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Digitalization as a Paradigm Changer in Machine-Building Industry

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Abstract

Digitalization is a contemporary societal topic among businessmen, scholars, politicians, and citizens. The way Uber has changed the taxi business and subsequently is providing new models for the entire transportation industry or even changing urban planning principles is a practical example of the impact of digitalization. This example illustrates that digitalization offers major returns for some and ultimate losses for others, which is similar to Schumpeter's "Creative Destruction" that he coined in 1942. Digitalization does not refer to a product or service; it is multiple technology-based products, services, and concepts as a systemic whole. Many of the impacts of digitalization are difficult to observe beforehand, as the impact rendered is systemic rather than a straightforward causal relation. Traditional strategic management theories and frameworks are used to analyze company performance and to explain which strategies individual firms or group of firms should implement to succeed. Many of the tools for top management aid in understanding changes in business environments and offer guidance for making the correct strategic choices, but in many cases, they fail to aid in the detection of systemic phenomena. At the same time, making these strategic choices is difficult, as explained by behavioral economics and management cognition, as the choices involve changing the status quo.

This dissertation examines the digitalization impact on the machine-building industry that serves global container handling customers - ports and terminals. It is a traditional capital intensive business-to-business industry that has a relatively small number of global players. The investigation adopted a value chain view in which machine builders are actors, actors apply digital technologies provided by enablers. The end customers, ports and terminals are referred as users. The objective of the research was to increase understanding of digitalization's potential for disruption or paradigm change as well as to identify the most important concepts that drive and inhibit this change. As the change brought about by digitalization is underway, it is necessary to understand whether the views regarding its impact differ between enablers, actors, and users. Mixed methods were applied that partly overlapped for triangulation purposes. The primary methodology included two rounds of Delphi interviews that were complemented by a survey and three case descriptions.

Big Data/Artificial Intelligence emerged as the most prominent digital technology that can enable disruption in machine-building. Empirical results have shown that Big Data/Artificial Intelligence challenges the ways knowledge is created; it is more effective when machines and their components are connected to data networks, and the technology is both rapidly advancing and becoming more affordable. The cost, speed, availability, and features of Big Data/Artificial Intelligence development are driven by multiple industries where machine builders can have a relatively small impact.

Empirical results have also shown that discipline and industry-based platforms are the most powerful economic drivers. The current management of the incumbents has little experience with these new elements, which have a major influence on industry dynamics. The platforms are especially powerful for change, as they enable a global network economy in which entrepreneurial knowledge workers can contribute to value creation in collaboration with startups and multinational corporations. Platform development cannot be stopped or delayed by incumbents in machine-building. They can ignore the development, adapt to it, or pursue a platform strategy of their own if the opportunities match the companies' capabilities.

Examples of the sub-drivers pushing the digital concepts forward are classical and rational productivity, lead times, features, quality, and cost. In addition, some of the inhibitive sub-drivers are relatively easy to identify, such as 3D printing speed or users providing access to their data. Concerns regarding data security delay investment, and changing legacy processes and systems requires time; however, empirical results have indicated that the strongest inertia is related directly to people and decision making. Three of the strongest people-related inhibitive sub-drivers are lack of systemic understanding, management beliefs, and lack of capabilities. The practical contribution for management is twofold. First, it must be believed that digitalization will somehow disrupt the current business, and second that the transformation is too complex to be only planned, but instead requires also experimental learning. A successful combination that has been suggested by books and articles as well as the results and comments from the Delphi interviews is developing an entrepreneurial mindset, conducting multiple small experiments, and applying the knowledge of external networks. This enables strategy formation through learning, which simultaneously develops the capabilities that are needed in data and user-centric business environments.

Keywords Digitalization, Industrial Internet, Big Data, Artificial Intelligence, platforms, open innovation, industry disruption, strategic management, Delphi, container handling industry

Tiivistelmä

Digitalisaatio on ajankohtainen aihe liikemiesten, tutkijoiden, poliitikkojen ja yksittäisten ihmisten keskuudessa. Yksi käytännön esimerkki digitalisaation vaikutuksista on Uber, jonka toimintatapa muuttaa taksiliiketoimintaa luoden samalla malleja koko kuljetustoimialalle ja vaikuttaen jopa kaupunkisuunnitteluun. Esimerkki valaisee myös sitä, miten digitalisaatio tarjoaa merkittäviä voittoja yksille ja kohtalokkaita tappioita toisille, kuten Schumpeter kuvasi ”luovan tuhon” ajatuksessaan jo vuonna 1942. Digitalisaatio ei ole yksittäinen tuote tai palvelu, vaan se on tuotteita, palveluita ja konsepteja, joita useat digitaaliset teknologiat systeemisesti mahdollistavat. Systeemisyys yksinkertaisten syy–seuraus-suhteiden sijaan tekee vaikutusten ymmärtämisen ja ennustamisen vaikeaksi. Perinteisiä strategisen johtamisen teorioita ja viitekehyksiä käytetään yritysten suorituskyvyn analysointiin ja sen ymmärtämiseksi, millä toimenpiteillä yritykset menestyisivät. Lisäksi monet ylimmät johdon työkalut helpottavat näkemään liiketoimintaympäristön muutoksia ja tarjoavat tukea oikeiden strategisten valintojen tekemiseen, mutta niissä on heikkouksia systeemisten ilmiöiden havaitsemiseksi. Behavioristinen taloustiede ja johtamisen kognitiotieteet auttavat ymmärtämään, miksi oikeat strategiset valinnat, jotka muuttavat vallitsevia uskomuksia, ovat vaikeita yksilötasolla.

Tämä väitöstutkimus tutki digitalisaation vaikutusta koneenrakennustoimialaan, joka palvelee maailmanlaajuista kontinkäsittelyä – satamia ja terminaaleja. Toimiala on perinteinen, siinä on suhteellisen vähän globaaleja toimijoita ja se sitoo paljon pääomaa. Tutkimus lähestyi ongelmaa arvoketjun näkökulmasta siten, että koneenrakentajat ovat toimijoita, jotka soveltavat digitaalisia teknologioita, joita puolestaan mahdollistajat toimittavat. Arvo syntyy lopullisesti käyttäjille, joita ovat satamat ja terminaalit. Tutkimuksen tavoitteena oli lisätä ymmärrystä digitalisaation mahdollisesti aiheuttamasta murroksesta tai muutoksesta nykyiseen arvonluontimalliin sekä siitä, mitkä tekijät hidastavat tätä kehitystä. Koska mahdollinen muutos on meneillään, käsitysten erovaisuuksien ymmärtäminen arvoketjussa mahdollistajien, toimijoiden ja käyttäjien kesken on tärkeää. Tutkimuksen päämenetelmä oli kahden haastattelukierroksen Delfoi-tekniikka sekä tulosten validiteetin parantamiseksi käytetyt kyselytutkimus sekä kolme case-kuvausta.

Tietomassojen suurtehokäsittely (Big Data) yhdessä tekoälyn (Artificial Intelligence) kanssa nousi tärkeimmäksi mahdollisen murroksen aikaansaavaksi digitaaliseksi teknologiaksi. Empiiriset tulokset osoittivat, että kyseiset teknologiat vaikuttavat uuden tietämyksen syntyyn ja että ilmiö kiihtyy, koska koneet ja niiden komponentit liittyvät kiihtyvässä tahdissa tietoverkkoihin. Kyseiset teknologiat kehittyvät edelleen samalla

kun niiden käytön kustannukset laskevat. Nämä teknologiat palvelevat useita toimialoja, mutta koneenrakentajilla itsellään on vähäinen vaikutus teknologian kustannuksiin, nopeuteen, saatavuuteen, ominaisuuksiin tai niiden kehittymiseen.

Empiiriset tulokset osoittivat myös, että tieteenhaara tai toimialapohjaiset alustat ovat voimakkaimmat potentiaalista murrosta aiheuttavat taloudelliset konseptit tämän tutkimuksen rajauksella. Alustat ovat uusia elementtejä, joilla on merkittävä vaikutus toimialan dynamiikkaan, mutta perinteisten yritysten johdolla on harvoin omaan opiskeluun tai kokemukseen perustuvaa osaamista niistä. Alustat saavat voimansa verkostovaikutuksista, joissa tietotyöläiset, startupit ja monikansalliset yritykset luovat yhdessä arvoa. Koneenrakentajat eivät pysty estämään alustojen syntymistä tai merkittävästi hidastamaan niiden kehitystä. Ne voivat ohittaa ilmiön, sopeutua siihen tai mahdollisuuksiensa ja kyvykkyyksiensä puitteissa luoda oman alustastrategiansa.

Merkittävä osa ajureista, jotka kiihdyttävät digitaalisia konsepteja, ovat perinteisiä ja rationaalisia, kuten tuottavuus, läpimenoajat, ominaisuudet, laatu tai kustannukset. Osa kehitystä hidastavista ajureista on helposti tunnistettavissa, kuten 3D-tulostimen nopeus tai kuinka moni käyttäjä antaa pääsyn dataansa. Huoli tietoturvasta hidastaa investointeja, ja olemassa olevien prosessien ja järjestelmien vaihtaminen on aikaa vievää. Empiiriset tulokset osoittivat kuitenkin, että voimakkaimmat hidasteet liittyivät suoraan ihmisiin ja päätöksentekoon. Kolme merkittävintä ihmisiin liittyvää hidastetta olivat systeemisten ilmiöiden huono ymmärtäminen, johdon uskomukset ja kyvykkyyksien puute. Tulosten merkitys käytännön strategiselle johtamiselle kiteytyy kahteen asiaan. Ensinnäkin johdon pitää ymmärtää ja uskoa, että digitaalisuus murtaa joiltakin osin nykyisen liiketoiminnan, ja toiseksi kehitys on niin monisyistä, ettei menestystä voi kovinkaan tarkasti suunnitella etukäteen. Osa tutkimuksessa käytetystä kirjallisuudesta ja Delfoi-haastatteluista saadut tulokset painottavat tällaisessa tilanteessa yrittäjyysmäistä ajattelutapaa ja paljon pieniä kokeiluja, joissa hyödynnetään ulkoisten verkostojen tietämystä. Toimintatapa mahdollistaa sen, että strategia voidaan luoda oppimalla, mikä samanaikaisesti kehittää kyvykkyyksiä, joita tarvitaan tieto- ja käyttäjäkeskeisissä liiketoimintaympäristöissä.

Avainsanat: digitalisaatio, teollinen internet, Big Data, tekoäly, alustat, avoin innovaatio, teollinen murros, strateginen johtaminen, Delfoi, kontinkäsittely

Acknowledgements

Composing a dissertation at the last quarter of an industrial career is not an obvious choice. A passion for science, the right topic, support throughout the process, and a mindset in which beliefs are questioned that have been developed over a lifelong career are required. The passion for strategy and the role of people in strategy formation was inspired by the late Professor Juha Näsi. Juha was a testimony to the vital impact a great professor has on students' lives and careers. After applying knowledge in various management roles, the inner question arose: what if? The ambiguity and strength of digitalization also offered unique opportunities in strategic management, including study with a motivation to learn. The magnitude of the importance of digitalization was illustrated by the keynote speech of Professor John Zysman from UC Berkeley, which he gave in Helsinki in the spring of 2012 at the SHOK summit. I thank John for the initial inspiration but also for his support during my research project. I was also seeking advice regarding whether an endeavor such as a doctoral dissertation was worth pursuing, so I turned to wise men who I knew and trusted. I thank Messieurs Jarl-Thore Eriksson and Markku Kivikoski, who are known scholars with ample of merits also in many sectors of the economy and society. You encouraged me and made me renew the old passion that Juha initially inspired as well as supported me at each meeting during the journey.

I was still undecided when I met my supervisor Professor Saku Mäkinen. In less than 30 minutes, the decision was clear. Working with Saku was like meeting an old friend after 10 years and continuing a conversation that was interrupted. The discussions with Saku have always touched the essence of the research question whether they have lasted 10 minutes or 10 hours, and I have received excellent guidance when I have lost track of the theory or methodology. Saku also suggested early on that systemic problems need systems thinking and introduced me to Professor Matti Vilkko. Matti stimulated my interest in systems thinking methodology and made me regret that I have not acquainted myself with the methodology before. He has also supported me through several discussions and provided comments on the systems thinking sub-chapter. I also wish to express my thanks to Professors Miia Martinsuo, Tommi Mikkonen and Kari Koskinen from Tampere University of Technology and Assistant Professor Robin Gustafson from Aalto University. You all have had an interest in my research project throughout the process and have always been available to discuss both the content and the methodology of the research.

An important issue in this dissertation is open vs. closed systems, whether in business or in society at large. I was first introduced to this topic at the Finnish Metals and Engineering Competence Cluster (FIMECC), which I was also privileged to serve as Chairman of the Board. FIMECC, which has now merged with Digile to form DIMECC (Digital, Internet, Materials & Engineering Co-Creation), was established by a number of companies and universities for co-research purposes. While in my role at FIMECC, I was able to work with both fellow board members and with those responsible for executing various duties. I thank them all collectively, but special thanks go to CEO Harri Kulmala, who has done an outstanding job of leading this community drawn from industry and academia. Harri has also been a frequent sparring partner in my dissertation work. I also thank Digile (the Need for Speed program) and its former CEO Pauli Kuosmanen and my own employer, Cargotec, both of which contributed to financing this research.

