early stage." (Company 2)

In some cases it was stated that customers were selected in the beginning based on the feedback needed for a certain project and these customers were then actively included in the development process.

> "We absolutely have to select them [the customers] in the beginning of these developments. These kinds of customers that also understand the benefits and then we receive true and direct and on-going feedback." (Company 3)

Regarding the co-development with customers it was also stated that more decision power should be given to the customers and end-users of the equipment as they can evaluate the usability the best. "Listening to the customer and understand[ing] what is important to them" (Company 9) was emphasized as a key factor. Such an approach was considered to be a shift from the traditional products-focused development where "customers and users – not the company internal management – should be allowed to make the decisions on what ideas are best." (Company 8)

Including customers from the beginning on was further said to allow identifying the services customers are truly looking for.

> "We have at least tried to open up to new things and to have a customer on board – an important customer. And then these partnerships have been obtained based on our needs. With the large and important customers we look at what kinds of contents and services we can offer." (Company 1)

Besides cooperating with customers, other partnerships were considered as a key factor in successfully implementing Industry 4.0 technologies and creating new products and services. As the technologies and the related know-how are so diverse and understanding Industry 4.0 requires diverse knowledge and expertise from different areas, companies recognized the need to open up to new forms of cooperation with external parties and to create an ecosystem with the different players involved.

> "We too do not do everything on our own, but we cooperate with other operators. I see that we get the best benefits by constructing a flexible infrastructure, in which we can best benefit our technological offerings and our know-how." (Company 10)

Start-ups were considered as having an important role in this eco-system thinking. Even though "in Finland there are many industrial companies that are leading on their own market" company representatives recognized that "big companies cannot do this [digitalization] on their own (Company 7). Start-ups were seen as important players in supporting large organizations with more innovative approaches and technologies. Such an approach was stated to be "a big opportunity to get small companies to network with larger ones" (Company 7) and successful cooperation among large and small players was considered to result in advantages for all parties involved.

> "I myself believe very strongly in this ecosystem thinking (...) no one can do these things on their own. You have to select the right partners and the right group, and there also start-ups play a role because they bring notably more courage and dynamics into these developments. Finding this harmonic ecosystem in which everyone has their role and it results in a win-win-win situation…if something like that can be created…that always helps bringing things forward." (Company 6)

Establishing an ecosystem thinking was further seen as a possibility to learn from other industries that are further ahead with the development and implementation of Industry 4.0 technologies.

> "We do not have to invent anything new. Everything and all the logical order of steps have already been invented in other industries so we could very well briskly make use of the knowledge that can be learnt from other industries." (Company 2)

The reasons for opening up to different forms of cooperation differed depending on the company and their weaknesses regarding Industry 4.0. Old-fashioned structures and lack of dynamism was one aspect that was tackled with the help of external companies that have a good understanding of the technologies and can bring fresh ideas.

> "This slowness we have tried to tackle with our external partners. By taking partners on board in the development process that understand how to develop this forward." (Company 3)

In addition to tackling challenges of transforming the internal culture, cooperation was seen as a way to shed light onto unclear aspects and difficulties with the technologies and their applications.

> "There are quite many missing pieces of which we are in the process of learning and then of course we are also actively looking for cooperation partners to help with this." (Company 1)

The knowledge gained from other parties regarding the company's weaknesses could then be complemented with the strengths of the company. Company representatives emphasized that they have certain weaknesses and lacks of capabilities within the company, which they cannot overcome on their own.

> "We ourselves have quite a good know-how of the processes and equipment and this is where we operate quite well. And if we think of these cloud services and data analytics and these kinds of offerings, then there we do not have such a good knowledge at all. For that we have partners who help us." (Company 3)

A way of getting experience on Industry 4.0 and with working in an ecosystem was said to be participation in pilot test projects in which different players cooperate in order to create reference cases. In such pilot projects "companies and sometimes research institutes and some kinds of financers build this solution – an overall solution with all the parties" (Company 5/Technology Expert), which is then tested with an actual customer company.

To ensure the spillover of know-how, some companies bring cooperation to the next level by making changes to the company structure and acquiring other companies with complementing know-how. Company acquisitions were said to broaden know-how and to enable responding to "customer's needs better than before as they are transforming their business operations to more and more data intensive services" (Company 14) which would then allow being among the first movers with the technologies.

Selection and Adaptation of technologies

The last sub-theme within the overarching theme of *Approaches to Industry 4.0* is the *selection and adaptation of technologies.* This sub-theme categorizes issues addressed regarding the choice of technologies and adapting them to the company own processes.

The described approach to adopting different Industry 4.0 technologies differed depending on the type of company. As many companies do not produce technologies themselves decision-makers stated that external technologies were accessed by purchasing them from outside providers and integrating them into the own business operations. Only those technologies that are most important for the business operations and that are more familiar internally were said to be further developed inside the company after their purchase.

> "We are purely a technology adopter and not a developer of machine technology so in this sense we use what is available for purchase and adapt this to our business operation. (…) We do have some technologies that are closer to our core - which relate more directly to our business operations – and those we may develop further. But very much we can integrate things that have been developed and we just pick them from the store shelves and incorporate these to our products and services so that we can build complete solutions for our customer." (Company 2)

For some companies the basis for choosing a technology lied in identifying those technologies that fulfill needs of the organization without changes being made to them. Having settled on one technology, companies showed willingness to make changes within their organization and processes in order to better fit the technologies.

> From the starting point it is like that that we try to find that kind of a technology that serves us (…) so the technology has to serve our business. But after we see that the technology serves our business our organization has to adapt to the technology." (Company 4)

A further relevant aspect in choosing and adapting technologies were future developments. As companies expressed uncertainties regarding future developments of the technologies, they saw the need to make adjustments to the selected technologies throughout time.

> "We know that certain paths need to be taken and we are moving forward all the time but where the world is in 10 years in terms of technology for that there really isn't any answer. So based on that some fine tuning has to be done all the time moving forward." (Company 4)

Additionally being open to new technologies and following their developments as well as being in contact with different technology players and service providers was mentioned as being an important aspect for success with new technologies. This was considered to allow to rapidly identifying new aspects that may be included in the thought process when planning future steps.

4.6 Uncertainties, challenges and risks

Throughout the data different kinds of uncertainties, challenges and risks regarding Industry 4.0 and the resulting developments were expressed by company representatives. The demanding issues regarding Industry 4.0 were for this reason categorized under the overarching theme of *uncertainties, challenges and risks*. Based on the differing nature of these factors they were divided into issues regarding *mobilizing customers*, *managing the internal transformation* of the own organization, facing the *new competitive landscape, seizing the benefits* of Industry 4.0, as well as *selecting investments*.

Mobilizing customers

One large factor of concern faced by many companies related to mobilizing customers to move along with changes resulting from Industry 4.0. The readiness of the market for these new technologies was seen as a critical factor here. Several sources saw a risk of customers not being willing to move to a new form of operation, which would be required to fully grasp the benefits brought by Industry 4.0. In this connection it was mentioned that the business models regarding Industry 4.0 technologies are still in their first steps and the operations of industrial companies are well established, which resulted in concern in getting such customers to move along with radical changes resulting from Industry 4.0.

> "Maybe the biggest challenges or uncertainties are whether the market is ready. Are the customers ready for IoT and how open they are in this relation and with what kind of a timetable we can get them along to this IoT, Industry 4.0 world." (Company 4)

Regarding this issue, the transformation of business- and revenue models was said to require customers to accept new reimbursement structures, which was seen as a critical aspect in successfully moving to new solutions. "Due to smart devices, traditional maintenance visits would no longer need to be done, but according to the contract the customer pays for exactly those visits" which was seen as a critical factor in "whether the customer is ready to move to this new business model, where instead of a concrete product the customer pays for something else" (Company 8).

Besides the risk related to whether customers are able to recognize the values brought by the technologies and are open to the changes brought by them, a further point of concern was related to the factor of whether customers would manage to successfully transform their organization even if the value brought by the technologies is recognized.

> "These large and radical changes in the whole logic of business activities do not always succeed and it could happen that customers are not yet ready to move to a new way of operating or they can't manage to get their own organization moving into that direction even though it would be a good concept with which one could notably support or improve the efficiency of operations." (Company 2)

Related to this is the concern expressed regarding the timing of introducing these changes. How much time should be taken in moving forward and how much should the customer be pushed to move along with new business models were emphasized as important issues to consider as "a too steep change may drive away customers, but then again things should be done before the customer is able to ask for them." (Company 8)

This readiness on the customers' sides was especially said to be critical in the case of offering new products and services that do not necessarily have anything to do with the original core business of the offering company. The availability of data allows companies to become more innovative in utilizing the data in some new way that may benefit customers, however, it was mentioned that customers react skeptically when faced with something new and unfamiliar.

> "So the reaction immediately is what? Can you actually provide this kind of a service and how is this going to go…so this is the factor that the buyer's mentality is a bit like that…that this is not a familiar thing." (Company 5/Technology Expert)

A further point of concern in terms of customers' willingness to accept the use of Industry 4.0 technologies related to the lack of standards and the uncertainty regarding the ownership and use of data. It was reported that in some cases customers are rather unwilling to have data from different part-processes collected in data banks or cloud services due to uncertainty of how this data will be used. Customers' unwillingness of providing the data was reported to hinder the creation of new services as customers would simply use the data provided through the delivered systems themselves instead of having someone external getting in touch with the data.