Dr. Jari Hämäläinen commented on the digitalization sub-chapter, and Mr. Frank Kho commented on the sub-section that described the container handling industry—thank you. Under the supervision of Professor Matti Vilkko, Mr. Tommi Nurmi completed his master thesis of evaluating statistical methods by using some of the survey data from this dissertation. After having completed his thesis, Tommi has been keen on discussing statistical methodology, and he also commented on the subchapter related to the survey, for which I am thankful. Mrs. Merike Koskinen kindly helped me with the Finnish abstract and my thanks for that. The Delphi panelists provided research input, but in each interview, the interviewees provided more than asked, and I am thankful to each one of you. The same way the case descriptions were read and commented by people who possess deep knowledge from the case firms. The names of the Delphi panelists are listed in the exhibit and case contributors in the respective case descriptions.

I also wish to thank pre-examiners Professor Emeritus Alok Chakrabarti from the New Jersey Institute of Technology and Adjunct Professor Osmo Kuusi from Aalto University and Turku University. Even when I thought that the manuscript was ready, they found new perspectives that I had overlooked, and I thank they for these valuable contributions.

You can blindly follow the rules, or you can think; I acquired that mindset from my first superiors in the workplace, who also turned out to be my mentors. I thank the late Mr. Terence Derry for what I learned about people relations in a business context. That was during the period when *What They Don't Teach You in Harvard Business School* was published, and I learned its lessons from him. Questioning existing paradigms requires a culture in which there are no bad questions. Under the leadership of Mr. Raimo Ylivakeri, I learned a leadership style that encouraged innovation. Last but not least, I would like to thank Mr. Christer Granskog, who not only strengthened the foundation of my knowledge but also provided an example of outstanding general management. He did not hide behind complexity or uncertainty; he mastered long-term and short-term goals and issues while exemplifying the role of management when faced with conflicting expectations among stakeholders. Most importantly, I learned how to utilize strategic thinking in day-to-day management, inspired initially by Professor Juha Näsi. Over a 30-year career, a network of colleagues and business partners accumulate. Many of them have been available for conversation on issues during this research or otherwise expressed support during my moments of frustration, and I offer my collective gratitude to all of them.

Life is full even without a dissertation; pursuing this type of a dream might be a bit selfish. I have at times been short-fused, mentally absent, and likely have fallen short in ways that I do not even realize. Thus, I thank my wife Riitta and sons Marko and Mika for their love, support, and patience. They were all a critical source of support regarding some of the thoughts that I have shared during the journey.

My final thanks go to my mother Kaisu and father Aimo, who have always trusted me to do things my way.

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List of Abbreviations

ADC	Analog Digital Converter
AI	Artificial Intelligence
AM	Additive Manufacturing
B2B	Business to Business
B2C	Business to Consumers
CAD	Computer Aided Design
CLD	Causal Loop Diagram
CPS	Cyber-Physical Systems
CRM	Customer Relation Management
EBIT	Earnings Before Interest and Taxes
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
GDP	Gross Domestic Product
GPS	Global Position System
GSM	Global System for Mobile communication
HCI	Human to Computer Interface
ICT	Information and Communication Technology
IoT	Internet of Things
IP	Internet Protocol
IPR	Intellectual Property Rights
JV	Joint Venture
LCC	Life Cycle Costs
NAISC	North American Industry Classification System
MBSE	Model Based System Engineering

MEMS	Microelectromechanical systems
MNE	Multi National Enterprises
M2M	Machine to Machine communication
OS	Operating System
R&D	Research and Development
SIC	Standard Industrial Classification
SME	Small and Medium Sized Enterprises
TEU	Twenty-foot Equivalent Unit
VAS	Visual Analogue Scale
VOIP	Voice over Internet Protocol
W-LAN	Wireless Local Area Network

Note — All words of explicit concepts or theories begin with capital letters, such as Big Data or Bounded Rationality

List of Key Concepts

Actor	A machine-builder, who integrates either the technologies of external suppliers or their company's own technologies in order to build machines using several engineering disciplines.
Continuous improvement	Incremental improvement as a result of a development activity. It is assumed that in competition, continuous improvement will ensure that a firm maintains its current position relative to its peers.
Digitalization	The use of digital technologies to create value for a firm. Digitization (as opposed to *digitalization*) can also be used in this way, but here this term is strictly considered as relating to the technological process of changing analogical data into a digital form.
Disruption	The paradigm change in rules concerning how value is created in business.
Driver	A factor that enables potential disruption in the machine-building industry. Drivers can be either digital technologies or economic/ strategic management concepts that utilize opportunities that the digital technologies enable.
Enabler	A firm that supplies digital technologies, which can be products or services, to actors and users.
Paradigm	The entire constellation of beliefs, values and techniques, and so on shared by the members of a given community (Kuhn, 1996). In this context paradigm relates to paradigm of value creation of a firm.
Sub-driver	A factor that inhibits or accelerates the disruptive impact of the driver.
Quantum leap	A major change in the market position as a result of a development activity. Typically, a quantum leap is the result of an innovation.
User	A firm, whose business is to handle containers at ports and terminals.

“Be the change that you wish to see in the world.”

Mahatma Gandhi

1 Introduction

Communities have sought ways to achieve objectives that they perceived as valuable for thousands of years, such as conquering new regions, cultivating land, or in modern times, developing and delivering products and services in exchange for financial rewards to be distributed to stakeholders. This journey has always included fixed characteristics, such as people and their relations, hierarchies, culture and social codes, other sets of people with the same goals, and state-of-the-art tools and methods.

The discipline that is dealing with the way of achieving these objectives is usually called strategy both in academic world and in common language. Sun Tzu expressed his thoughts about strategy in the *Art of War* over 2000 years ago (Sun, 1963). Leadership as a means to achieve goals is not specifically a new invention, either; Niccolò Machiavelli's *Il Principe* was published in 1532 (Machiavelli, 2003), and like Sun Tzu's book, it is read by business leaders in the current millennium. The *Wealth of Nations* published in 1776 by Adam Smith was a milestone for modern economics (Smith, 2014) in the same way that *The Principles of Scientific Management* by Fredrick Taylor in 1911 was for modern business administration (Taylor, 1998). Innovation has always produced unexpected results, causing disruptions or paradigm changes. The list of disruptive innovations is endless: fire making, bows and arrows, steam engine, spinning jenny, telegraph, transistor, Internet, etc.

Likewise, learning by experimenting and sharing knowledge is as old as mankind (Wenger and Snyder, 2000). The major disruptions in knowledge creation are the invention of writing by the Sumerians in 3000 BC (Fischer, 2008) and the invention of printing by Johannes Gutenberg in 1448 (Childress, 2008). In this dissertation, it is assumed that the ability to transform any type of data, observations, events, etc. to digital forms as well as the ability to process it, store it, and share it economically, globally, and in real time have the same type of systemic characteristics as the invention of writing or printing.

Is digitalization as disruptive as Uber in taxi business suggests? Do the strategic management schools and tools detect the systemic change in business environment in way that that can be used for strategy formation? The objective of this dissertation is to increase understanding on the potential impact on digitalization on machine-building industry and factors that either drive or inhibit the development.

1.1 Motivation

The motivation for this research included also personal inspiration. I have been fortunate to witness the transformation of a Finnish state-owned aircraft factory to a technology center that is a global leader in the development of automated ports and terminals over the last 30 years. I have been part of the transformation in senior management by leading functional or business organizations and part of the corporate staff responsible for strategic planning, mergers and acquisitions, and technology. This journey brought me either temporarily or for longer periods to one-third of the world's countries, which has increased my understanding of globalization on the macro level and of people with different backgrounds on the micro level.

The factory celebrated its 75th year anniversary in 2011, and Cargotec published the history of the factory (Koivuniemi, 2013), which was also a story of survival during several disruptions beginning with war and war reparations. The pace of change accelerated in the 1980s. The product offerings narrowed from tens of categories to half a dozen, and the factory eventually began to serve only one customer industry: ports and terminals that handle containers. The transformation also involved a geographical change from a domestic supplier to a center that is a part of a global network. The internationalization generally followed the pattern described by Luostarinen (1979) in which products, operations, and markets have their own internationalization patterns but jointly contribute to the development, growth, and mature phases of the internationalization of a firm. At the same time, the value chain narrowed from a fully integrated factory to a competence center (research and development, sales and marketing, project management, services, and support functions). Between 1994 and 2005, the factory underwent five ownership changes, including several changes in the company and product names. The last milestone was in 2012 when the factory moved to a purpose-built technology center, including a large test site, laboratories, and a workshop for prototypes, which is located near Tampere University of Technology in Finland.

The common denominator of survival was versatile technological competence throughout the organization. The core competence related to machine-building, and the digital technology adaptation was evolutionary. Information technology came first to administrative processes, and then it was embedded in production machinery. In the 1980s, programmable logic was introduced in the products. Today's autonomous machines represent a continuum of that development. They are highly sophisticated, but the fundamentals of business have remained the same in comparison with digitalization in the media business. A popular claim is that digitalization has a marginal impact on capital intensive industries. Increasing the understanding of this claim was the personal inspiration behind this dissertation, which is also relevant in determining whether there is a need for the next transformation of that former aircraft factory.

The Internet of Things, Industrial Internet, and Big Data are all examples within the digitalization domain. They have all appeared in recent years in the Gartner's hype curve (LeHong et al., 2014). McKinsey Global Institute (Manyika et al., 2013) published a research report in which 12 disruptive technologies in order of their estimated potential economic impact by year 2025 were listed. The first six are relevant to this dissertation. General Electric (GE), which is considered the father of the Industrial Internet concept, described the fundamental logic for a machine builder in their white paper (Evans and Annunziata, 2012). In table 1 on page four, and example is used in which it is estimated that the value of 1 % fuel savings in commercial aviation would amount to $30 billion in savings over 15 years. This could be achieved using the Industrial Internet, and the benefit could be shared between the developers and the users.

These data suggest that digitalization would be highly relevant for all machine-builders, but it does not necessarily indicate industrial disruption. For many companies, the main digitalization agenda is related to the growth opportunity that it offers; however, there are ample disruption examples from other industries, such as the management beliefs of Kodak in films vs. digital photography (Lucas and Goh, 2009), IBM as an example of surviving disruption through transformation (Gerstner, 2002), and Amazon disrupting bookstore businesses with digitally enabled customer insight and superior logistics (Kimble and Bourdon, 2013). Every industry has its special characteristics and it also easy to state these examples are not applicable to one's own industry. To better understand the discussions that took place in management in the industries that have experienced digital disruption, senior executives from three industries who were insiders in the digitalization discussion before the disruption took place in their respective industries (media, fine paper, and retail) were interviewed.

An Editor-In-Chief of a large newspaper explained the media's experience with digitalization. In the early 1990s, newspapers were "ready": printing was effective, distribution was in order, readers were satisfied with the content, and owners received good returns on their investments. At the same time, local language was protecting national newspapers from international competition, and the domestic market was stable between the national leaders and regional newspapers. The production process was the first to be digitalized. Then digitalization emerged in the form of internet, emails, mobile phones, and laptops, but they were tools used to complete the same processes as before. The new millennium experienced a change driven by owners' ambitions and the dot.com era. Several visionary experiments were performed, but they were buried at the same time as dot.com had its crash landing. Google and YouTube were identified as potential future competitors but were underestimated, partly due to several parallel changes at the time and partly due to earlier failed experiments that might have been premature. The disruption caused by digitalization also occurred during a low cycle, so the focus was on cutting costs. There was also considerable natural inertia, as the majority of the assets and personnel were in printing and distribution. Incumbents were not able to translate the experiments to the next level, which was eventually done by players outside of the industry, such as Google and Facebook; however, this has also pushed the surviving incumbents toward digitalization maturity that surpasses most other industries.

Electronic mail did not create a "paperless office," a slogan from more than 15 years ago, which could be the reason paper companies did not experience the magnitude of digitalization in their industry. A retired executive from a large Finnish wood processing company stated that the impact on paper demand was underestimated simply because improvements in old strategies still paid off, which in practice referred to investments in faster machines or shutting older machines down. The weak signals of digitalization existed but they were more apparent to colleagues whose business was not dependent on the fine paper. In hindsight, it is obvious that investments in new raw material-based products would have been a good option. This scenario was available, but it was shadowed by the old paradigm. The focus has now shifted, but the lead times for success are lengthy.

The retail example is analogical. Currently, shops and department stores are in the midst of closing; however, many of these stores were built when e-commerce was already changing consumer habits. A former retail executive admitted that this situation was foreseeable over 10 years ago. The impact of digital development was acknowledged, and there were several experiments using digital technologies that had been conducted; however, as previously mentioned, the magnitude of the impact was underestimated. The root cause for the underestimation was the same as in media: digitalization was predominantly operating under the old paradigm. In retail, this meant that Big Data was utilized to optimize the supply chain or that information was used for bargaining with suppliers. To a lesser degree, it was used for improving marketing communication with customers, recognizing changing consumer behaviors, and innovating business models.

Practitioners have acknowledged the potential of digitalization. A growing number of digital strategies have been implemented in firms, and experiments have been initiated. There is a justified assumption that digitalization also has an impact on firms' competencies. Old competencies change or disappear by automation, which is both a managerial and a societal issue. At the same time, the need for new types of competencies has emerged. A study by Oxford University (Frey and Osborne, 2013) has suggested that the next wave of computerization will impact also knowledge work. Also new ways of working emerge in startup companies. This is one reason that even large multinational companies have begun to use learnings from startups, which is evident in GE's CEO Jeffrey Immelt's explanation for hiring 1,000 people from Silicon Valley:

> "If you give them the room and pick the right idea, you can hire great people with a great mission and you can change a company."[1]

1.2 Research questions

This dissertation is based on an assumption that digitalization will change some of the fundamentals regarding the way that machine-builders create value during the next 10 years. The potential changes in paradigms are assumed to be systemic, but to obtain theoretical and empiric evidence, the research question was divided into sections. The

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[1] GE CEO Jeffrey Immelt in The World Energy Innovation Forum, Pando Daily 15.5.2014

objects of the impact are categorized as products, services, operations, and business models. The factors that enable the potential impact are called drivers, and they can be digital technologies or economic/ strategic management concepts that utilize opportunities that digital technologies enable. The inquiry focused on disruptive impacts, which can be referred to as paradigm changes or as changing the rules regarding how value is created in an industry. It is an important distinction from quantum leaps in market positions, which is a normal objective of major R&D projects of the firms. For most industries, the largest share of development money is invested in continuous improvement because in tough competition keeping the current market position requires already a lot of effort.

Machine-builders are called “actors” that use the technology of several domains and that use engineering disciplines to integrate those technologies to solve the needs of its customers, which in this dissertation are called “users.” Firms that supply digital technologies that can be products or services are called “enablers.” Actors might have their own core technology and might make multiple choices regarding how they compete within the market they have selected. A typical choice for actors involves which part of the value chain it opts to have own resources. To narrow down the empirical portion of this dissertation, the actor must have following characteristics:

- The solution of the actor is a long-term investment for the users regardless of whether it is accounted for on the balance sheet or considered a cost item in the profit and loss statement
- The actor operates in a market in which there is a global supply and demand
- The solution of the actor in the user process is critical and consequently uptime is critical
- The machines have already autonomous versions or those will likely be available within the next 10 years

The last “in scope” criteria is particularly important, as the autonomous vehicles utilize various types of digital technologies. Autonomous operation is also quite different for users, as the important part of the users’ value has been dependent on the actions of an operator (often a driver). It is also a change to the development paradigm of the machines for the actor. An important part of machine behaviour data has been based on drivers’ experiences. Autonomous machines create data that is measurable. It is often real-time data, and it can be perceived as factual. This type of data is a new source of input that the actor can use when developing new products, services, operations, and business models. Autonomous operations have though existed for decades in the process industry.

Finally, the value is captured by the user. In an industrial context, the user can be a power station, a chemical plant, or a service provider. The empirical portion of this dissertation assumed that users are global container handling operators at ports. A port operator uses systems, machines, and services to serve its customers, which include shipping lines at sea and trucking and railroad companies on land.

The primary assumption is:

> *Digitalization is a major systemic enabler for future competitive advantages of the machine-building industry, and in some phase of the value creation, it is or will be disruptive within the next 10 years.*

The research questions are:

> *Which drivers enabled by digitalization accelerate or inhibit disruption in a machine-building industry that serves global container handling?*
>
> *Do the enablers, actors and users have different views on the drivers or sub-drivers that either accelerate or inhibit the disruptive development?*
>
> *How are disruptive drivers related to each other in a machine-building industry that serves global container handling?*

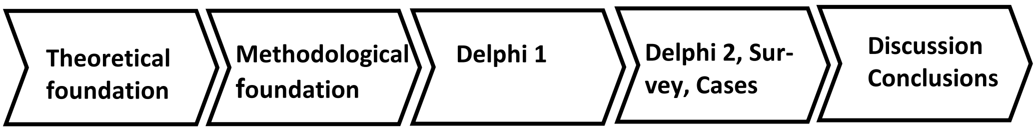
The answers to these questions will provide support for decision-makers regarding their current strategic choices and allocation of resources. Ultimately, the benefit materializes in better value creation or in extreme disruption with a higher likelihood to stay in business or to lead the change.

1.3 Structure of the dissertation

Chapter two describes the theoretical foundation for the empirical research. The research question is considered from three perspectives. Industry evolution, disruption, and convergence address the question from an external viewpoint. Firms take actions in businesses, and the strategic decisions are usually made by management. Therefore, the second perspective of the theories is derived from economics and strategic management. The characteristics of digitalization might explain some of the disruption potential. Digitalization has also triggered new strategic concepts, such as platforms, and thus the third perspective of the theories involves digitalization. The inquiry focused on systemic changes, which resulted in a rather wide theoretical range

The third chapter presents the research methodology. Mixed methods were utilized, and the primary method used is the Delphi technique, which was triangulated by a survey and three case descriptions. Findings from thematic Delphi round one served as input for Delphi round two. They were also used to fine-tune the survey and case design. The survey was also used to expand the coverage of the Delphi interviews.

The results are presented in chapter four so that each method forms an individual section. The chapter begins with a short description of the container handling industry to provide a background for the interpretation of the results. The discussion and conclusions combine qualitative (Delphi interviews and cases) and quantitative (survey) results in chapter five. Also the validity and reliability is reviewed in this chapter. The chapter concludes by summarizing key contributions and suggestions for future research avenues. The structure of the dissertation is described as a process in Figure 1.



	Theoretical foundation	Methodological foundation	Delphi 1	Delphi 2, Survey, Cases	Discussion Conclusions
Objective	Derive potential drivers of disruption based on theory	Design methodology based on the inquiry	Validate drivers Suggest accelerative and inhibitive sub-drivers	Analyze the potential disruption, its drivers and sub-drivers	Discuss, conclude and validate results Suggest new research avenues
Specification	Industry evolution Strategy and top management Relevant digitalization concepts	Mixed methods * Delphi * Survey * Cases	Answers to open questions based on the theoretical framework	Leading expert judgment * Delphi panel * Survey participants Case descriptions	Triangulation between the three methods, theory, and industry
Result	Framework for the empirical research	Framework and methods for the empirical research	Industry refined framework for the Delphi round 2. Survey and case design	Disruption analysis by the value chain	* Disruption impact * Critical drivers * Critical sub-drivers * System model * Contribution to theory and practice * Future research avenues

Figure 1. The research process

2 Theoretical foundations

The inquiry involved investigating potential industrial disruption, its drivers, and its inhibitors. A general assumption regarding disruption in business is that somehow the rules regarding how value is created change. More generically, it is similar to a paradigm change.

Thomas Kuhn (1996) defined the usage of a paradigm:

> On the other hand, ‘paradigm’ stands for the entire constellation of beliefs, values and techniques, and so on shared by the members of given community. On the other hand, it denotes one sort of element in that constellation, the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as a basis for the remaining puzzles of normal science.

A new innovation often acts as a catalyst in this type of a change. In this dissertation, the catalysts that were studied were related to digital technologies. Bower and Christensen (1995) characterized technologies that can be disruptive by stating:

> The technological changes that damage established companies are not usually radically new or difficult from a *technological* point of view. They do, however, have two important characteristics: First, they typically present a different package of performance attributes—ones that, at least at the outset, are not valued by existing customers. Second, the performance attributes that existing customers do value improve at such rapid rate that the new technology can later invade those established markets.

The first set of theories focuses on how industries evolve. In that evolution, changes initiated by businesses largely depend on decisions made by a firm’s management. Therefore, the second set of theories involved both strategic management and theories that focus on managers as part of the organizations of those firms. To understand the potential of digitalization as well as the drivers and inhibitors, the chosen digital technologies were reviewed from a systemic perspective. There is an assumption that digital technologies offer a wide range of systemic concepts that impact both the external business environment and the internal processes and capabilities of firms. This led to a situation in which the three main theory areas consisted of a large number of individual perspectives. To keep the perspectives manageable, there was an attempt to focus on the seminal theories of each perspective; the judgement on selection was either based on academic citations or research indicating major usage by the practitioners. Chapter two concludes by merging the three sets of reviewed theory areas with the framework.

2.1 Industry evolution

This dissertation focuses on a machine-building industry that serves global ports and terminal customers, and therefore this sub-chapter begins with the perspectives of established industries. Thereafter, theories that explain how industries evolve are reviewed. Evolution can be either incremental or radical. Particular interest is paid to the players, components, and mechanisms that are involved in industry dynamics.

2.1.1 Industry definition

The broad definition of an industry, "a particular form of branch of economic or commercial activity,"[2] can lead to interpretations based on the type of activity, such as a service industry, or the product, such as the automobile industry. Established industries are already categorized. The most practical categories can be found by viewing lists of classified industries from federations or by examining companies that are grouped under different industries based on the stock exchange. The United States has a pivotal position in trading stocks or other financial instruments of companies. The U.S. Securities and Exchange Commission is the governing authority, and it uses SIC codes (Standard Industrial Classification) when categorizing companies by industries.[3] SIC coding is relatively fine-tuned; however, the category to which the focus of this disserta-

[2] http://www.oxforddictionaries.com/definition/english/industry, retrieved 6.6.2016
[3] http://www.sec.gov/info/edgar/siccodes.htm, retrieved 6.6.2016

tion belongs (3510 = construction, mining & materials handling machinery & equipment) is not exhaustive when considering the needs of users. One way to solve this issue is moving towards more aggregate grouping and using the NAISC (North American Industrial Classifications System) in which the industry would be classified into the group of 31-33[4], which is manufacturing. This would include the needs of the user but would also include several products that are not relevant. Despite the weaknesses of both the SIC and the NAISC, similar categories offer suitable platforms for research within the industry or between industries, especially if statistical methods or time series are applied. The same longevity that simplifies the trend analysis might create inertia that delays the renewal. This could be explained by the multiple stakeholders that have emerged based on classifications, such as financial analysts, standardization organizations, trade associations, employee organizations, labor unions, conferences, and trade magazines. The convergence of industries blurs the boundaries between old industries and emerging new industries.

Some components appear to be characteristics in the theory of industry. Components such as supply, demand, price, and competition are rooted in the very principles of economic theories, even if the details differ depending on which economical system they represent. The division of labor (Smith, 2014) was originally based not only on specialization but also on the high amount of the value being in a manual work in the industrial production. The evolution of services, and later, knowledge-based services, has brought several intangible assets to complement the original factors of production: labor, raw materials, and capital. Products and services fulfill needs in the market, but they do have substitutes. Substitutes can be different products, methods, or services that fulfill the same need, which often is the explicit object of innovation. Differentiation is a smaller degree of substitution that is also important in avoiding price competition (Conner, 1991). One of the main conclusions in her article (Conner, 1991), which compared five schools of industrial organization economics, was the importance of unique capabilities, which are quite different when considering labor to be a homogenous factor of production. The impact of a non-economic environment on economic development has been discussed since the infancy of the economics field. Schumpeter (2012) highlighted also that it is wrong to simplify economic development by decoupling it from the surrounding societal development.

[4] http://www.census.gov/cgi-bin/sssd/naics/naicsrch, retrieved 6.6.2016

One of the most often cited modern theories used to explain industry dynamics is Michael Porter's Five Forces (1979). The supply (bargaining power of suppliers) and demand (bargaining power of customers) form the core of the model. Substitutes in economics have been translated as a threat of new entrants or a threat of new products and services. These forces impact the dynamics that already exist between the current competitors of a particular industry.

The Schumpeter's (2012) societal view of in economic development was not included in the Five Forces. Thomas Freeman's (2015) stakeholder model paved the way for today's sustainability as an explicit form of business practice. The list of stakeholders is extensive: customers, competitors, media, employees, special interest groups, environmentalists, suppliers, governments, local community organizations, owners, and consumer advocates. As an extension to Porter's (1979) Five Forces, Freeman (2015) suggested that adding stakeholders as a sixth force would complement the model. Laplume et al. (2008) conducted an extensive literature research based on 179 articles between 1984 and 2007 and concluded that past stakeholder research was divided into five categories: Identification and Salience, Stakeholder Actions/Response, Firm Actions/Response, Firm Performance, and Theory Debates. The Identification and Salience group was closest to the industry definition, and there were 19 theoretical and 13 empirical articles during the period examined. Mitchell et al. (1997) studied the typology and salience of the stakeholder theory for the management of a firm and determined that stakeholders must possess power, legitimacy, and urgency, and the strength of the impact depends on the number of attributes that are simultaneously present. In both papers, the view of stakeholders is firm-centric, and they do not capture the stakeholder role as a source of potential industrial disruption. The same pattern is evident in articles at large; searching "Stakeholder" in Web of Science (6.6.2016) provides 129290 results, "Stakeholder, Industry" provides 14795 results, and "Stakeholder, Industry, Disruption" only provides 43 results.

The Schumpeterian (2012) view was also present in the PEST (Political, Economic, Social, and Technological) model (Aguilar, 1967). It is firm-centric and was not designed as a tool to diagnose industrial disruption, but it describes the factors that according to Aguilar (1967), form sources of external strategic information that top management must understand for strategic planning. The PEST model has also got derivatives when scholars have added e.g. legal, environmental, or ethical factors to the original model. The limitations of PEST and its derivatives were discussed by Burt et al. (2006) in the context of scenario planning. The paper emphasized that the business environment is also an outcome of management thinking. In addition, it suggested that the their scenario methodology contains a process of sense making that can identify discontinuities in the environment better than applying the static PEST model (Burt et al., 2006).

2.1.2 Industry evolution

Emergence suggests that something new is being created; evolution is normally accompanied by development, which is a continuum of something that already exists. Disruption refers to discontinuity in development, whereas convergence is a special case, as the mechanism of disruption relates to a merger of two or more existing phenomena. Innovations based on digital technologies can most likely be a catalyst in all of the four above mentioned forms of industrial evolution.