> "With our customers there is quite a lot of suspicion and fear of what happens with the data (…) there are these customers who want all of the data to stay inside their walls (…) so this kind of a hassle with the data complicates things. (…) We make some adjustments to our delivered machines and the customer then transfers this data to their own provider so we won't see what kind of data the customer has." (Company 3)

Additionally to this, the factor that customers often do not buy all the machines from the same manufacturer was mentioned to complicate the process of creating all-encompassing solutions and improvements, as this would require getting all the relevant data from all machines included in the production process.

> "If the whole process is not done on our machines that's where the challenges begin, how we can take proper care of the whole process and how we can get the data from some part-processes with which we can then optimize the process as a whole." (Company 3)

A further problem regarding the creation of new business models was said to result from the change that companies which traditionally provided solely the equipment and technologies for manufacturing now offer additional services. One company representative expressed the problem that customers are afraid of letting external companies with more widespread know-how than traditional software providers into their processes as this may result in learning-effects that can be used in providing services to competitors.

> "There is also this aspect that we deliver technology to many different customers and then some customers think in that kind of a way that if they let us too close in optimizing their production process then we would learn things there and would then transfer this knowledge to their competitors (…) so in that sense it would be easier if we were some kind of independent software house that doesn't have any relation to the functioning of the machines." (Company 3)

A result of these challenges regarding the mobilization of customers addressed by some companies was the lack of good reference cases that would allow to create trust on the customer' side.

> "And then getting the right references of which we can then say that we produce true value for our customers and customers pay for that. So we actually have very little references to show that these value creation elements actually exist. And this is for us the biggest question or focus that we want to look at now." (Company 1)

Managing the transformation

Besides the challenges related to mobilizing customers, a further point of concern expressed by the majority of companies included in the analysis referred to *managing the transformation* of their own organization. Conceptualizing and realizing new business- and service models was said to be something rather unfamiliar for well-established industrial companies. This sub-theme categorizes all issues that were addressed regarding managing the internal organizational change.

An issue that was said to provide challenges here was the transformation of moving from selling physical and tangible goods to more abstract service constructs. Companies felt that this is a big change to which the organizational structures and the mindset inside the company have to be adapted.

> "In the industrial sector it has traditionally been about physical machines, raw-data and plants. In the digital world data and analyzing it and reusing it is at the center of everything. This is a big change in perspective." (Company 9)

Company representatives repeatedly expressed their concern about the maturity of their own organization and its ability to transform into a service provider and to successfully adapt their operations in order to fully benefit the technologies.

> "We have come a long way, our organization is this very traditional engineers house used to making these big investment projects (…) and

> turning this into an agile and fast moving service operation is quite a big change ahead." (Company 1)

"Changing the culture and the slowness of changing the culture internally" (Company 2) in order to allow for more courageous, experimental approaches under the existing time pressure to respond to Industry 4.0 was seen as a critical issue. Company representatives expressed doubt in how agile their organizations are in applying everything that it already possible. The lack of an experimental culture and not being able to change the internal culture rapidly enough was expressed as a factor hindering companies in their attempt to grasp the benefits provided by the technologies "especially when speaking about big processes and big facilities" (Company 6). Many of these concerns related to the fact that the organizations are very large and well established and therefor slow to change.

> "We really are this old-fashioned house (…) we plan first and make sure that everything that there is to think about has been thought about and then we start executing. This way these things take a very long time and in these things we could be better." (Company 3)

Additionally, the speed of technological developments and integrating the technologies was seen as providing challenges as this would require fast learning and rapid change within the organization.

> "Let's take big data and analytics as an example. The technology exists, there is plenty of data and we can build analytics systems and reports that provide useful information – but how do we really put that into practice and change operational models? Can the operational organisation learn new things as fast as technology is changing?" (Company 8)

The difficulties in transforming the organization were reported to result in some form of inertia due to "a general lack of courage" (Company 6) in moving forward with uncertain factors and trying out different possibilities. Although recognizing the need to transform the organizational culture and ways of operating, some company representatives also emphasized the need of finding the right balance between the existing operations and the new opportunities resulting from Industry 4.0. A factor mentioned here was the risk of cannibalizing processes that are working well by changing too much, or loosing grip of the traditional business by putting too much focus on these new opportunities.

> "Related to this Industry 4.0 is a lot of hype and easily we take such large leaps with these technologies that the essentials are forgotten. So about this we have been discussing quite a lot here and we need to find a fitting balance." (Company 1)

New competitive landscape

A further risk that was said to result from the developments regarding Industry 4.0 was the *changing competitive landscape*. Company representatives repeatedly stated that Industry 4.0 opens up the market for players that go beyond the traditional competition. This was seen as an important reason to find ways of distinguishing from new competitors in order to maintain the market position.

> "The development also lowers the threshold for competition. Whoever can challenge the company with a good idea or solution. The competition faced by industrial companies might in the future come from outside the own industry boarders." (Company 9)

As "competition is becoming more fierce all the time" (Company 2), it was emphasized that ways of distinguishing from competitors have to be found, and clever solutions need to be created rapidly enough. Since "technology enables new services (…), technology changes the roles of different actors all the time" (Company 12).

In addition to new competitors, the fact that change is also happening on customers' sides was also recognized and it was emphasized that these developments should be closely monitored.

> "We can no longer only monitor what our traditional competitors and those on the same level as us are doing. There is also a large amount of new producers and new types of players, which are also on a strong track and then of course we have looked a lot at what our customer base is doing and there too things are on the move and it is of course quite important to be on the lookout so we don't fall behind." (Company 1)

Seizing the benefits

A further factor that was expressed as providing challenges was how to fully understand and seize the benefits of Industry 4.0 technologies. Implementing the different technologies and the resulting opportunities into real operational use was repeatedly expressed as very challenging.

Some decision-makers showed difficulties in truly understanding the value bringing effects of the technology for their business and applying these to the company's operations.

> "Understanding the value brought by the technology and bringing this to business operations (…) how this actually relates to business operations that is the challenge." (Company 6)

Even in cases where the values of the technology had been clearly identified, transferring the know-how and the value to actual products still provided difficulties. The challenge was considered to lie in "how industrially working solutions can be developed from the know-how." (Company 7)

> "In my opinion it is quite clear for us how we can benefit from the technologies and a clear vision exists of how these technologies could be used. But then in practice it is a different thing, so what we are actually able to do." (Company 3)

Related to this is the creation of business models that allow the organizations to turn the use of the technologies into actual revenue streams. Although many companies stated that they have a good understanding of the technologies and recognize the technological possibilities, "how to actually create new revenue with this and how to make substantial changes and create things customers are actually willing to pay for" (Company 6) was still rather unclear. For most companies "the biggest question still is how to make this a healthy business activity." (Company 1)

Other challenging factors in fully benefitting from Industry 4.0 related to practical issues and the use of technologies for replacing actual workforce.

> "There are practical challenges ahead of us (…) The question is how we can reach the driver's level of productivity and trustworthiness with the help of sensors, cameras and distant monitoring." (Company 11)

Despite all the difficulties and challenges it was mentioned that the biggest threat would be not to do anything. In some way the benefits have to be seized before it is too late.

> "In my opinion the biggest risk is that we do not do anything. Someone else certainly is and that narrows down our chance for success on the company level as well as nationally and internationally." (Company 12)

Selecting investments

Some inertia regarding Industry 4.0 developments and taking the technologies into use also resulted from the question of deciding where to start and *selecting investments* that should be focused on first. In some cases companies were overwhelmed by the broadness of the issue, which resulted in uncertainties of what to focus on first and how much should be invested considering the uncertainty of the future developments.

> "We have discussed a lot about whether our organization is mature and maybe it is not a question of whether we should invest but of where we should start."(…) because we always compete like crazy and related to this is how much we should invest." (Company1)

Due to the broad amount of existing possibilities there was some uncertainty on which of these opportunities actually make sense to implement. "Nowadays anything is basically possible but how cost-efficient or how reasonable is it to actually take things forward" (Company 4) was an issue providing difficulties to decision-makers. Realizing all technological possibilities simply because they exist was seen rather critically.

In this connection of what to focus investments on, a big risk was seen in locking into technologies that do not become dominant. The large amount of technologies and providers existing on the market and the uncertainty regarding future developments provided difficulties for companies in deciding which technologies to focus on. "So should they simply take this smart solution from this one producer into their own operations or would there be something better or something cheaper from someone else" (Company 5/Technology Expert) was described as hindering implementation and falling "too much in love with one technology that then doesn't bring you far after all" (Company 12) was considered a big risk.

> "The challenge or barrier is maybe in what we should invest. Because even in Finland there probably exist hundreds of service providers and concepts and in what direction – and in what to invest probably is the biggest workload and also the biggest challenge." (…) A risk of course are competing technologies and choosing the technologies. There are many producers and if one technology goes past us because we have chosen a different technology – that is of course a big risk." (Company 4)

As Industry 4.0 is still at a rather early stage and technologies develop very rapidly, companies showed uncertainty regarding what the future of Industry 4.0 and the technologies looks like. Companies felt that with these developments it is challenging to make estimations and to reliably plan ahead and prepare for future developments, as no one truly knows how these things will develop. This was a further factor complicating the selection of technologies.