The question of emergence is existential; what was there before the industry was born? In the same way, scientific discipline industries can be formed by allowing a subset of existing industry to form its own industry. Logically, one of the contributors is new knowledge, or innovation. If a new medicine is invented, the extent of the application required to form a new subindustry from more generic pharmaceuticals is a matter of definition. It is unlikely that a firm's innovation activity is targeted to form new industries; rather, the aim is most likely to satisfy the new or existing needs of the market. Abernathy and Utterback (1978) discussed the importance of making a distinction between evolutionary and radical innovation. The distinction cannot exclude the ex-ante incremental activity that yields an unplanned radical impact as a side effect.

Although the Five Forces (Porter, 1979) can explain industry disruption, the model was developed at a time when the physical value chain held more importance. Porter (1979) also highlighted strategy formation based on the understanding of the industry evolution provided by the model. Later the model has been extensively used as a tool for owners to make portfolio decisions regarding where to invest and divest in industries. For these reasons, the Five Forces (Porter, 1979) is viewed as a model that explains both incremental and radical evolution within an industry, but it is not viewed by default as a model explaining the change for the fundamental rules of value creation. The axis of value chain vs. external threats poses the first question of whether there is a logical difference between the two regarding their impacts on industry evolution. In established industries, the players in the direct value chain might have a long history and knowledge of each other, which would suggest more towards incremental evolution. The likelihood and impact of external threats is also dependent on the entry barriers of the industry. According to Porter (1979), the threat of industry includes six major entry barriers: economies of scale, product differentiation, capital requirement, cost disadvantages independent of size, access to distribution channels, and government policy. Physical production played an important role when the Five Forces was introduced. Digitalization introduces characteristics that do not fit well into the Five Forces. If the physical product can be decoupled from the value creation, the model might become weaker. Digital products and services behave differently than physical products also with the entry barriers having global scale, real-time product differentiation, low capital, and virtual distribution. Porter (1979) considered the experience curve to be a major factor related to the cost disadvantages, which is an important paradigm in several industries. Porter concluded that the new entrant might be more cost effective than the experienced competitor when it can utilize a new technology, which is an important notion in digitalization. Government policies in virtual products and services are related e.g. to data security and ownership. Afuah and Utterback (1997) combined the view of the Five Forces and the phases of evolution (fluid, transitional, specific, and discontinuity) and argued that the Five Forces without the context of an evolutionary phase provides a static view of industry development.

There are also perspectives that consider evolution from a temporal perspective. The diffusion of innovation describes the process of the adaptation of innovations by customers. Rogers (2003) called the phases Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. In his theory (Rogers, 2003), the size of the population forms a curve that is similar to normal distribution. Utterback and Abernathy (1975) concluded that there is a sequence of innovation in which the focus moves from product innovation to process innovation after the rate of innovation of the product has declined. The S-Curve is another focal theory that explains the temporality of industry evolution. Based on the product perspective Foster (1986) suggests that the lifecycle of a product follows the S-curve where the development is slow in the beginning and in the end but fast during the time when the product has passed the introduction. The theory explains that development in the next S-curve is driven by new technology and/or innovation. The S-curve theory does not implicitly affirm whether the change affects the dynamics only inside of the existing industry or whether it also applies to industrial disruption. Klepper (1997) argued that there are a number of industries in which evolution does not follow the phases of the product lifecycle theories.

There are also other perspectives of industry evolution. From the supply perspective, evolution is often accompanied by scientific discoveries and innovation, whereas market-based evolution suggests an unsatisfied or hidden demand. Malerba (2007) divided the challenges in industry evolution into demand, knowledge, networks, and co-evolution. He also viewed the evolutionary process as industry-specific. Malerba et al. (2007) coupled experimental users and demand-driven industry dynamics, and concluded that the evolution of the suppliers of new technology is initially dependent on experimental users and an unsatisfied niche market.

One of Robertson's (1967) four conclusions was that innovation can be categorized depending on the strength of its impact on established patterns. McGahan (2000) separated industry evolution into non-architectural and architectural, and she divided non-architectural into Receptive and Blockbuster categories and architectural into Radical Organic and Intermediating categories. She concluded that the Receptive category is more stable with a focus on continuous improvement and e.g. distribution, transportation, and retail would be in that category (McGahan, 2000). The examples are most likely not static, and McGahan (2000) pointed out that retail was an example of Receptive evolution only before the Web. The Blockbuster category involves large upfront risks prior to success. A characteristic of both architectural categories is the first mover advantage, which Radical Organic receives from product and process innovation and Intermediating receives from innovation related to customers and suppliers.

Low and Abrahamson (1997) added an entrepreneurial view to industry evolution. The view involves the development phases of the industry in an organizational context. The phases are Movements (emerging industries), Bandwagons (growth industries), and Clones (matured industries). The Movement phase is characterized by a need for legitimacy, the entrepreneur's ties to several non-overlapping networks, social factors in stakeholder motivation, and innovative strategy. The Bandwagon phase rapidly attracts new competitors, which shifts the focus to resource acquisition. The Clone phase is characterized by intense competition, and evolution is driven by efficiency of execution.

Disruption in industry evolution implies discontinuity which in business often is attached to how value is created. Many of the earlier evolution theories contain aspects that can lead to disruption, but they are not easy to foresee ex-ante; however, disruption seems to be a phenomenon that is an integral part of an economic system. Schumpeter (2008) argued that capitalism can never be stationary and that Creative Destruction is the fundamental engine that destroys existing economic structures by periodically replacing them with new ones.

Dosi (1982) introduced a theory that argues that demand alone cannot explain industry discontinuities and that there are also technological paradigms that function similarly to scientific paradigms. He argued that trajectories are the result of market or technology-based innovations, whereas discontinuities are a result of a new paradigm that also considers society at large in addition to the market and technology. This view is similar to Schumpeter's (2008) view. Tunzelmann et al. (2008) reviewed technological paradigms, and 26 years later, their biometric study showed that Dosi's (1982) argument had evolved into a focal theory on technological paradigms. They also claimed that Dosi's (1982) theory bridged technology-specific knowledge and firm-specific capabilities.

Prescott et al. (2014) defined Industry Convergence as "the blurring of industry boundaries that creates competition among firms, which did not compete with another previously." Several convergence articles are related to the ICT industry. Lee et al. (2010) argued that in advanced countries, the competitive advantage in new economies is highly multidisciplinary and includes scale, scope, expertise, and convergence. They constructed a framework in which the evolution of convergence and organizational innovation had six levels: Product->Functional->Organizational->Technology->Industry->Bio-artificial. Hacklin et al. (2010) called the convergence phases as knowledge, technological, applicational, and industrial phases.

There have been several attempts to design a model that can foresee potential convergence. Fai and Tunzelmann (2001) stated that growing complexity based on patents drives the flow of knowledge from one industry to another and consequently enables convergence. Curran et al. (2010) analyzed chemicals, pharmaceuticals, personal care products, and food and agriculture and concluded that a patent analysis can provide indications of emerging convergence.

Important contributors to convergence include knowledge flow, competence development, and enabling networks. Srinivasan et al. (2007) concluded that vicarious learning is an important contributor for converging markets by analyzing the data of digital photography development. Lei (2000) argued that industry convergence places significant pressure on companies' core competencies as a competitive advantage and that companies should be more alert regarding the development of adjacent industries. The importance of networks was studied by Lee (2007), and he used data from the telecom industry. The framework is shown in Figure 2. His conclusion was that the quality, quantity, and diversity of the information from networks do contribute to timing and rapid entry into the market.

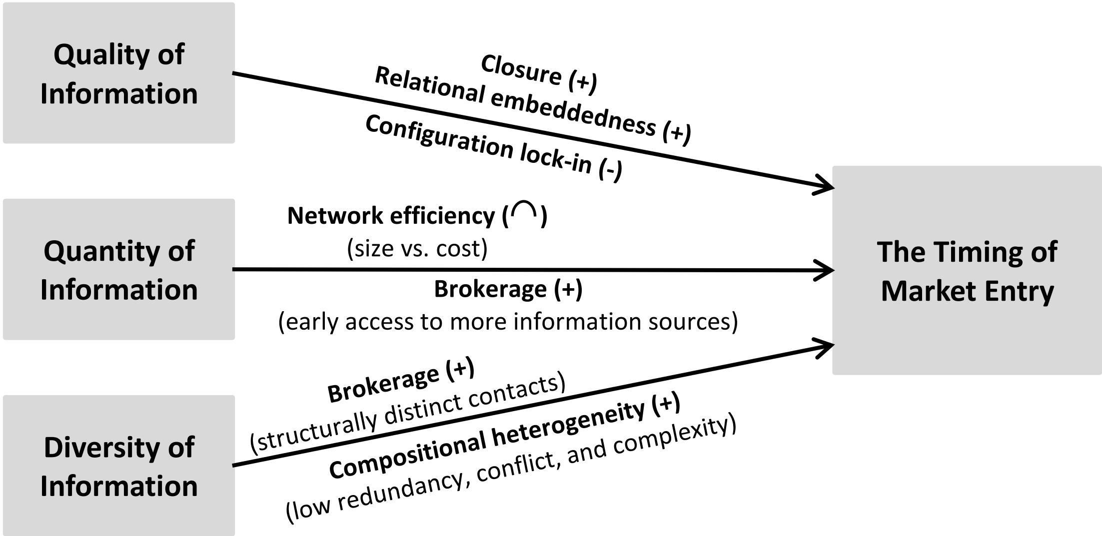


Figure 2. Network resources, mechanism, and expected relationships (Lee, 2007)

The European Union called the convergence of telecommunication, information media, and electronics as TIME industries[5]. Hacklin et al. (2013) argued that drivers for the TIME industry are related to the advancement of technology, open architectures and standards, policy and regulatory reforms, and changes in end-user demands. The view is slightly different according to an earlier article by Gambardella and Torrisi (1998), who studied the electronics industry and concluded that technological convergence does not necessarily imply market convergence, partly due to the large amount of industry or product-specific assets of the existing actors. The difference in these views might be explained by the increasing role of intangible assets that can currently be shared. Benner and Ranganathan (2013) also investigated the telecom industry and studied investors' beliefs and analysts' reactions regarding convergence using data from VOIP technology. Their conclusion was that divergence works more positively with growth-driven investors than margin-driven investors. The finding might indicate inertia in convergence if the investor community behind the potential converging industry is margin-driven. Rao et al. (2006) examined the same industry from a different perspective when they studied the fusion of several disruptive technologies and used Skype as a specific case. They concluded that new business models play an integral role in technology fusion based on disruptive convergence.

[5] http://www. europarl.europa.eu/Jobs of the future require multi-skilling, retrieved 6.6.2016

2.1.3 Disruptive vs. sustaining change

The heading reflects the earlier viewpoints of evolutionary vs. radical (Abernathy and Utterback, 1978) innovation or development targeting a current S-curve or a shift to the next S-curve (Foster, 1987). Christensen’s (2011) book, *Innovator’s Dilemma*, has gained vast popularity among practitioners, and it is often referred to when incumbents discuss the potential impact of digitalization. Schumpeter (2008) and Dosi (1982) discussed industrial disruption, paradigm changes, and discontinuities, whereas disruption alone more often implies radical changes in product-based market positions in business. This does not exclude a pattern that leads to the disruption of industries. Due to its merits in day-to-day management practices, this sub-chapter specifically examines the degree of radicalness using Christensen’s (2011) framework.

The daily activities involved in operating a company and investing in development to maintain a historical competitive advantage requires a significant amount of time and effort from management. The fact that the investment pays off might divert management’s focus away from activities that target disruptive and riskier opportunities. Christensen's (2011) *Innovator’s Dilemma* has gained vast popularity due to its fundamental argument: doing the right thing might still push you out of business. The fact that the theory is gaining more popularity now than 20 years ago could imply that there are a growing number of issues for which the “right thing” has changed; based on this dissertation, the change would be enabled by digitalization. The two core elements of his theory are characterized as follows:

> “***Sustaining technologies*** *have in common that they improve the performance of established products along the dimensions of performance that mainstream customers in major markets have historically valued.”*

> *“**Disruptive technologies** bring to market a very different value proposition than had been available previously and underperform established products in mainstream markets but they have other features a few fringe (and generally new) customers value.”*

Christensen’s framework was based on case research from several industries, i.e., computer disks, steel, and excavators. The cases had a commonality that the good companies provided supplied based on a need expressed by customers, which led to performance oversupply (more features that customers needed). In these cases, the disruption was based on a technology that was simpler, less expensive, and reliable.

The core elements of his theory are shown in Figure 3, which also illustrates that over time, disruptive technology addresses the needs of the high-end market.

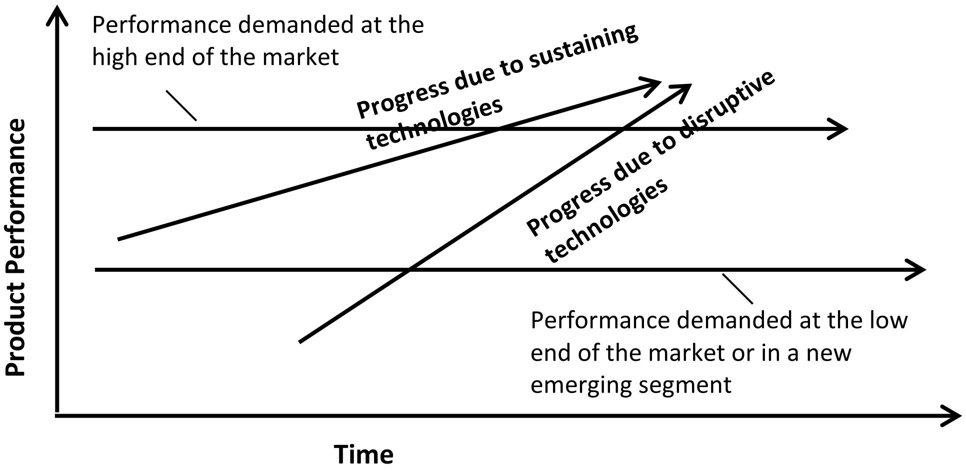


Figure 3. Impact of sustaining and disruptive technological change (Christensen, 2011)

The low-end market customers are not necessarily the same what Rogers (2003) referred to Innovators, or experimental users, as defined by Malerba et al. (2007).

Henderson and Clark (1990) developed a framework that examined the potential failure of incumbents using a concept called Architectural Innovation, which refers to changing the linkages between the product concept and its core components. If the link remains unchanged while the concept is reinforced it is called Incremental Innovation, whereas a discontinuity in the concept refers to Modular Innovation. Changing the link and reinforcing the concept is referred to Architectural Innovation and if there is a discontinuity it would imply Radical Innovation. Henderson and Clark (1990) suggest that "Architectural Innovations destroy the usefulness of architectural knowledge of established firms.", whereas Radical Innovation forms a new Dominant Design. Utterback and Abernathy (1975), who developed the concept of Dominant Design, asserted that there is a time period in a given industry when a firm can apply a dominant competitive strategy based on innovative product design.

Danneels (2004) discussed the definition of Christensen's Disruptive Technology, its assumptions, and its core conclusions. The overall conclusion was that the theory is useful but overly simplistic, and consequently, most of conclusions involved the need for future research avenues. Danneels (2004) pointed out unanswered aspects of the theory, such as:

- When does technology become disruptive?
- Can ex-ante predictions for firm's success be made based on theory?
- Are there other factors in addition to the incumbents that would explain the disruptive impact better?
- Is there a way to model the customer orientation's role in disruptive technology?
- Is separate activity in disruptive technologies the only successful way to address the issue?

Danneels (2004) also argued that the customer-related critique of the theory is not justified as Christensen's view was not against customer orientation. Tellis (2006) followed a similar process in examining the core elements of Christensen's theory and reached a conclusion that is similar to Danneels' conclusion, which is that the theory has become too generic considering the quantity of data it is based on. Tellis (2006) suggested two specific conclusions:

1. The same problem as with Disruptive Technology occurs in the S-Curve technological evolution.
2. The underlying explanation of visionary leadership is not considered.

Markides' (2006) critique of Disruptive Technology was that it was too technology-driven and did not take into account business model innovations, which have different characteristics. Sood and Tellis (2011) argued that disruptive attacks can occur in both low-end and high-end markets and that incumbents introduce disruptions as often as entrants, which are not always less expensive, as Christensen (2011) suggested. Based on the model that Sood and Tellis (2011) applied to four markets (external lighting, desktop printers, data transfer, and analgesics), they reached three conclusions:

1. Disruption takes place from multiple directions.
2. Disruptors do not always introduce disruptive technology.
3. Disruptive technologies do not always follow the S-Curve; the development can be sporadic.

A recent critique by Bergek et al. (2013) challenged both current sources of incumbent targeted disruptions, competence (technology) and demand (market), based on case studies on electric cars and gas turbines. They stated that current industries possess more inertia than current theories suggest. They explicitly argued that Creative Accumulation, a term they used for the concept, requires the simultaneous and rapid fine-tuning of existing technology, the acquisition of new technologies, and the integration of those technologies into superior products and solutions. Indirectly, this would mean that incumbents have better chances to be disruptors than Christensen (2011) suggests, and that sometimes being disrupted might be better explained by the poor implementation by the incumbents than by the Disruptive Technologies theory.

The question of the predictability of Disruptive Technologies was included in Christensen's critique, and there are number of articles that address this question. Linton (2002) modeled the factors that have an impact on whether an innovation is disruptive and used MEMS (Microelectromechanical systems) as a reference, as it has numerous applications and high anticipated growth rates (lowest 60 % over a 6-year period) with a high variance (highest 19900 %). He discussed learning curves, changes in market size, repurchasing, supply constraints, replacement technology, and complementary products. Based on his quantitative model, he argued that forecasting potential disruptive innovations requires each market to be analyzed independently before reaching a conclusion. Linton (2002) also asserted that the inhibitors of supply and demand must be understood to improve the quality of the forecast. Husig et al. (2005) tested Christensen's (2011) concept in making ex-ante predictions on the disruptiveness of W-LAN technology. They concluded that W-LAN would not be disruptive and that the methodology is useful for practitioners because it offers a continuous and systematic way of following the progress of potentially disruptive technologies. Based on their literature review, Govindrajan and Kopalle (2006) argued that technology-based disruption models are not effective in making ex-ante predictions for potential disruptive technologies but that they provide good frameworks for ex-ante predictions regarding which type of firms could develop disruptive technologies.

Technology strategies and technology roadmaps have been used by management for future technologies as part of the overall strategy of firms; however, the principle question regarding whether or not disruptive technologies can be predicted remains. Walsh (2004) combined the road mapping tool and disruptiveness, and MEMS was used as a reference technology. Figure 4 presents the components of the factors needed for roadmaps.

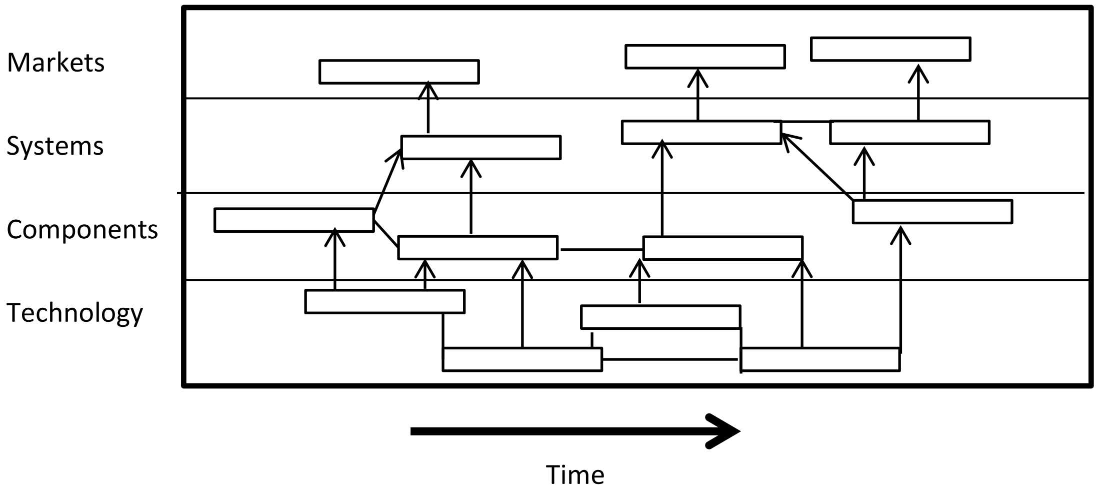


Figure 4. Multitier visual output of a technology roadmap (Walsh, 2004)

The road map illustrates a systematic process based on a framework comprised of existing theories, expert judgment, and data. The process provided 15 conclusions, and the framework and process were argued to be useful (Walsh, 2004). The framework includes links between components and systems that were slightly different than those presented for Architectural Innovation by Henderson and Clark (1990). Walsh (2004) highlighted the need for a wide coverage of stakeholders in the process to avoid entrapment by Sustaining Technologies. Kostoff et al. (2004) presented similar findings, but their view was more process-oriented and also included stakeholder participation and workshop procedures. They emphasized the potential offered by text mining as a new technology-based tool (Kostoff et al. 2004).

The lack of competence of the incumbents in relation to Disruptive Technologies is one critique of Christensen's model. Henderson and Clark (1990) suggested that Architectural Innovation destroys the existing knowledge of incumbents. Danneels (2004) discussed the issue indirectly when investigating the need for separate organizations for Disruptive Technologies. Henderson (2006) argued that incumbents' weaknesses regarding disruption are not only explained by cognitive failures of top management but also by a lack of technological and market-related competencies. Garrison (2009) also analyzed the competence perspective of Disruptive Technologies. He concluded that a response capability is critical in the early adaptation of Disruptive Technologies and that smaller firms tend to do this better. Garrison (2009) related this response capability with the technologically opportunistic business culture of a firm.

Christensen has extended the original theory several times since 1997, and in his paper (Christensen et al.) published in 2002, he pointed out that core requirements in applying the theory are the ability to make the distinction between Sustained and Disruptive technologies or ideas as well as to manage them differently. One of the Christensen original claim (2011) for incumbents' weakness to detect disruptive business ideas is that they appear to be marginal for the faith of the company in the early stage. Christensen et al. (2002) also discussed the fundamental aspect of repeatability, which would require a separate process for disruptive ideas, as they are difficult to accomplish. They explained that one of the few companies that has provided an array of disruptive innovations is Sony. Wessel and Christensen's (2012) recent article included business models in the disruption discussion, which addressed prior criticism. They also concluded that inertia limits disruption and outlined five barriers:

- Conservative customers
- Difficult technological implementation
- Lack of proper ecosystems
- Immaturity of the technology
- An unchangeable current industry cost structure

Wessel and Christensen (2012) posited that the advantage of disruptive innovations must be realistic, rather than trying to break inertia that is based on natural reasons, such as ships carrying heavier cargo than planes.

2.2 Economy, strategy formation and top management teams

Stakeholders, and other factors that form the external environment of a firm, have been discussed in relation to industry evolution. In the value chain, enablers, actors, and users' strategic actions also direct the course of future development. The actions are based on management decisions. This sub-chapter reviews the literature on strategy formation and top management teams. First, a few perspectives regarding the aspects of economics in digitalization and knowledge-based businesses are briefly presented.

2.2.1 Knowledge based economy

The fundamental factors of production—labor, raw materials, and capital—will inevitably be involved in machine-building in some form. Firms in the machine-building industry's value chain also continue to maximize profits to compensate owners through dividends and to invest the remaining profits in the firm for future profits. The profit is made using the factors of production with innovative methods and procedures to deliver products and services to customers, and the price is dependent on the competition in the market. Digitalization allows for increasing value, which is delivered in intangible forms. This is a shift toward a new type of knowledge-based business. Digitalization allows also knowledge workers to participate in value creation independent of their location and at least partly independent of whether they work as private entrepreneurs, in startup companies, or in multinational corporations.

The World Economic Forum (2015) introduced a concept of Output Economy, that utilizes smart connected devices, and as a result, enables optimization on a higher systemic level, whether it involves energy saving or improved health. This also expands the concept of products and services. The Outcome Economy concept is illustrated in Figure 5. The concept was presented as a roadmap to the Industrial Internet, but it also reveals that the higher the development stage, the less dependent the value creation is on the original factors of production, except of the knowledge workers if they would be defined as labor in the original context.

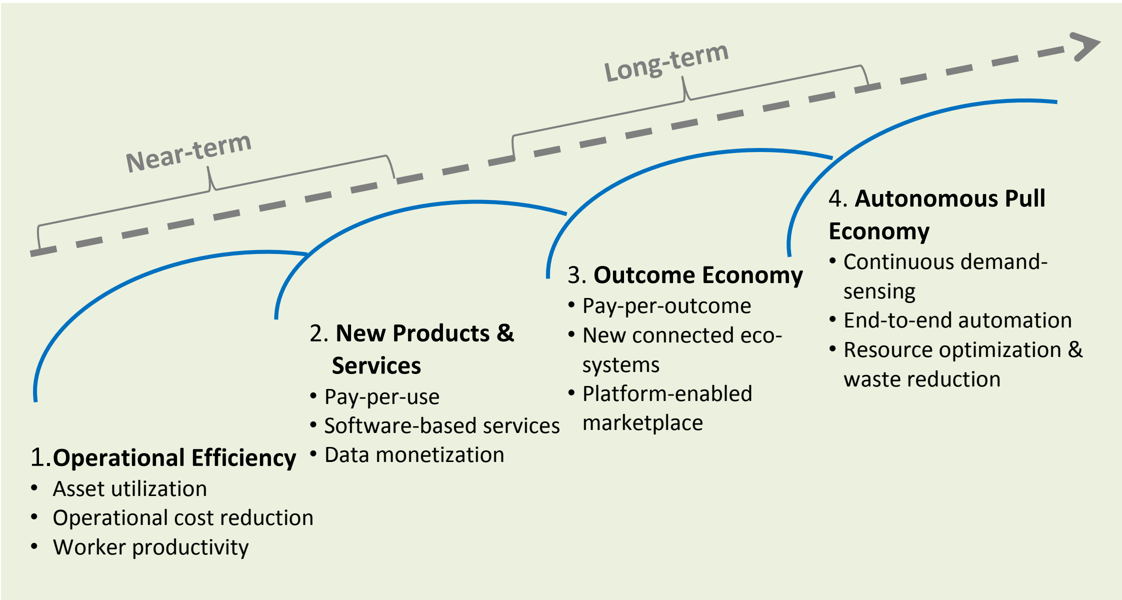


Figure 5. Outcome Economy concept (World Economic Forum, 2015)

Because an increasing amount of value in digitalization is based on processing knowledge, a resource-based view on economics is crucial. Conner (1991) studied the topic in the context of an industrial organization economy and identified five schools of economy: Perfect Competition, Bain, Schumpeterian, Chicago Responses, and Transaction Cost. By analyzing those against what was known on resource dependency, she concluded that:

> "*Performance differentials between firms depend to significant measure on possession of unique inputs and capabilities.*"

She highlighted the importance of capabilities in collaboration with Prahalad (Conner and Prahalad, 1996) by arguing that privately held knowledge is a focal source of the competitive advantage of a firm. In the digital era, both privately held resources and transaction-based fundamentals are challenged. Crowd concepts push the limits of firm-centric resources.