> "The technology field develops with such a speed that I would think that it's very difficult for anyone to see very far into the future and how this will develop." (Company 2)

5 DISCUSSION

5.1 Overview

The aim of this thesis was to provide an overview of how companies in Finland perceive and respond to opportunities provided by GPTs in the form of Industry 4.0. In general, the findings show that responding to the opportunities provided by Industry 4.0 is by far not a straightforward process, but a complex issue requiring the creation of new skills, know-how and organizational and strategic adaptation. The fact that the findings go far beyond technological considerations illustrates the role of Industry 4.0 technologies as enablers in creating opportunities and complementary innovations very much like previous GPTs.

While all companies considered Industry 4.0 to be an opportunity as long as acted upon, the findings show that the willingness to respond does not represent the ability to do so in practice. Although all companies have implemented aspects of Industry 4.0 into their strategies and have initiated a response and in many cases already offer products and services that make use of the technologies, the mentioned difficulties of companies in turning these visions and strategies into action show that they are still a long way from the full transformation that they themselves consider necessary. For this reason, the opportunity may still turn to a threat for those companies which do not manage to overcome the challenges and uncertainties associated with Industry 4.0.

The existence of various related terms and a lack of a clear definition of different concepts certainly complicate discussions on the issue. The expansion of different applications and the creation of complementary innovations have already resulted in the creation of a broad range of technologies and innovations that all interact in new processes and the findings indicate that the structures and the evolutionary relations of the different technologies included in the concept are not always understood. The differences in perception show parallels to the existing public discussions on whether Industry 4.0 can be considered the Fourth Industrial Revolution or simply an expansion of automation as the Third (e.g. Drath & Horch 2014; McKinsey & Company 2015). It could be argued that those companies that consider Industry 4.0 to be an expansion are more proactive as they have anticipated the change for decades and have continuously automated and digitalized their production, which now serves as a basis for Industry 4.0. Those companies that considered it to be more of a sudden disruption may not have seen the change coming as far along as others, and are only reacting now as the change becomes more apparent.

The findings of this study support and expand many findings and arguments made in previous research on strategic management and adoption of technology, as well as GPTs. In the following chapters, the perceptions and responses to Industry 4.0 identified within the data are discussed in the light of previous research and the theoretical contributions of the study are addressed.

5.2 Contributions to literature on strategic management and adoption of technological change

As already found by Carneiro (2006), the findings of this study illustrate that understanding the dimensions and the benefits of the technologies, how they can be applied to a certain business environment and how the mentality and the organization within the company may have to change in the light of a new technological development are all factors influencing the recognition of technological opportunities. The findings clearly show that these factors and especially making-sense of the change are issues decision-makers are struggling with. Only when these factors are understood, decision-makers felt they could proceed to the next step of planning the actual implementation and identifying enablers necessary for benefitting the technologies.

As pointed out by Miles et al. (1978), it is these perceptions of the change that then reflect in the strategic choices and adaptive behaviour of organizations. The findings of this study support this as they illustrate how the interpretation of the same development in the form of Industry 4.0 can differ from decision-maker to decision-maker.

This research further emphasizes the importance of creating new capabilities in order to exploit new technologies (cf. Lavie 2006; Rosenbloom & Christensen 1998), and contribute to this stream of research by offering insights into ways of how new capabilities can be created in the light of technological change.

The findings suggest that technological know-how, while certainly being a supporting factor, may not be the most important issue. The technologies themselves are often obtained from outside providers and the problem lies less in developing the actual technologies but in understanding their potential value and transferring this to the business side and developing capabilities to match the new situation. This shows clear parallels to prior literature that has identified that developing the necessary capabilities after investing into a new technology is one of the main reasons of failure in the light of technological change (Tripsas 1997). From this perspective, the study revealed that opportunity sensing and identification capabilities, capabilities for seizing the opportunities as well as transformational capabilities play an important role in the light of Industry 4.0. Technology-sensing capabilities, described in literature as gaining knowledge and understanding of the technologies (Teece 2012) were addressed by interviewees as the ability to understand the development process and maturity of the technologies as well as their value for the company. Transferring this value to the business side and developing enablers and complementary factors that allow creating new products and services, can be seen as capabilities needed for seizing and responding to the technological opportunity (cf. Srinivasan 2002; Teece 2012). While Teece (2009) states that the alignment of business models to new technologies is an overlooked factor in strategic management, the need to make changes to the business model and the organization as a whole in order to seize this opportunity was recognized as crucial by most decision-makers in this study.

Integrating knowledge, transforming the organization and actually putting the strategies into practice requires those capabilities termed as integrative capabilities in literature (Woiceshyn & Daellenbach 2005). In the context of this study, both external and internal integrative capabilities showed to play an important role. On the one side, interviewees mentioned that technologies are obtained from outside providers and the mentioned challenge of identifying the right technology and the right provider shows that external integrative capabilities to recognize and evaluate external opportunities (cf. Woiceshyn & Daellenbach 2005) are needed. Further, it was stated that the technologies then need to be adapted to company-own processes, which is described by literature as the internal adjustment to the company specific use (ibid.).

A way of responding to the high uncertainties and difficulties in making sense of the technologies as well as the need to adapt several factors was to create overall strategies and plans, and to identify enablers necessary to successfully implement the technologies. This supports Leonard-Barton's (1988) argument that clear strategic goals and visions of companies allow them to evaluate their existing capabilities in order to identify supporting factors such as required knowledge, or managerial and physical systems that are missing from the organization. It becomes evident from the findings in this study that decision-makers were quite critical towards the abilities of their organization and the changes that need to be made, which can certainly be considered an advantage in the light of the high transformational requirements.

Although all companies identified the need to create new capabilities and other supporting factors, the focuses differed from company to company. This may be explained by the differences in existing company-specific capabilities (cf. Leonard-Barton 1988). While in some cases the initial focus lay on differing organizational changes such as the culture or way of making decisions, other companies focused more on technological factors. The majority of decision-makers, however, recognized the need to adapt both the technology and internal organizational factors. This provides support for a mutual adaptive approach to the implementation of new technologies as introduced by Leonard-Barton (1988). Supporting the argument of Leonard-Barton (1988), the findings illustrate that the implementation of the technologies can be considered the actual innovation as companies recognized the need to develop entirely new business- and revenue models and complementary factors. As already mentioned above, the companies included in this study were able to see beyond the technologies themselves, and recognized that benefitting from these technologies requires other related investments in overall change and the development of supporting factors. This supports findings made by Milgrom & Roberts (1990) regarding manufacturing technologies and their implementation being part of a cluster of mutually reinforcing changes. The high challenges described by decision-makers therefor provide support for Leonard-Barton's argument that the implementation of production technologies, "i.e., getting them up and running in daily operations is at least as challenging a managerial problem as their invention" (Leonard-Barton 1988, p. 251). This may be considered especially true in the case of such technologies related to Industry 4.0 that are not necessarily made for one specific purpose but require vision and R&D in identifying applications.

The approach used by companies in order to manage the overwhelming transformative and innovative requirements and in overcoming uncertainties was to break down the implementation into smaller, more easily manageable steps. Such a stepwise approach allows for investments to be focused and to trigger a stepwise improvement and the adaptation of technological- and organizational factors. Such a stepwise approach is also indicated by Leonard-Barton (1988) in connection with mutual adaptation. Building on theory, differences in the adaptability of certain technologies and organizations can be seen as reasons why the findings show that in some cases technological adaptation predominates while in other cases organizational changes do (cf. Leonard-Barton 1988).

As discussed in the framework for this study, adaptation can differ in magnitude and Leonard-Barton (1988) distinguishes between small and large cycles of adaptation. The author points out, that large cycles are rare due to the high cost and resistance to make fundamental changes. Nevertheless, decision-makers in this study expressed the need for such changes that result in new strategy formulation and drastic alterations to the organization and processes within the company, which shows that large cycles of mutual adaptation between the technology and the organization are considered necessary under Industry 4.0. The findings certainly provide evidence for Leonard-Barton's (1988, p. 265) argument that when it comes to the implementation of technologies there is "a need for experimental introduction (…) with the intent to learn". Decision-makers in this study confirmed this as it was stated that experimenting and "rapidly testing and trying out new thoughts and ideas" (Company 9) is essential in moving forward with the implementation of Industry 4.0 solutions. The advantage of such an approach is further supported by Hage (1987), who studies the responses to technological opportunities, and finds that companies that are ready to face the high costs of technical experimentation and organizational changes are better off in competitive industries.

The disruptiveness of Industry 4.0 and the need to act rapidly seems to be somewhat in contrast with the small-step approach described by decision-makers. However, as found by previous research, even when a complete transformation is necessary, the changes can be implemented over time (cf. Milgrom & Roberts 1990). Interviewees agreed with this as it was stated that small steps should be taken "but more often" (Company 8). Participants further supported Brynjolfsson et al.'s (1997) argument that the implementation of radical change should be spread over episodic steps in order to prevent confusion and disruption as it was mentioned that taking many small steps "allows to involve people better and to give them the necessary time to get used to the changes" (Company 8). Letting things "expand with the strength of the business" (Company 1) can hence reduce the negative effects of disruptive change for the organization and taking small steps towards the implementation of Industry 4.0 can be considered a way to balance the radicalness of the concept.