The transaction economy is also challenged by a sharing economy, or open source movement, in which contributors might have hedonistic, intellectual, social, or other similar motives that cannot be explained by rational economic theories. In his book *Managing in the Next Society*, Peter Drucker (2002) emphasized cognitive science and posed a question to firms: how are knowledge workers attracted? A mismatch of firms' values has resulted in some knowledge workers remaining independent and applying their own values in open networks, which was the case in the Linux movement.

Uber and Airbnb popularized the sharing economy discussion based on the financial benefits of asset sharing. Belk (2010) studied sharing and made a distinction between sharing, gift giving, and commodity exchange. He also argued that a powerful driver in a sharing economy is the changing attitude toward ownership. Sharing in B2B is not new; shipping lines have shared vessel capacity between competitors for years; however, sharing in B2B is more similar to a transaction economy, as it is based on contracts that reserve capacity. For consumers, sharing seems to be driven by platform businesses that act as marketplaces that contain the information needed for sharing to be effective. Ownership issues were also examined when Bardhi and Eckhardt (2012) investigated sharing in the context of passenger cars in the Zipcar case. They defined Access Based Consumption as "transactions that can be market mediated but where no transfer of ownership takes place" (Bardhi and Eckhardt, 2012). They also concluded that market-mediated sharing eliminates the social reciprocity aspect. John (2013) analyzed the rise of sharing Web 2.0 not only from an economics viewpoint but also based on its societal impact. Sharing ideas, which is enabled by information networks, is also a growing phenomenon. The platforms are reviewed in sub-chapter 2.3.1, and the open innovation paradigm is reviewed in sub-chapter 2.3.2.

A final note on economics is that the division for B2B and B2C is also blurred by industry convergence. Fifteen years ago, Achrol and Kotler predicted (1999) that a network economy would have similar consequences for B2B as it has had for B2C.

2.2.2 Strategy formation

Firms should answer the type of research questions of this dissertation as part of their strategy formation. Whether digitalization will enable industrial disruption should be determined based on that process, and whether to ignore, adapt, or become a disruptor should be determined based on external opportunities and internal capabilities. Management typically uses explicit tools in its strategy formation, or at least post-ante it can likely be concluded that there was a certain type of strategy thinking utilized to reach conclusions and make decisions.

The tools are often derived from particular strategic thinking or strategic schools, and therefore they logically reduce the perspective to that of the premises of the strategy tool.

Business environment is not stable, which would imply that schools and tools are also to a certain degree of temporal. The selection of tools might also impact the actual strategic choices. In this dissertation, the schools and tools are reviewed based on potential disruption enabled by digital technologies. Value chain and process thinking, industry beliefs, and business models are reviewed in this context in their own sub-chapters.

Strategy can be analyzed from a corporate or a business perspective. Corporations often approach the strategy from an owner's perspective, including visions, missions, values, portfolios (which businesses they are in), financial structure, performance management and organizational structures. If the corporation operates in multiple businesses, they have to design the roles between the corporate and businesses as well as the themes they wish to drive across businesses. Corporations must prove that they are more than the sum of their parts. Collis and Montgomery (1998) suggested that resource allocation (general vs. specialized) can be utilized to analyze this, which takes into consideration the scope of the business, coordination mechanisms, control systems, and the size of the corporate office. Businesses must make choices regarding how they create value by serving their customers better than the competition, which often includes decisions on markets, customers, products, and services. In addition, cost vs. value, required capabilities, and numerous functional statements, such as distribution and production models (owned or outsourced), should be considered. Strategy is also a process that involves a varying number of participants of the organization or the participation of stakeholders. Minzberg and Lampel (1999) discussed the evolutionary nature of the process due to learning, borrowing, and blending new with old in the competition in evaluating new ideas. It is also known that planning without communication and implementation does not yield the expected results.

There are number of articles and books that have discussed the different perspectives or schools of strategy. Several of the schools evolved based on a theory of a scholar or a framework of practitioners. Minzberg et al. (1998) listed 10 strategic schools: Design, Planning, Positioning, Entrepreneurial, Cognitive, Learning, Power, Cultural, Environment, and Configuration. Cummins and Wilson (2003) distinguished 13 different perspective of strategy: Ethos, Organizing, Intention & Anticipation, Orchestrating Knowledge, Data and Sense-Making, Creativity, Exploration & Interconnection, Systems Thinking, Process-Power-Change, Marketing, Numbers, Decision Making, and Orientation & Animation. De Wit and Meyer (2005) framed strategy into Process, Content, and Context. Content includes strategic thinking, formation, and change. Näsi and Aunola (2002) used a framework in which strategic logic included four perspectives: Strategic Management and Strategic Management of Structures are administrative in nature, whereas Strategic Game and Strategic Leadership are situational and environment-driven.

The 10 schools by Minzberg et al. (1998) comprise a comprehensive framework that combines strategic thinking and strategy formation, and it is used here as a framework to review respective theories. A number of strategic tools are placed inside of the schools and some of them are developed later than Minzberg et al. (1998) published their framework.

The Design School requires understanding the external environment in relation to a firm's internal capabilities, and therefore the SWOT (internal strengths and weaknesses and external opportunities and threats) tool is included in this school. This school also highlights the architectural and conceptual character rather than the form, as the name suggests. Humphrey (2005), one of the developers of SWOT, underlined the importance of formal planning when using the tool in his retrospective description. Minzberg et al. (1998) argue that the Design School has been one of the most used one by practitioners in strategy formation. Chandler's assertion (1990) that structure follows strategy fits to the philosophy of this school. Case methodology has a strong link with this school as well.

The Planning School emphasizes the formal planning process. Planning as a discipline is familiar in engineering or product development in which structures, hierarchies, processes, checklists, iterations, and reviews are used daily. If top management has a focal role in the Design School, detailed planning implies a greater role for planners, and the management role shifts toward an approval role. Minzberg et al. (1998) refer Igor Ansoff as one of the important pioneers in this type of strategic thinking.

The Positioning School assumes that based on analyses, an optimal strategy with generic characteristics can be chosen. BCG matrix is a prime example of that. Using the BCG matrix (Henderson, 1970), businesses are analyzed based on the growth of the market in relation to the market position, and depending on the status of the business in the portfolio (matrix), there is a specific optimal generic strategy available. Later Porter's (1985) generic strategies of cost focus or cost leadership and differentiation or differentiation focus became almost the industry standard. Ansoff's product / market window (Ansoff, 1957) is however a good example of a tool that can be applied with logic of Design, Planning or Positioning School. In that model product or market could be either existing or new and the model was designed for diversification strategies. The analysis, market attractiveness, and choice of generic options phases comprise an integral part of this model, and therefore it can be argued that it belongs to this school. The bestseller *Must-Win Battles* (Killing et al., 2006) can be included here due to its analytical process coupled with generic advice, although it has characteristics of the Design School (external opportunities vs. internal capabilities).

The Entrepreneurial School is based on visionary leadership, and according to Minzberg et al. (1998), it can also be defined as strategic thinking by seeing through (behind, above, below, beyond, ahead, and beside). They also connected this to the Schumpeterian (2008) view of entrepreneurialship in economics. This type of person-centric and intuitive strategy formation has been linked to corporate leaders, such as Jack Welsh, and owners of entrepreneurial companies, such as Richard Branson of Virgin and Steve Jobs of Apple. In the digital domain, Eric Ries' *Lean Startup* (2011) has become an important handbook. The attributes of entrepreneurial management and intuition in the development of this handbook could place concepts such as the Minimum Viable

Product in the Entrepreneurial School, but Ries' (2011) focal element of continuous learning would suggest that the Learning School would be an equally justified interpretation.

The Cognitive School is different from the other schools because it focuses on strategists' mental processes. The role of the Cognitive School in this dissertation is related to management cognition as one sub-driver that can explain the inertia or acceleration of drivers that cause industrial disruption. Therefore, management cognition is reviewed in more detail in sub-chapter 2.2.3.

The Learning School involves the connotation of capabilities and strategy formation. The Core Competence of the Corporation article by Prahalad and Hamel (1990) is one milestone of that school. They defined Core Competencies as "collective learning in the organization" in integrating diverse production skills or multiple technologies as well as organizational value creation. This implies that resource development is a vital task of top management. Conner and Prahalad (1996) shared a similar view regarding resource dependency in a knowledge-based economy. Minzberg et al. (1998) included the perspective of rule breaking and ignoring industry beliefs as characteristics of the Learning School, although this visionary attribute could also be included in the Entrepreneurial School. Rule breaking is mentioned in the principles of Hamel's (1996) strategy formation: "If there is any hope of industrial revolution, the creators of strategy must cast off industrial conventions." The same concept was discussed in Kim and Mauborgne's (2005) *Blue Ocean Strategy* (reconstructing market boundaries) and the *Business Model Generation* by Osterwalder and Pigneur (2010). Unlike Hamel (1996), who emphasized resources, Kim and Mauborgne (2005) and Osterwalder and Pigneur (2010) both highlighted the process. Osterwalder and Pigneur (2010) developed later their thinking into the Business Model Canvas, which is their trademark in this decade's strategy tools.

The Power School suggests that strategy formation is a political process. Although there are elements of political compromises in the strategic processes of firms, perhaps with the exception of the Entrepreneurial School, this school emphasizes observation rather than a set of tools for practitioners. Due to the external compromises, the school is related to the stakeholder theory (Freeman, 2015). Minzberg et al. (1998) discussed the role of strategic alliances in this school; however, it can be argued that forming alliances is one strategic choice regardless of whether or not the risk of compromises increases.

Minzberg et al. (2010) stated that the Cultural School is based on the concept that strategy formation is also a social process. For effective results, the cultural aspects of participants must be understood and considered. For competence or resource-based views, there is a stronger need to manage the cultural dimension as well, as discussed previously; however, it could be argued that managing cultural dimension is not only relevant in strategy formation but also in all leadership or stakeholder relations. The national culture poses a dimension of its own in the international business environment. The cultural aspect is related to this investigation in the same way that management cognition is related, which will be reviewed in sub-chapter 2.2.3.

The Environmental School reduces strategy formation to a responsive role. The fundamental belief is that there are a number of general forces that affect strategy formation; however, firms cannot influence them. Minzberg et al. (2010) listed population ecology as one of the main sources of strategic thinking. During the investigation of this dissertation, it was assumed that digitalization is a systemic phenomenon that has an impact on knowledge creation. If this assumption is correct, then no firm or group of firms could change it. As a critique to a passive response, the premise would still be generic enough to allow for successful strategy formation.

The Configuration School is a temporal dimension of the schools. It presents different models of organization based on the premise that their use is situation-driven, which is similar to Chandler's (1990) assertion. As moving from one organizational ideal to another is a laborious process, Minzberg et al. (1990) presented several examples regarding transformation or change management for this school. Thus, in this dissertation, the aspects of the Configuration School are similar to management and leadership, which are reviewed in sub-chapter 2.2.3.

Minzberg et al. (1990) classified their schools in two different ways. First, they classified Planning, Design, and Positioning Schools as Prescriptive Schools, and the remainders were classified as Descriptive Schools. Then, they illustrated the activities based on publications and management attention over time. The Prescriptive Schools had a medium level of support due to the introduction phase in the early 1970s. The Planning School was popular from the mid-1970s to the mid-1980s when the Position School gained popularity over the declining Planning School. The Descriptive Schools have had growth activity since their respective introductions, but the Learning and Configuration Schools experienced increased growth. The Configuration School might not be comparable because it is considered to be a temporal hybrid of the other schools. Another synthesis method involves placing the schools in a matrix where the predictability of the external environment is the y-axis, and the x-axis represents the rationality of the internal process. The synthesis is presented in Appendix 1, and the main conclusion is that the extreme unpredictability and natural internal processes are characteristics of the Cognitive and Learning Schools.

The analysis of strategic schools by Minzberg et al. (2010) did not discuss all major tools used by practitioners. All schools have some type of implicit or explicit assessment as part of the strategy formation, and tools such as the Key Success Factor based analysis and planning by Daniel (1961) or the popular Balanced Scorecard (Kaplan and Norton 1992), which combined customer perspectives, business objectives, and development plans with financial measurement, played or still play a role. Also, specific frameworks for holistic strategies, such as 7S (Structure, Systems, Style, Staff, Skills, Strategy, and Superordinate Goals) by Waterman et al. (1980) have been useful without being strongly linked to a certain school, which is the case also with purpose-built models, such as the Repeatable Model (Zook, Allen 2012), for exploring growth opportunities based on the current core of a firm. Rigby and Bilodeau (2005) conducted a management tool survey and found that tools are temporal and have different strengths and weaknesses, and they also recommended that tools be adapted to the situation of the firm. This would imply that the tool selection can affect the outcome negatively if the incorrect tool is chosen. The same study (Rigby and Bilodeau 2005) revealed that at the time of the research, innovation was a vital element of corporate success but tools for senior management were not up to par, whereas the most effective tools were available for strategic planning.