Although the organizational receptiveness factors identified by Brynjolfsson et al. (1997) as influencing the pace of change appear in the findings and clearly play a role in the implementation process, their influence on the adoption differs somewhat from the previous literature on the issue. Brynjolfsson et al. (1997) found that a stepwise approach needs to be supported by a culture that supports experimentation and risk-taking. In contrast to this, the lack of these factors seemed to be the reason behind a stepwise approach for the participants. Approaching implementation in small steps rather seemed to be a response to the described difficulties of transforming the organizational culture and getting customers on board with change. As companies reported difficulties in creating revenue- and business models in connection with the new technologies, a stepwise approach that allows for experimentation may be the only solution to solve these problems over time. As shown in the findings, advancing in smaller experimental steps was considered to create learning effects and an understanding of the technologies, which may be seen as a way to fight the potential inertia resulting from the uncertainties and the evolutionary character of the technologies. As stated by decision-makers, the technologies evolve at such a rapid pace and result in new developments that are challenging to foresee. This shows that the characteristics of the technologies resulted in the new environment to be perceived as rather dynamic, and advancing in small steps may provides the necessary flexibility in responding to new developments along the way. As also described by Leonard-Barton (1988, p. 260) mutual adaptation is recursive as it allows to "circle back" to decision points and reconsider them.

Building on the technology sourcing options introduced by Leonard-Barton (1998), it can be found that Industry 4.0 is on the one hand relates to high uncertainties and on the other hand requires the creation of entirely new capabilities. Regarding these two factors, Leonard-Barton's framework leaves little options as these factors are on the two contrasting ends of the framework. As suggested by Leonard-Barton (2011) this can be solved by combining different sourcing options, moving from low- to high commitment with decreased uncertainty. Indeed, the ecosystem thinking described in the findings illustrates that in most cases the option for sourcing the technologies was a combination of external sourcing through acquisition, partnerships as well as joint development programs and internal development and adjustment of technologies. Own research and development activities were considered necessary even when the technologies are sourced from an external provider due to the need for companies to integrate and adapt the technologies to their own processes and to develop products and services based on them. Building on the literature on technology sourcing options, this combination may allow companies to cope with the high complexity and the high level of required expertise, while also developing capabilities of their own (cf. Leonard-Barton 2011). Understanding the bigger picture and the architecture as a whole were considered to require the creation of a new infrastructure with different actors, and for companies to be linked to an ecosystem.

The ecosystem approach further allows for capabilities of different nature to be combined and to share risks. The creation of ecosystems can hence be seen as a way for companies to overcome weaknesses and to close capability gaps by joining forces and learning from others. Cooperating with start-ups was emphasized as a way to benefit from their knowledge and to create more agility, which can be seen as a response to incumbent companies' difficulties in dealing with change as suggested by Tushman and Anderson (1986) or Henderson and Clark (1990). As argued by the authors, established companies that build on routines and assets developed under the old environment face difficulties in the light of disruptive change. This certainly becomes evident from the current findings as many decision-makers referred to their organizations as "old-fashioned" (Company 3) or "very traditional" (Company 1) and the required "change in perspective" (Company 9) under the aspect of a lack of experience with change was considered a major risk in the changing environment.

Besides cooperation with other businesses and institutions, companies responded with increased customer involvement. As customers too are part of the application sector of the technologies, they play an important role in the new industry structure. Increased customer involvement can further be seen as a way to respond to the uncertainties regarding the mobilization of customers as it allows for them to be engaged in the process. In addition, this may allow for a joint transformation of the industry structures and gaining customers' trust with new solutions.

A graph summarizing the responses as a stepwise, mutual adaptive implementation process embedded in an ecosystem can be found in Figure 4.

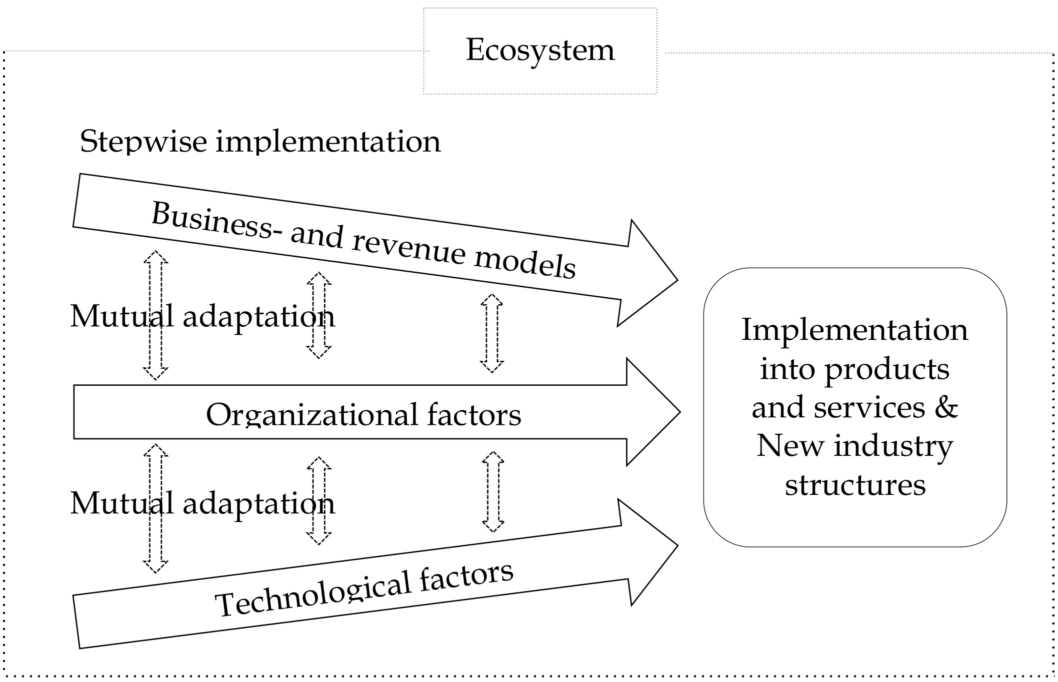

Fig. 4: Overview of the mutually adaptive and stepwise implementation process embedded in an Ecosystem

5.3 Contributions to literature on General Purpose Technologies

The findings of this study contribute to the literature on General Purpose Technologies as they add the company decision-making perspective to the discussions. The characteristics of GPTs can be applied in this study to understand the change companies are currently facing and the associated perceptions and responses.

As stated already by Rosenbloom and Christensen (1998), whether a technology is radical cannot necessarily be decided beforehand and different definitions on what makes change radical exist. As discussed in the framework, this argument has been found to hold also in the case of new GPTs as Lipsey et al. (1998) state that whether a change represents a modest advance, a GPT or anything in between is not necessarily predictable in the beginning.

The findings of this study provide evidence for that, as they illustrate that different perceptions regarding the potential as well as the effects of Industry 4.0 exist among decision-makers. The expressed difficulties in making sense of the technologies and in estimating how they will develop over time supports the theoretical postulations made regarding the challenge to foresee how GPTs and their different applications will evolve due to the difficulty to foresee complementary effects and follow-up innovations (cf. Lipsey et al. 1998).

The different perceptions of Industry 4.0 being revolutionary and disruptive or rather evolutionary may be explained by the typical tree-like structure of GPTs where one main technology gives rise to several others as described by Lipsey et al. (1998). This reflected in the findings as some decision-makers considered the technologies to be disruptive innovations of their own, while others saw them as being enabled by previous automation. Companies that considered the current developments to be part of a larger process of technological developments felt them to be less revolutionary.

The fact that the concept links several different technologies into a system and influences the creation of new innovations, resulted in difficulties in understanding the developments and the perception that everything and nothing relates to Industry 4.0. It can be argued that the changes resulting from GPTs can be perceived rather narrowly, focusing on the main technology, or more broadly if taking all the complementary, follow-up innovations and developments of new applications into consideration. When looking at the greater picture of overall changes triggered by Industry 4.0, it may be perceived as more disruptive and influential compared to when single technologies such as Internet of Things are considered. The differences in understanding what Industry 4.0 means and which technologies the concept includes can hence provide a further explanation for the differences in perceived radicalness.

The difficulty to predict the developments and impact of Industry 4.0 technologies further reflected in an uncertainty of whether they actually bring anything substantially new. The fact that some doubt regarding the usefulness and actual break through effects of Industry 4.0 technologies does appear in the findings substantiates the claim made in the framework regarding possible initial uncertainty or doubt on the productivity gains of a new GPT. As described by Helpman and Trajtenberg (1994), GPTs typically evolve in two phases where increased productivity may not be visible until complementary investments have been made. This may explain the expressed uncertainties on the actual value of Industry 4.0. Evaluating whether some companies are not at all responding to this opportunity due to the initially negative growth inherent in new GPTs as theorized in the framework based on Helpman and Tratjenberg (1994), would require further research including such companies that have not implemented Industry 4.0 strategies. The lack of companies that do not respond at this point in time, or that perceive Industry 4.0 as a threat may therefor not be representative for the situation in Finland but could be explained by the nature of the sample.

Although various terms and perceptions of Industry 4.0 exist, this did not seem to substantially influence the responses of companies included in the study. This could be explained by the fact that although decision-makers used different terms and have different understandings of whether the technological developments are revolutionary or evolutionary, this did not change the meaning of the technologies for company's future competitiveness. The findings even indicate that Industry 4.0 goes beyond an opportunity, but is instead considered as something that is essential in surviving competition. This supports the claim made by Hall and Khan (2003) as the authors argue that the choice faced by decision-makers in any case is whether to adopt the technologies now or later, instead of whether to adopt at all. In the context of this study, the decision was clearly adopting now rather than later even if this means facing unresolved uncertainties. This may be explained by the competitive threat and the recognized need to develop supporting factors, which is a time-consuming process. As implementation of the technologies is rather slow, the need to start the process timely becomes even more important.