This dissertation investigates disruption or paradigm changes in lieu of quantum leaps in market positions or continuous improvement. Digitalization is described as a systemic phenomenon. This would locate the enquiry in the place of the framework (Appendix 1) where the external world is uncertain and complex, and the internal process is closer to natural than rational. Based on the framework, this would suggest closeness to the Learning School, and that cognitive and cultural factors should be considered.

2.2.3 Top management team

Management plays a central role in strategy formation, which was discussed in the previous sub-chapter, and it plays an equally important role in the implementation of strategies. This sub-chapter focuses on the soft perspectives that might impact strategy formation and implementations, such as culture, values, and leadership, as well as more tangible aspects, such as structure and governance. If the assumption of complexity and uncertainty is correct, strategic choices do carry more weight. Was Kodak's failure to see digital photography (Lucas and Koh, 2009) linked to culture and leadership, or is Christensen's (2011) *Innovator's Dilemma* in which success in sustaining technologies prevents incumbents from identifying emerging disruptive technologies connected to the mental models of management and organizations?

Culture and values

There are cultural aspects linked to firms as well as to the society or country to which the members of those firms belong. The same applies to the values of the firms' vis-à-vis the values of the individuals who work for those firms. Schein (2009) defined culture as "a pattern of shared tacit assumptions that was learned by a group as it solved its problems of external adaptation and internal integration that has worked well enough to be considered valid and, therefore, to be taught to new members as the way to perceive, think, and feel in relations to those problems." The practical test for the inquiry of disruption or paradigm change is whether a firm is risk adverse or not. Hofstede et al. (2010) defined culture as a formation of stacked layers in which the inner layer is values and following layers are rituals, heroes and symbols. Practices cut the stacks across and they are visible to external observers, but their cultural meaning is only understood by the insiders.

It is rare that multinational corporations have monolithic cultures, as they are often formed by acquisitions, and thus they inherit the cultures of the acquired companies in addition to the variances of local cultures and customs of the countries and locations in which business entities operate. The influence of top management on culture is questionable. A strong wave of corporate culture took place at the same time that Japanese companies began to succeed globally based on quality, which was not only a result of methods but also of a strong corporate culture of quality. For this dissertation, the cultural question is partly related to corporate comfort zones. Schein (1984) pointed out that anxiety reduction in corporations is a more stable phenomenon than positive problem solving with innovation, which is a fundamental part of human nature. Hofstede et al. (2010) identified four relevant business dimensions that had cultural differences: power distance, collectivism versus individualism, femininity versus masculinity, and uncertainty avoidance. The premise of the movement was that culture was stronger than written strategy and that there was a causal relation between corporate culture and performance. Barney (1986) concluded that organizational culture can be a sustainable competitive advantage if it is valuable, rare, and difficult to imitate. Corporate culture was harnessed in the late 1980s and early 1990s as a management tool to build a desirable culture. This took place at a time when globalization accelerated, and corporations began to increasingly deal with issues of managing people with diverse cultural backgrounds. Schein (2009) pointed out the importance of subcultures, which stem from mergers and acquisitions, globalization, technological complexity (occupational cultures), and opportunities offered by information technology.

Based on their research, Tellis et al. (2009) stated that the flattening world has diminished national factors on radical innovation, but the importance of internal corporate culture is strong. Recently, Google's attempt to maintain a start-up type of innovation culture by allowing employees to devote 20 % of their work time to individual projects is a well-known example. The top management vehicle often involves a change program towards the desired culture, whether it is an innovation, performance, quality, or safety culture. The time required to accomplish this often exceeds the allotted time of the program. In the midst of the corporate culture boom, Beer et al. (1990) discussed the reason that change programs do not produce change. Their conclusion was that the majority of the programs began from the top and targeted changes in attitudes, whereas the focus should have been on tasks, roles, responsibilities, and learning.

Hofstede et al. (2010) defined values as "broad tendencies to prefer certain states of affairs over others and continued by stating that values are also feelings with an added arrow indicating a plus or a minus side and deal with pairings like moral versus immoral."

Based on the literature review, Schwartz and Bilsky (1987) stated that the definition of values has five common features:

> "Values are (a) concepts or beliefs, (b) about desirable end states or behaviors, (c) that transcend specific situations, (d) guide selection or evaluation and (e) are ordered by relative importance."

As with culture, there is a justified question regarding the extent to which top management can impact the values of a firm as well as how quickly it can be accomplished. In family-owned companies, the owners logically have more impact and say regarding values. Value definition played a similar role in firms as corporate culture but more than 10 years later. While the initial proposition was to create an innovative corporate culture, innovation was eventually listed as a corporate value. A similar challenge in multinational companies also occurred: corporations might be formed as a result of multiple acquisitions, and they operate in several countries. One can separate two extremes when defining the company values: synthetic aspirational values vs. defining underlying values based on the company's evolution. A detrimental case occurs when the written values contradict the behavioral values. One example is public punishment for mistakes when the firm claims that experimentation is a core value. The role of culture and values in this dissertation is a potential sub-driver for some of the forces that drive or inhibit industrial disruption that is enabled by digitalization, and an experimental culture is an example of an accelerative sub-driver.

Structure and governance

Structure has been briefly discussed in strategy formation. In large firms, corporate strategy often defines the structure and governance as well as the role of the corporate office, as stated by Collis and Montgomery (1998). The strategy schools include differing views of the role of structure. "Structure follows strategy" by Chandler (1990) is a different concept from the resource-based strategy scholars use. In all cases, the board of directors and top management also play a formal role in the firm, which is governed by company laws, and the roles vary depending on whether the firm is publicly or privately owned.

The size of a firm and its complexity most likely has an impact on the optimal governance model. There are also managerial limits that impact performance. Penrose (1995) discussed this in his book, and his view can be interpreted as arguing that the limit is only temporary, as top management ultimately determines its organization's structure and who it wishes to hire based on experience, competence, or personality. Booz-Allen and Hamilton (Kocourek et al. 2000) offered corporations four different types of governance choices: holding, strategic management, active management, and operationally involved.

The organization design to create value in firms varies. Line vs. staff is a familiar concept in the military; functions in firms' are normally discipline-based. Process and matrix organizations are both hybrid versions of a straight forward line organization. Network economy has blurred the boundaries of internal and external organizations. Organizations are also normally hierarchical and divided into groups, divisions, lines, departments, and teams, and the extent of the hierarchy correlates with the size of the organization. The type of business (consumer, industrial, service, global, local, project, and multi vs. single product) that the firm is in, also impacts top management's optimal choices regarding how to organize.

The examples presented are practical examples to address the question regarding how firms should be organized rather than an exhaustive review of organizational theories. The question that is related to this investigation is whether organizational preferences are connected to potential disruption. Based on research by Charitou and Markides (2003), 68 % of firms that engaged in disruptive strategic innovation activities did so in a separate unit. Corporate labs, for example, normally do not have the responsibility of commercialization. In the current millennium, and specifically due to the unprecedented success of startups, there is a new renaissance for corporate ventures. The Finnish ICT Corporation Tieto is a prime example. This corporation established an internal startup in 2014, and the CEO Kimmo Alkio discussed his rationale:

> "The objective is to break boundaries, change operational clock speed, get closer to customers and speed up decision making."[6]

Establishing a separate organization with disruptive activities implies that there is an assumption of a potential disruption or that the firm wishes to be a disruptor. Using an internal organization or external networks relate to the operational model of the firm. Use of external networks, which are discussed in the sub-chapters 2.3.1, Platforms, and 2.3.2, Open Innovation, can also include a notion that external networks can yield more novel ideas than the internal resources of the firm is able to provide.

Leadership

Visionary leadership is a characteristic of the Entrepreneurial School of Minzberg et al. (2010). An organization can have a leadership culture, and managers can be referred to as great leaders, such as Steve Jobs, though his leadership style was criticized. Leaders manage other people and therefore have an impact on firms or society at large. Leadership was also discussed by Sun Tzu (1963) or Machiavelli (2003). The Oxford Dictionary generically defines leadership as "the action of leading a group of people or an organization, or the ability to do this,[7] which connects leadership to personal competencies. Large organizations typically train management in leadership. Perhaps the most widely used equilibrium of leadership styles in business is autocratic vs. demo-

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[6] Tieto CEO Kimmo Alkio in Kauppalehti 23.2.2015
[7] http://www.oxforddictionaries.com/definition/english/leadership, retrieved 10.6.2016

cratic. Tannenbaum and Schmidt (1958) discussed this equilibrium as well as the need for situational aspects of the styles. They concluded that the difficulty of right style in right situation lies in the inner forces of the leader: the value system, confidence in subordinates, personal leadership inclinations, and feelings of security in an uncertain situation.

There are several other typologies available, and Westley and Minzberg (1989) divided visionary leadership into creator, proselytizer, idealist, bricoleur, and diviner. The visionary attribute is often related to the novelty of the actual strategic choice, whereas leadership styles can be related to the way that the strategy is implemented. Child (1972) discussed leadership aspect based on his dominant coalition concept and its power over the structural design of an organization when making strategic choices. A dominant coalition generally refers to top management, but in extreme cases, it can refer solely to the leader. In a turbulent environment, leaders manage uncertainties by simultaneously implementing incremental improvement and transformation (Tushman, 1997).

Deschamps (2005) analyzed the necessary leadership skills in the context of the type of innovation strategy applied by a firm. The model is presented in Figure 6, and transformative innovations, that digitalization might enable, can be placed in the top right corner, as it is systemic and often includes external partners. According to Descamps, this leadership style refers to a "pragmatic architect" who envisions a new system and also understands the components and their relations as well as how to accomplish the goal when some of the critical knowledge is outside of the firm's borders. Moore (2005) defined innovation categories based on product leadership, customer intimacy, operational excellence, and category renewal. He also pointed out that the required leadership style varies based on the category. Moore (2005) expanded the thinking into two categories: the core – your unique source of competitive advantage and context– everything else. He stated that core becomes context over time, and the benefit of a startup is that the focus is predominantly on the core. He also stated that context creates harmful inertia for renewal, and consequently, the leadership challenge is to recognize and prevent it.

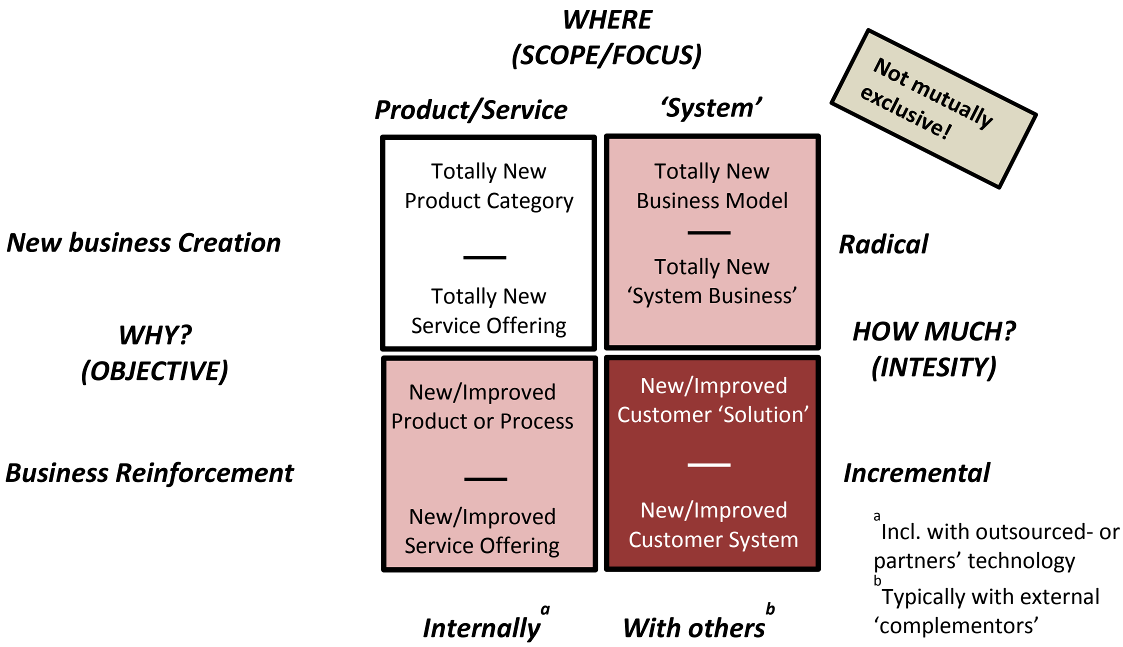

Figure 6. Typology of innovation by strategic focus (Deschamps, 2005)

Managerial Cognition

In strategy formation, cognition is a characteristic of the Cognitive School by Minzberg et al. (2010). It was concluded that it does not provide an explicit view on strategy but rather a group of theories that explain management decision making. This is particularly important if it is assumed that during emerging disruption or paradigm change, decision making is more difficult. One of the salient theories that explain management choices was presented by Kahneman and Tversky (1979), who challenged the utility theory's assumption that gains and losses work the same way depending on the state of wealth by introducing the Prospects Theory. Empirical data showed that utility curve is steeper for losses than for gains. Kahneman and Tversky (1979) introduced a weighting function to the formula that includes both probability and desirability; they also concluded that with very low probabilities, events are normally ignored, whereas very high-probability events are regarded as certain. The reference point also plays a major role in the context of digitalization. For instance, firm A would base their decisions on the actions of main competitors B, C, and D, and a small gain is perceived as a victory, even though it would fall behind the digital development of company X in an adjacent industry.