As mentioned earlier, whether a technological development can be considered a GPT cannot necessarily be foreseen at the beginning (Lipsey et al. 1998). It may hence be argued that at this point in time it is not clear whether Industry 4.0 and the related technologies can truly be considered GPTs. Nevertheless, the attributes of the concept as described by participants in this study do show clear parallels to the characteristics associated with GPTs.

The pervasiveness of such technologies, described by literature as a variety of possible uses across the economy that evolve over time (ibid.), was recognized by decision-makers as the various applications of Industry 4.0 technologies being improving efficiency, reducing risks and creating entirely new products and services.

The broad options for utilizing the technologies also reflected in one of the biggest challenges being to identify possible applications of Industry 4.0 technologies within the company's operations. This indicates that the technologies related to Industry 4.0 perform a generic function that can be adapted to different applications. Based on the findings it can be stated that the perceived uncertainty related to new GPTs is rather high, as the generic function requires companies to identify possible applications and the future developments of the technologies are unclear. In addition, it was stated that they have the potential of shifting the industry structure and bring new competitors into the picture.

As discussed in the theoretical framework, the horizontal externalities inherent in GPTs link the interest of different actors within an economy (Bresnahan & Tratjenberg 1992). This was clearly recognized by decision-makers in this study as all of them mentioned the need for increased cooperation in one way or another. Overall, the ecosystem thinking discussed earlier illustrates that the horizontal externalities inherent in GPTs (ibid.) are responded to by horizontal integration of key actors in the value chain. The fact that participants mentioned that no one can be successful with Industry 4.0 on their own shows the importance of opening up to cooperation with suppliers, customers as well as competitors in order to grasp the full potential of a new GPT.

The characteristic of potential for improvement and technological dynamism where innovational efforts and learning effects increase the performance of the GPT as described by Bresnahan and Tratjenberg (1992), reflected in the findings in the need to experiment with different options and conduct R&D in order to adapt the technologies to a certain use. This further supports the argument made in the previous chapter regarding the implementation of Industry 4.0 technologies being the actual innovation and proves the argument of Leonard-Barton (1988) to be particularly applicable to GPTs.

The factor of innovational complementarity that has been found to result in new organizational and industry structures, new skills and business processes and the development of other supporting technologies and skills that cooperate with the GPT (Brynjolfsson & Hitt 2000; Lipsey et al. 1998), reflects in the findings in a need to make overall changes. Decision-makers recognized that with their current business models, know-how and capabilities, benefitting from the technologies could not be achieved and that a short cut to the exploitation of Industry 4.0 technologies does not exist. This shows clear parallels to studies by Jovanovic and Rousseau (2005) or Renshaw and Van Alstyne (1997) who find diffusion of GPT to be slow due to network externalities and the need to re-organize the entire company. While several authors have addressed the diffusion on an economy-level, this study provides insights to the company level implementation and can help to further explain why the diffusion of GPTs is a rather slow process. The stepwise approach to implementation discussed in the previous sub-chapter shows that the high need for overall change related to such technologies does not allow implementing the changes from one day to another. As described by one interview participant, while the technologies could in some cases be taken into use rather easily, the lack of supporting factors and new processes that would allow actually benefiting from the technologies hinders this.

The mutual adaptive approach taken by companies shows clear parallels to previous research on GPTs where changes to various factors in the organization as well as the technology itself were found to be made (Brynjolfsson et al. 1997). In their study on IT and its effects on organizational transformation, Brynjolfsson et al. (1997) describe the necessity to coordinate interactions among various factors in the business system. The findings of the present study show that a mutual adaptive approach can be used in order to better coordinate these factors. Through such an approach organizations avoid the pitfalls that have been found by Brynjolfsson et al. (1997) to occur if companies invest into

GPTs without implementing organizational change to match the new environment.

In summary, considering the findings of this study in the context of the characteristics of GPTs, it can be found that the generic function of the technologies requires them to be adapted to new applications, and leveraging complementary factors requires innovations supporting the GPT's use. In combination with the evolutionary process where diffusion and improvement of the technologies are intermingled and develop over time, these factors were responded to through steps of adaptation where changes are made to various factors in the organization, and the technologies are adapted and reinvented for different purposes (cf. Leonard-Barton 1988). A large-cycle mutual adaptation as introduced by Leonard-Barton (1988), can hence be considered a suitable response to all three characteristics of GPTs and their interplay.

6 CONCLUSIONS

6.1 Concluding remarks

Companies are increasingly confronted with change in the form of new technological developments and responding and acting upon such change plays a crucial role in companies' future competitiveness. Industry 4.0 provides an example of such far-reaching technological change as it affects a broad range of companies from innovative technology providers to more traditional manufacturers with little history in dealing with change and transformation. The broad impact of Industry 4.0 technologies on several businesses and the entire economy show parallels to the introduction of General Purpose Technologies in the past. Such technologies differ from the introduction of other technologies in the form of capital investments or new generations of existing technologies due to their pervasiveness, high technological dynamism and presence of innovational complementarity (Bresnahan & Tratjenberg 1992).

This work sheds light on the approaches to Industry 4.0 in the Finnish context and builds on literature on strategic management of technological change and GPT-literature by providing a perspective on how such technologies are perceived and responded to by companies. The findings illustrate that through their interplay, the characteristics of GPTs influence certain perceptions and actions of decision-makers and result in new structures of interdependencies and complementarities leading to an evolutionary change process.

This reflected in the responses in a need for organizational transformation, the renewal of business- and revenue models and processes, the creation of new products and services as well as novel strategies and changed customer and supplier relationships similarly as with prior GPTs (cf. Brynjolfsson & Hitt 2000). That companies have recognized the need to make organizational changes and to implement certain enablers in order to fully benefit from the technologies by creating novel products and services shows that benefitting from such technologies requires developing complementary factors and they result in the creation of several related innovations and renewal. However, it seemed to be exactly these aspects of the technologies that provide the biggest challenges.

The wide option for use and the initial uncertainty of their development result in challenges in understanding the nature of change brought by new GPTs and evaluating how they may be applied to company-own processes. This is especially demanding for long established companies that are the focus in this study as managing the high transformational requirements in the light of a lack of experience with renewal, was considered one of the biggest challenges. As a result, companies approach Industry 4.0 with some precaution and in a slower manner in order to make changes more incremental. Balancing the existing business and the new opportunities as well as the need to act fast while avoiding overwhelming customers and members of the organization with change are factors that need to be taken into consideration. Regarding this aspect, the study shows that investing into such an unknown future and managing the high transformational requirements can be tackled by implementing technologies in a stepwise process of mutual adaptation that allow for adjustments and learning to occur along the way. Overall, the approach taken by companies illustrates that even a disruptive technological revolution may be responded to by an evolutionary change process that allows breaking down the potentially disruptive change into more easily manageable steps.

Nevertheless, since a short cut to the exploitation of opportunities provided by GPTs does not exist, basics need to be developed and a long-term roadmap for their implementation is required. In order for GPTs to provide opportunities instead of threats a proactive approach towards their exploitation is necessary. It is not simply a question of technology, but the transformation of organizational structures and business processes and the creation of a new industry structures where different actors cooperate in developing the technologies and their applications needs to be managed. In line with prior literature it can be found that the implementation of such technologies may be the greater managerial challenge and the implementation can be considered the actual innovation behind the technologies (Leonard-Barton 1988).

6.2 Managerial implications

The broadness of the required change and the uncertainties on Industry 4.0 potentially creates some inertia and uncertainty on how to start the process. A takeaway from the findings is that managers should start by clearly identifying the values the technologies bring for their business operations and identify the ways they can be benefitted from in products and services. Evaluating the status quo in the company and implementing a strategy and a system where the goals are clearly identified is certainly crucial in finding out how to make the transition from one stage to another happen.

The findings in combination with previous literature then show that in the light of the uncertain development of the technologies as well as the uncertainty of where to start, the approach to Industry 4.0 should be developed in a way that enables stepwise learning. Breaking the implementation down into smaller and more easily manageable elements can prevent inertia and avoid a too disruptive effect. This allows for adaptation to occur and can create a fully integrated implementation process. In addition, members of the organization are given time to adjust, instead of being overwhelmed with change.

While a clear strategy and some idea of the future Industry 4.0 architecture are certainly necessary in order to understand the greater picture, identifying the first points of focus and getting started with the change seem most important in order to avoid getting stuck in the status quo. Industry 4.0 certainly requires some risk-taking, however, as it is impossible for anyone to have a detailed plan on how this will turn out, actions should be taken despite these uncertainties. Due to the characteristics of GPTs evolving over time, things will most likely only clear up with increased experience, and pieces will only come together throughout the process.

The changes brought through Industry 4.0 may also require changes in management and leadership. As the findings suggest, more freedom and risk-taking should be given to employees in order to create a more experimental culture where members of the organization can exchange ideas and try out new approaches. Managing a complex ecosystem consisting of several different actors also demands new managerial skills. The findings suggest that the style of decision-making needs to be adapted and customers should receive more influence and power in the R&D process. The horizontal and vertical externalities inherent in GPTs suggest that as important as the horizontal cooperation among different actors from customers to outside suppliers, is the cooperation inside the company and a vertical integration of the different internal processes. Technological know-how needs to be combined with managerial and strategic capabilities in order to create hybrid know-how. Chief Information Officers, being at the center of the technology- and the business side could play an important part in linking the different elements together and could in the future have a bigger role in the creation of the business strategy.

6.3 Limitations and future research

This research is subject to several limitations that need to be addressed. One major factor limiting the generalizability of the findings is the size of the sample. The strategic sensitivity of the subject under study and the need for interview participants to be actively working in management positions all under the aspect of a rather limited time frame for conducting the study, provided a challenge in finding enough interview participants. While the secondary data provided a lot of information on the issue, more in-depth interviews would have been beneficial in order to create a reliable overview of the topic under study. The specificity of the subject further limited the amount of secondary data available. In order to create more generally valid results regarding perceptions and responses to GPTs, further research on decision makers' perceptions and responses to prior GPTs would be necessary.

The interview participants were contacted by E-mail and over LinkedIn and were asked to contact the researcher if they were interested in participating in the study. Such a self-selection of participants may allow questioning the representativeness of interviewees. Company representatives who do not consider Industry 4.0 as being an important subject for their company may not have had any incentive to participate in a study on the topic. Although the sample certainly includes such companies that are among the frontrunners and such companies that still face higher uncertainties and challenges, it cannot be considered as being representative of Finnish industrial companies. Repeating a similar study with a larger sample representative of the industrial sector in Finland may allow generalizing the strategic approach to the technologies. Including also companies of different size and non-listed companies would further support the generalizability of results and offer interesting insights into the creation of ecosystems among small and large players. Including various different companies would allow gaining better understanding of the perceptions of such companies that see Industry 4.0 more as a threat.

Due to the limited size of the sample, company specific factors were left out of the analysis. As factors such as company size, age or specific business field may influence how companies respond, including such factors in future research may offer valuable insights in understanding different approaches to Industry 4.0.

A further potential limitation lies in the lack of a clear definition of Industry 4.0 and other related concepts. As the findings show, the use of the term Industrial Internet is more common in Finland, which may have affected the number of participants, as those unfamiliar with the concept Industry 4.0 may have been prevented from participating. The lack of a clear definition and the different terminologies appearing in the findings may reduce comparability. However, throughout the process it was paid close attention to these factors and it was ensured that technologies referred to by participants and the secondary data were included in the Industry 4.0 concept. Nevertheless, conducting such a study using the term Industrial Internet may allow for more participants and for a better comparability of findings.

The topic certainly offers several possibilities for further research. Regarding the company decision-making perspective on GPTs, this thesis provides a rather broad overview and a first introduction on how the specific characteristics of such technologies influence perceptions and responses. While the literature on GPTs is well developed from an economic literature perspective and the effects on the economy and the diffusion of such technologies within an economy has been thoroughly studied, more research from the company perspective would be necessary in order to identify patterns of how opportunities related to such technologies are perceived and responded to. The findings of this thesis show the importance of organizational factors in the form of new business and revenue models, new organizational cultures, structures and skills that complement the use of the technologies. Focusing more on firm-level data can further shed light on how such far-reaching technological change can best be implemented. With increasing importance of digitalization for almost all sectors, identifying strategies regarding the implementation of technologies that support business processes have high practical relevance. Little information exists on the organizational factors that influence the success of GPT implementation and in particular how the characteristics of GPTs influence decision-making within companies could be studied in more detail.

Regarding literature on strategic management of technological change, research builds strongly on the role of capabilities in exploiting technological opportunities and the implementation of strategies that take technological considerations into account. While these are certainly crucial aspects and are also found to play an important role in this study, the findings also indicate that there may exist a discrepancy between what strategies and plans are made regarding new technologies and actually putting them into practice. The difficulties described by decision-makers focused strongly around the questions of how to transfer the potential of new technologies into business models and how to get the process started. Besides the contributions of Leonard-Barton, the literature on the actual implementation of technologies from a strategic point of view is comparably scarce as many studies focus strongly around technological issues. As highlighted by this study, even though ideas and visions exist within the company, the implementation then provides the actual challenge and studying the process of implementation as a form of innovation of its own could provide further valuable insights. How to manage and coordinate the creation of complementary factors and the creation of new business processes well as a change in organizational culture in the light of a new GPT are questions of increasingly high practical relevance.

REFERENCES

Abernathy, W.J. & Clark, K.B. (1985). Innovation: Mapping the winds of creative destruction. *Research Policy*, 14(1), 3–22.

Aggarwal, V.A., Posen, H.E. & Workiewicz, M. (2016). Adaptive capacity to technological change: A microfoundational Approach. *Strategic Management Journal.* [Online] Available from: 10.1002/sm [Accessed 02. November 2016].

Aghion, P. & Howitt, P. (1998). On the Macroeconomic Effects of Major Technological Change. In: Helpman, E. (ed.), *General Purpose Technologies and Economic Growth*. Cambridge, MIT Press, 121–144. [Online] Available from: http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=9364&site=ehost-live&ebv=EB&ppid=pp_15 [Accessed 17. April 2017].

Ailisto, H. (ed.), Mäntylä M. (ed.), Seppälä, T. (ed.), Collin, J., Helen, M., Juhanko, J., Jurvansuu, M., Koivisto, R., Kortelainen, H., Simons, M., Tuominen, A., Uusitalo, T. (2015). *Finland – The Silicon Valley of Industrial Internet. Government's Analysis, Assessment and Research Activities*. Report Number: 10.

Anderson, P. & Tushman, M. (1990). Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change. *Administrative Science Quarterly*, 35(4), 604–633.

Ansoff, H.I., 1979. *Strategic Management*. First Edition. London, The Macmillan Press Ltd.

Aragón-Correa, J.A. & Sharma, S. (2000). A Contingent Resource-Based View of Proactive Corporate Environmental Strategy. *Academy of Management Review*, 28(I), 71–88.

Bledowski, K. (2015). The Internet of Things: Industrie 4.0 vs. The Industrial Internet. [Online] Available from: https://www.mapi.net/forecasts-data/internet-things-industrie-40-vs-industrial-internet [Accessed 04. March 2017].

Bundesministerium für Bildung und Forschung (n.d.). *Zukunftsprojekt Industrie 4.0* – BMBF. [Online] Available from: https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html [Accessed 03. February 2016].

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in psychology*, 3(2), 77–101.

Bresnahan, T.F. & Tratjenberg, M. (1992). *General Purpose Technologies: "Engines of Growth"?* National Bureau of Economic Research. Working Paper Number: 4148.

Brettel, M., Friedrichsen, N., Keller, M., Rosenberg, M. (2014). How Virtualization, Decentralization and Network Builduing Change the Manufacturing Landscape: An Industry 4.0 Perspective. *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing*

Engineering, 8(1), 37–44.

Brozovic, D. (2016). Strategic Flexibility : A Review of the Literature. *International Journal of Management Reviews,* 00, 1–29.

Brynjolfsson, E. & Hitt, M.L. (2000). Beyond Computation: Information Technology, Organizational Transformation and Business Performance. *Journal of Economic Perspectives*, 14(4), 23–48.

Brynjolfsson, E., Renshaw, A.A. & Van Alstyne, M. (1997). The Matrix of Change. *Sloan Management Review*, 38(2), 37–53.

Carneiro, A. (2006). Adopting new technologies. *Handbook of Business Strategy*, 7(1), 307–312.

Chakravarthy, B.S. (1982). Adaptation: A Promising Metaphor for Strategic Management. *The Academy of Management Review*, 7(1), 35–44.

Drath, R. & Horch, A. (2014). Industrie 4.0: Hit or hype? Industrial Electronics Magazine. 8(2), 56-58. [Online] Available from: http://www.control.lth.se/media/Education/EngineeringProgram/FRTN20/2016/docslide.us_industrie-40-hit-or-hype-2.pdfIEEE [Accessed 20. January 2017].

Eisenhardt, K.M. & Martin, J.A. (2000). Dynamic Capabilities: What are they? *Strategic Management Journal*, 21(10/11), 1105–1121.

Eriksson, P. & Kovalainen, A. (2008). *Qualitative methods in business research, Introducing qualitative methods.* SAGE Publications Ltd. [Online] Available from: http://dx.doi.org/10.4135/9780857028044 [Accessed 22. April 2017].

Fereday, J. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), 80–92.

Garrety K., Robertson P.L., Badham R. (2001). *Communities of Practice, Actor Networks and Learning in Development Projects. The Future of Innovation Studies, Eindhoven, The Netherlands*. [Online] Available from: http://www.tm.tue.nl/ecis/papers/iii-4-2.pdf [Accessed 12. November 2016].

Gartner (2015). *What Is Industrie 4.0 and What Should CIOs Do About It?* [Online] Available from: http://www.gartner.com/newsroom/id/3054921 [Accessed 05. January 2017].

Geissbauer, R., Vedso, J. & Schrauf, S. (2016). A Strategist's Guide to Industry 4.0. *strategy+business*, (83), 1–10.

Guest, G., Bunce, A., Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*, 18 (1), 59–82.

Hage, J. (1987). Responding to Technological and Competitive Changes: Organization and Industry Factors. In: Donald Davis (ed.), *Managing Technological Innovation.* Jossey Bass, San Fransicso, 44-71.

Hall, B.H. & Khan, B. (2003). *Adoption of New Technology.* Department of Economics, University of Berkeley. Working Paper Number: E03-330. [Online] Available from: https://escholarship.org/uc/item/3wg4p528 [Accessed 02. April 2017].

Helfat, C.E. & Winter, S.G. (2011). Untangling Dynamic and Operational

Capabilities: Strategy for the (N)ever-Changing World. *Strategic Management Journal*, 32, 1243–1250.

Helpman, E. (ed.) (1998). *General Purpose Technologies and Economic Growth.* Cambridge, MIT Press. [Online] Available from: http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=9364&site=ehost-live&ebv=EB&ppid=pp_15 [Accessed 17. April 2017].

Helpman, E. & Trajtenberg, M. (1994). A time to sow and a time to reap: Growth based on General Purpose Technologies. *NBER Working Paper Series.* Working Paper Number: 4854 [Online] Available from: http://www.nber.org/papers/w4854 [Accessed 04. April 2017].

Helpman, E. & Trajtenberg, M. (1996). Diffusion of General Purpose Technologies. *NBER Working Paper Series.* Working Paper Number: 5773 [Online] Available from: 10.3386/w5773 [Accessed 04. April 2017].

Henderson, R. (1993). Underinvestment and Incompetence as Responses to Radical Innovation: Evidence from the Photolithographic Alignment Equipment Industry. *The RAND Journal of Economics*, 24(2), 248–270.

Henderson, R.M. & Clark, K.B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly*, 35(1), 9–30.

Hitt, M., Keats, B. & DeMarie, S. (1998). Navigating in the new competitive landscape : Building strategic flexibility and competitive advantage in the 21st century. *The Academy of Management Executive*, 12(4), 22–42.

Hung, S.-W. & Tang, R.-H. (2008). Factors affecting the choice of technology acquisition mode : An empirical analysis of the electronic firms of Japan, Korea and Taiwan. *Technovation*, 28(9), 551–563.

IGI Global. (n.d.). Digitalization. [Online] Available from http://www.igi-global.com/dictionary/digitalization/7748 [Accessed 12. February 2017].

Jovanovic, B. & Rousseau, P.L. (2005). General purpose technologies. In: Aghion, P., Durlauf, S.N. (eds.), *Handbook of Economic Growth*. Elsevier B.V, 1182-1207. [Online] Available from: 10.1016/S1574-0684(05)01018-X [Accessed 20. April 2017].

Juhanko, J. (ed.), Jurvansuu, M. (ed.), Ahlqvist, T., Ailisto, H., Alahuhta, P., Collin, J., Halen, M., Heikkilä, T., Kortelainen, H., Mäntylä, M., Seppälä, T., Sallinen, M., Simons, M. & Tuominen, A. (2015). Suomalainen teollinen internet – haasteesta mahdollisuudeksi. The Research Institute of the Finnish Economy. Report Number: 42. [Online] Available from: https://www.etla.fi/wp-content/uploads/ETLA-Raportit-Reports-42.pdf [Accessed 20. November 2016].

Kirk, J. & Miller, M. L. (1986). Reliability and validity in qualitative research, Qualitative research methods. SAGE Publications, Inc. [Online] Available from: doi: 10.4135/9781412985659 [Accessed 20. April 2017].

Kruppa, M. (2016). Industrie 4.0 - Consulting. VDMA Industrie 4.0 Forum. [Online] Available from: http://industrie40.vdma.org/documents/4214230/5356229/Industrie%2040%20Business%20Models.pdf/905c7493-ba18-43a1-84c0-8f195955c76e [Accessed 10. January 2017].

Lambe, C.J. & Spekman, E.R. (1997). Alliances, External Technology Acquisition, and Discontinuous Technological Change. *The Journal of Product Innovation Management*, 14(2), 102–116.

Lasi, H., Kepmler, H.G., Fettke, P., Feld, T. (2014). Industry 4.0. *Business & Information Systems Engineering*, 4, 239-242. [Online] Available from: DOI 10.1007/s12599-014-0334-4 [Accessed 20. November 2016].

Lavie, D. (2006). Capability Reconfiguration: An Analysis of Incumbent Responses to Technological Change. *Academy of Management Review*, 31(1), 153–174.

Lengnick-hall, C.A. & Beck, T.E. (2005). Adaptive Fit Versus Robust Transformation: How Organizations Respond to Environmental Change. *Journal of Management*, 31(5), 738–757.

Leonard-Barton, D.A. (1998), Importing and Absorbing Technological Knowledge from outside the Firm. In: Leonard-Barton, D.A. (ed.), 2011, *Managing Knowledge Assets, Creativity and Innovation*. World Scientific Publishing Co., Singapore, 41–88. [Online] Available from: ProQuest Ebook Central [Accessed 12. April 2017].

Leonard-Barton, D. (1992). Core Capabilities and Core Rigidities. *Strategic Management Journal*, 13 (Special Issue: Strategy Process: Managing Corporate Self-Renewal), 111–125.

Leonard-Barton, D. (1988). Implementation as mutual adaptation of technology and organization. *Elsevier Science Publishers*, 17(5), 251–267.

Lipsey, R. G., Bekar, C. & Carlaw, K. (1998). What Requires Explanation? In: Helpman, E. (ed.) General Purpose Technologies and Economic Growth. Cambridge, MIT Press, 15-54. [Online] Available from: http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=9364&site=ehost-live&ebv=EB&ppid=pp_15 [Accessed 17. April 2017].

McEvily, S., Eisenhardt, K.M. & Prescott, J.E. (2004). The Global Acquisition, Leverage, and Protection of Technological Competencies. *Strategic Management Journal*, 25(8/9), 713–722.

McKinsey & Company (2015). Industry 4.0 – How to navigate digitization oft he manufacturing sector. McKinsey Digital. [Online] Available from: https://www.mckinsey.de/files/mck_industry_40_report.pdf [Accessed 01. April 2017].

Miles, R.E., Snow, C.C., Meyer, A.D., Coleman, H.J. (1978). Organizational Strategy, Structure, and Process. *Academy of Management Review*, 3(3), 546–562.

Milgrom, P. & Roberts, J. (1990). The Economics of Modern Manufacturing: Technology, Strategy, Organization. *The American Economic Review*, 80(3), 511–528.

Pricewaterhouse Coopers (2016). *Industry 4.0: Building the digital enterprise. Key findings from 2016 Global Industry 4.0 Survey – Finland's perspective.* [Online] Available from http://www.pwc.fi/fi/julkaisut/tiedostot/industry-4.0-digital-operations-survey-key-findings-finland-2016.pdf [Accessed 01. November 2016].

Rosenberg, N., Trajtenberg, M. (2004), A general-purpose technology at work:

The Corliss steam engine in the late-nineteenth-century United States. The Journal of Economic History, 64(1), 61–99.

Rosenbloom, R.S. & Christensen, C.M. (1998). Technological Discontinuities, Organizational Capabilities, and Strategic Commitments. In: Dosi G., Teece, D.J., Chytry, J. (eds.), *Technology, Organization, and Competitiveness: Perspectives on Industrial and Corporate Change*. Oxford, University Press, 215–245.

Rüßmann, M. Lorenz, M., Gerbert, P., Waldner, M, Justus, J., Engel, P. & Harnisch, M. (2015). *Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries*. [Online] Available from: https://www.bcgperspectives.com/content/articles/engineered_products_project_business_industry_40_future_productivity_growth_manufacturing_industries/ [Accessed 01. Oktober 2016].

Schwab K. (2016). *The Fourth Industrial Revolution: what it means, how to respond.* [Online] Available from: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ [Accessed 23. March 2017].

Shimizu, K. & Hitt, M.A. (2004). Strategic flexibility: Organizational preparedness to reverse ineffective strategic decisions. *Academy of Management Executive*, 18(4), 44–59.

Smit, J., Kreutzer, S., Moeller, C., Carlberg, M. (2016). *Industry 4.0*. European Parliament, Directorate General for Internal Policies. Study for the ITRE Committee. [Online] Available from: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf. [Accessed 02. December 2016].

Srinivasan, R., Lilien, G.L. & Rangaswamy, A. (2002). Technological Opportunism and Radical Technology Adoption : An Application to E-Business. *Journal of Marketing*, 66(3), 47–60.

Syrjälä, K. (2016). Email sent to Cecilia Weinmann, 02. November 2016.

Teece, D.J., Pisano, G., Shuen, A. (1990). *Firm capabilities, resources and the concept of strategy. Consortium on Competitiveness and Cooperation*. University of California at Berkeley, Center for Research in Management, Working Paper Number 90-0.

Teece, D. & Pisano, G. (1994). *The Dynamic Capabilities of Firms: An Introduction.* International Institute for Applied Systems Analysis. Working Paper Number: 94–103.

Teece, D.J. (2012). Dynamic Capabilities: Routines versus Entrepreneurial Action. *Journal of Management Studies*, 49(8), 1395–1401.

Teece, D. J. (ed.) (2009). Dynamic Capabilities And Strategic Management: Organizing For Innovation And Growth. New York, Oxford Press. [Online] Available from: http://search.ebscohost.com/login.aspx?direct=true&db=nlebk&AN=265018&site=ehost-liveEBSCOhost [accessed 16. April 2017].

Tripsas, M. (1997). Surviving Radical Technological Change through Dynamic Capability: Evidence from the Typesetter Industry. *Industrial and Corporate Change*, 6(2), 341–378.

Tushman, M. & Anderson, P. (1986). Technological Discontinuities and Organizational Environments. *Administrative Science Quarterly*, 31(3), 439–465.

Woiceshyn, J. and Daellenbach, U. (2005). Integrative capability and technology adoption: evidence from oil firm. *Industrial and Corporate Change*, 14, 307–342.

Zhou, K.Z. & Wu, F. (2010). Technological Capability, Strategic Flexibility, And Product Innovation. *Strategic Management Journal*, 31, 547–561.

APPENDIX 1: OUTLINE OF INTERVIEW QUESTIONS

Questions related to perceptions of Industry 4.0 and the meaning of it for the company

- What role do technologies related to Industry 4.0 play for your company?
- In what ways can these technologies be benefitted in your company?
- Can you currently foresee the future effects of the technologies related to Industry 4.0?
- In what ways does Industry 4.0 affect your operations?
- What arguments are used to justify investments in Industry 4.0?
- What arguments are used against investing into these technologies?
- Have these arguments changed within the past two years?

Questions related to technological know-how and the integration of the technologies

- What is your internal level of know-how of the technologies?
- How much can you rely on your existing technological know-how when it comes to Industry 4.0?
- How is the necessary know-how for these technologies developed?
- How do you get in touch with these technologies?
- Who in the company is responsible for planning the future use of these technologies?
- Is there a need to adapt the technologies for their use in your organization?
- Is your organization able to fully grasp the benefits from technologies related to Industry 4.0?

Questions related to problematic and unresolved issues regarding Industry 4.0

- What are the biggest challenges related to Industry 4.0 for your business?
- What are your company's strengths and weaknesses related to Industry 4.0?
- What are the risks of not investing or investing too late?
- What other technologies are discussed as alternatives for Industry 4.0?
- What kinds of developments would cause your firm to stop exploring Industry 4.0?

Other follow-up questions

- How are you planning to proceed with this issue from here?
- Does anything else come to your mind that you consider important and would like to add?

APPENDIX 2: OVERVIEW OF THE SECONDARY DATA USED IN THE STUDY

	Title	Type of Source	Industry	Informant position
Company 7	Ei kivaa uutta liiketoimintaa, vaan onnistumisen pakko - Konecranesin valtava IoT-urakka (Tekniikkatalous) 2015	Journalistic Article /Company Interview	Engineering & service	CEO
	Konecranesin Lundmark: "Teollinen internet tulee nousemaan tai kaatumaan tietoturvaan" (Talouselämä) 2015	Journalistic Article /Company Interview		CEO
	Teollinen Internet ainutlaatuinen kilpailukyvyn lähde Suomelle (Solita Think Tank) 2015	Journalistic Article/CIO as Author		CIO
Company 8	CIO interview: Antti Koskelin at Finland's Kone (Computer Weekly) 2015	Company Interview	Engineering & service	CIO
	Teollinen Internet vaatii yrityksiltä uudenlaista ekosysteemoajattelua (Solita Think Tank) 2015	Development manager as Author		Chief development officer
Company 9	Teollinen internet kerää tietoa ja luo uusia palveluja (Mediaplanet Teknologiainfo) n.d.	Journalistic Article / Company Interview	Industrial machinery	Business director
	Teollinen Internet	CIO as Au-		CIO

	muuttaa liiketoiminnan perusteita (Solita Think Tank) 2016	thor		
Company 10	Teollinen internet ei ole teknologiakysymys (Kauppalehti) 2016	Journalistic Article/CEO as Author	Services, Pulp and Energy, Paper and Automation	CEO
	Teollinen internet on totta jo tänään – tulevaisuus on vielä luotava (Teknologiateollisuus) 2016	Journalistic Article/CEO as Author		CEO
Company 11	Metsäkoneeseen tuli sähköposti 1990-luvulla: "Miten niin teollinen internet tulee vasta nyt" (Tivi.fi) 2016	Journalistic Article	Heavy equipment	Planning chief
Company 12	Internet of Things synnyttää alykkäämpiä kaupunkeja ja älykkäämpää asumista (Solita Think Tank) 2015	Journalistic Article/CIO as Author	Construction, services	CIO
Company 13	Metsä Groupin kehittämä Metsäverkko sähköistää puukaupan (tieto.fi) 2015	Company publication	Forest Group	Director Customer services
Company 14	Suomalainen Etteplan ostaa kaksi teollisen internetin yritystä 29 miljoonan euron kaupassa (Helsingin Sanomat) 2016	Journalistic Material	Engineering	CEO
	Etteplan laajentaa palvelukonseptiaan teollisen internetin sovelluksiin kahdella yrityskaupalla (Company Homepage) 2016	Company Press Release		Management
Company	Caverion julkaisee asi-	Company	Building	CEO

15	akkailleen alustan kiinteistöjen teollisen internetin palvelujen hyödyntämiseen (Company Homepage) 2015	Press Release	and industrial services	
	Äly auttaa teollisuuden käyttövarmuuden optimoinnissa (Company Homepage) 2016	Company Press Release		Management
	Case Caverion (promaintlehti.f) 2016	Journalistic Article		-
Company 16	Incap toimittaa teollisen internetin laitteita Comsel Systemsille (Kauppalehti) 2015	Journalistic Article	Engineering services	-
Company 17	Teollinen Internet astui laivaan (tivi.fi) 2015	Journalistic Article	Manufacturing and service	VP Services & Solutions

APPENDIX 3: THEMATIC ANALYSIS: CODES, SUB-THEMES, OVERARCHING THEMES

Codes	Sub-themes	Overarching Themes
Industry 4.0 as an umbrella term	Terminology	Conceptualization and understanding of Industry 4.0
Digitalisation as a broad term		
Industry 4.0 as a German concept		
Incremental elements	Impact of Industry 4.0	
Radical elements		
Industry 4.0 as Expansion		
Industry 4.0 as Disruption		
Industry 4.0 as an Opportunity		
Diverse perceptions of what I 4.0 actually is	Making sense of Industry 4.0	
Understanding the transformative effect		
The actual value of Industry 4.0		
Prerequisite for future competitiveness	Industry 4.0 strategies	
Technology- and business strategy		
Smart solution strategy		
Industrial Internet as the strategic core		

Codes	**Sub-themes**	**Overarching Themes**
Minimize losses	Improve efficiency	Use of Industry 4.0 technologies
From reactive and predictive- to cognitive form of operating		
Strengthening of business operations		
Connect knowledge from different sources		
Avoid machine breakdowns		
Help customers to improve their operations		
Optimize use of resources		
Improve assets' safety, reliability and use	Improve safety and reduce risks	
Use of technologies replaces people in dangerous places		
Reduce risks from faulty equipment		
Create new services through data analytics and cloud technologies	Development of new business- and revenue models	
Benefit from the knowledge that collects		
Make use of the hype created through I 4.0		
Operate independently of the location		
Offer consulting services		
Moving from transactional business to relational business		

Codes	**Sub-themes**	**Overarching Themes**
Connectivity of devices	Technological factors	Enablers for the implementation of Industry 4.0
Lear from others		
Understand development and maturity of technologies		
Technological capabilities		
Create an open culture and reduce the fear of failure	Organizational & human factors	
Substantial internal change required		
Risk-taking capabilities for trying something new		
Adaptation needs to happen on customer's side		
Development of service abilities		
Need for hybrid know-how	Comprehensive understanding and know-how	
Understanding of the overall architecture		
Developing business side and identifying supporting technologies		

Codes	Sub-themes	Overarching Themes
Advance in small experimental steps	Advance in experimental, small steps	Approaches to the implementation of Industry 4.0
Make use of knowledge from other industries		
Moving from the technology test phase to developing the business side		
Approach from the outside to the inside		
Proof of concepts		
Find cooperation partners for missing pieces	Creating an Ecosystem	
Codevelopment with customers		
Joint development programmes and pilot tests		
Seeing the bigger picture		
Vertical and horizontal integration		
Approach from the customer's perspective and the customer's problems		
Include start-ups		
Integrate and adapt external technologies	Selection and adaptation of technologies	
Refine technologies that are close to core		
Fine tuning while moving forward		
Select technologies that serve the business		

Codes	Sub-themes	Overarching Themes
Customers readiness to move to a new form of operating	Mobilizing customers	Uncertainties, challenges and risks
Getting the first references		
Timing of change		
Suspicion and fear of customers in terms of data usage		
Customers' acceptance of the transition of the supplier to a service provider		
Linking different providers		
Readiness of own organization	Managing the internal transformation	
Transforming to a service operator		
Lack of courage and experimentation		
Old-fashioned ways of thinking		
Finding a balance between existing operations and new technologies		
Building a safe architecture		
No longer sufficient to monitor traditional competitors' actions	New competitive landscape	
Customer base on the move		
Identifying factors of distinguishment		
How to create a clear business- and revenue model	Seizing the benefits	
Understanding the value brought by the technology		
Putting strategies and visions into practice		
Implement technologies into operational use		
Where to get started and what to focus investments on?	Selecting investments	
Choosing a technology provider		
Choosing from competing technologies		
Rapid development of technology field		
How cost-efficient and reasonable is it to take things forward?		