Intuition has been studied extensively in decision-making theories, and it can be assumed that strategic choices are common decisions for senior executives. Simon (1987) stated that in a management context, intuition is similar to professional judgment, and intuitive decision-making seldom takes place without an analytical process. Kahneman (2011) discussed the dilemma of intuition vs. analytical / rational in the context of fast and slow thinking using a vast number of examples, such as hindsight inadvertently distorting objectiveness. Another important contributor is framing, and Kahneman (2011) illustrated that a factually identical situation might lead to a different judgment based on framing. Rosenzweig (2007) argued that causality, which is often simplified, is an important source of management delusion.

According to Webster,[8] the world view is "a comprehensive view of the world and human life," and it could be argued that a world view of digitalization is still developing. Most likely, there are already strong "world views" that might be diverse or even polarized. This could also be the case in the long-term; Starbuck (1982) stated that no organization has a complete monolithic ideology, and even individuals can have multiple ideologies and still act logically. Smircich and Stubbart (1985) discussed whether the interpretation of the environment by a strategist is objective or perceived, a concept of the Enacted World, and they stated that "environments are enacted through the social construction and interaction processes of organized actors."

Simon (1979) viewed rational human behavior as subject to major boundaries of the environment as well as to the capacity of human beings (Bounded Rationality). Later, Simon (1991) also pointed out that the same mechanisms are relevant for organizational learning. One factor that reduces the rationality according to Kahneman (2003) is Judgment Heuristics, which causes the decision-maker to use a limited number of heuristic principles when solving complex problems. According to Kahneman, this is useful but can lead to systematic errors.

Stubbart (1989) divided managerial cognition into categories, networks, and inferences. He argued that the categories included experiences that are prerequisites for human cognitive abilities. Strategic schools of the previous sub-chapter serve as a good example of such categorizing. Stubbart (1989) also argued that the categories used by managers differ from those used in management science and also differ between managers. One of the issues raised was that managers' cognitive maps are flawed due to

[8] http://www.webster-dictionary.org/definition/worldview, retrieved 15.7.2015

excess causality or because they are based on strategic concepts that are too abstract. In Stubbart's (1989) article, managerial inference was based on rationality, heuristics, and expertise; he used integrating of information from a SWOT analysis to strategy formulation as an example of a cognition problem.

2.2.4 Value chain and process thinking

Value chains play a pivotal role in this dissertation from three perspectives. First, they are unbuilt into the research question where potential industry disruption and its drivers are analyzed separately based on the view of enablers, actors and users. Second, the value chain plays a central role in Porter's Five Forces (1979), which is a seminal theory of industry dynamics. Third, industrial companies have included value chain perspective as part of their strategies, operations, and development activities for decades.

The value chain is another popular concept developed by Michael Porter that yielded a large number of citations even 30 years after it was introduced in his book *Competitive Advantage—Creating and Sustaining Superior Performance* (1985). Figure 7 describes his concept in which directly added value activities are called "primary activities," and activities that enable the direct activities are called "support activities." If value chain thinking is a successful concept in operational improvements in businesses, then can the same concept create inertia in a potential emerging paradigm change?

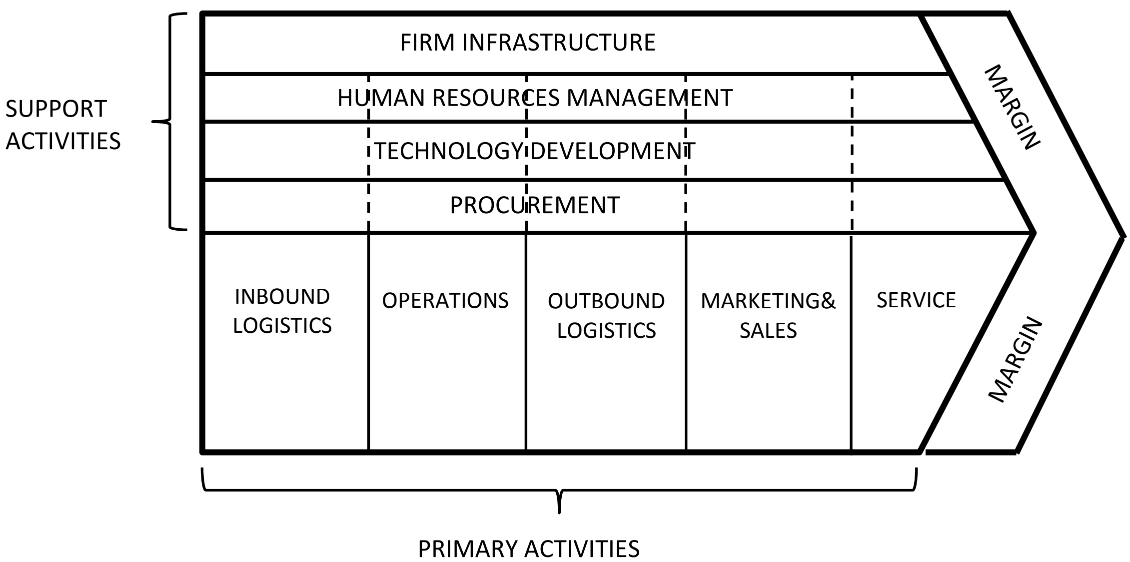

Figure 7. Value chain (Porter, 1985)

Porter's value chain (1985) was publicized at the same time that total quality management began to flourish. The English translation of Ishikawa's (1985) *What is Total Quality Control? The Japanese Way* was a milestone in which the philosophy of breaking functional silos and focusing on processes took place ("the next process is your customer"). Value chain thinking was also rooted in the business process of re-engineering and process management. Hammer stated (1990) that one must rethink the way different phases are completed in the process. In essence, it calls for a quantum leap in processes but very seldom is a source of renewal in company strategies or at the industrial level; however, there are notable examples of supply chain innovations that changed the industry practices, such as the well-documented Dell case in the computer industry. Lee (2002) commented that Dell's success was based on their highly modular product structure, their build-to-order concept, and the ability to maintain a stable process in a highly unpredictable demand of innovative products. Process management was revitalized due to large enterprise systems, as consultants introduced a practice in IT projects in which the first phase was a description of a current process ("as is") followed by an aspirational "to be" process. This practice included an intrinsic logic of improvement.

In the development work of a firm, value chains and process thinking are combined with decision making in Cooper's gate model. Cooper (1990) stated cycle time reduction and improvement of hit ratios as drivers of the philosophy of gate systems in innovations. For example, the project can only progress to the next phase after the gate approval, but the goal of the system was a stronger market analysis in the early phases. Critique for the gate model involves the easy termination of a project, especially in large organizations in which there are large numbers of staff resources to evaluate proposals. This can proportionally increase incremental innovation that has a higher success rate but a smaller upside. Veryzer (1998) contended that the gate model is not the optimal approach to discontinuous innovation. The software industry challenged the sequential concept of gate systems in development for the same reasons that Cooper originally presented—time and hit ratio—by introducing the agile manifesto[9] in 2001, which included the following principles:

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation

[9] http://agilemanifesto.org/ retrieved 10.6.2016

- Responding to change over following a plan

The manifesto led to various methods, such as Scrum. The unique feature of Scrum (Schwaber and Beedle, 2002) compared to the gate model is Sprint, which is a predetermined period that is less than four weeks. The Scrum team develops a product or feature in the Sprint that meets the requirements and is ready for publishing. Another unique feature of Scrum is the retrospective phase, which is a session to evaluate the work of the team and present improvement ideas before the next sprint. Sprint retrospective can last a maximum of three hours.

Recently, several radical value chain and process innovations have been enabled by digital technologies, and some were coupled with a business model change. This has occurred both in primary and in support activities or processes. Digital entertainment is a good example in which the process of satisfying a need, such as listening music, has been reinvented—downloading files instead of buying records or CDs from a shop. If a firm can deliver their products or services through digitalization, legacy systems are still a challenge. Incumbents often invest a vast amount of money in IT systems that make their current processes effective. Writing them down or upgrading them to accommodate a new process or business model is expensive. Often, the new type of infrastructure is service, which is attractive from a capital expenditure point of view, but the switching cost is a critical issue. Trigeorgis (1993) discussed this from a financial management perspective and determined that there should be financial modelling for active management to change the conditions of the original investment, which are IT systems in this case. For disruptive platform investments, the problem is twofold if an incumbent wishes to be the disruptor. First, the incumbent is responsible for the cost of legacy systems, and at the same time, it should invest in the possibility that the market would follow, including competitors, which resembles the Prisoners Dilemma[10] as a decision problem (In game theory, a situation in which two players each have two options whose outcome depends crucially on the simultaneous choice made by the other, often formulated in terms of two prisoners separately deciding whether to confess to a crime).

Cable and Shane (1997) studied the Prisoners Dilemma in relation to venture capitalists and entrepreneurs and concluded that cooperation is a preferred option. This could be interpreted in a value chain context that two important competitors could cooperate in building a new “standard” for the value chain for the benefit of the industry.

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[10] http://www.oxforddictionaries.com/definition/english/prisoner's-dilemma

There has been a tendency in high-wage countries to focus activities on the users, leave the upstream to suppliers, and act as a system integrator. This is evident in companies that manufacture the hardware of digital technologies. Therefore, it is notable that successful digital companies also practice different value chain strategies, such as Tesla Motors, which is a small car company with a business model that differs from the models of the automobile industry. At the same time, they have a high integration in production, own key components, and have a massive manufacturing site[11] despite their digital business concept.

2.2.5 Industry beliefs

Incumbents operate in established industries. Are there recipes that work collectively similarly to management cognition on an individual level? An industry recipe allows management to identify a sound space for their strategy that includes technological, financial, and social dimensions (Grinyer and Spender, 1979). Examples include economy of scale, need of flexibility, local vs. global, and asset or research intensive. Another example is the early mover advantage, which has a link to learning. Spence (1981) concluded that learning can create similar entry barriers as economies of scale in certain industries. Based on extensive case studies, Spender (1989) stated that the dynamics of an industry recipe are not driven by what firms believe about the industry but what managers believe about their companies.

Dominant Logic is similar to an industry recipe. Prahalad and Bettis (1986) defined it:

> "a dominant general management logic is the way in which managers conceptualize the business and make critical resource allocation decisions, be it technologies, product development, distribution, advertising or human resource management."

They also argued that the limit of diversity of corporations is not driven by the variety of markets or technology but by the variety of dominant logics. Their suggested sources of Dominant Logic are shown in Figure 8.

[11] http://www.teslamotors.com/gigafactory retrieved 7.7.2015

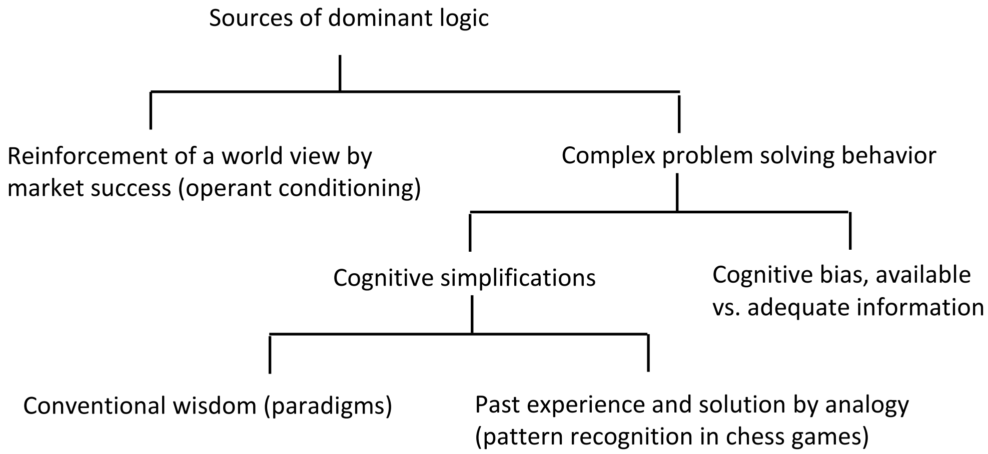

Figure 8. Sources of Dominant Logic (Prahalad and Bettis, 1986)

Industry recipes in this dissertation could look like:

- Enabler: virtual = scalable business model
- Actor: large installed fleet of machines = good spare part business
- User: good location = structural competitive advantage

Matthyssens et al. (2006) studied five different industries regarding value innovation and concluded that industry recipes are present in industry networks and managers in a way that creates inertia for value innovation.

2.2.6 Business models

Markides' (2006) earlier critique that Disruptive Technology is too technology-driven and do not take into account business model innovations, is the motivation to explore business models further. Business models are used to determine how a firm creates a better value than competitors; thus, it is related to strategy. If successful companies apply a similar business model, the model can also be related to an industry recipe; machine and spare parts could be referred to as a razor blade business model, which has been applied in numerous industries, such as consoles and videogames or printers and ink. Business model innovation is not only used for new businesses but also to reinvent old businesses (Hamel, 1999). Tikkanen et al. (2005) stated that there are four conceptual levels of management cognition that are related to business models: industry recipe, reputational rankings, boundary beliefs, and product ontologies.

The benefit of business model thinking in systemic changes is that usually business models consider several aspects of the business simultaneously. Osterwalder’s (2004) dissertation provided a thorough analysis of different models of strategic thinking, and he suggested components that should be included in the business model. He also analyzed the elements of the components, such as fixed pricing (pay-per use, subscription, or list price). The dissertation also explained that different business models are more suitable or are at least used in specific industries. Osterwalder later published a book in collaboration with Pigneur (2010) in which the Business Model Canvas was launched as a tool, which is illustrated in Figure 9.

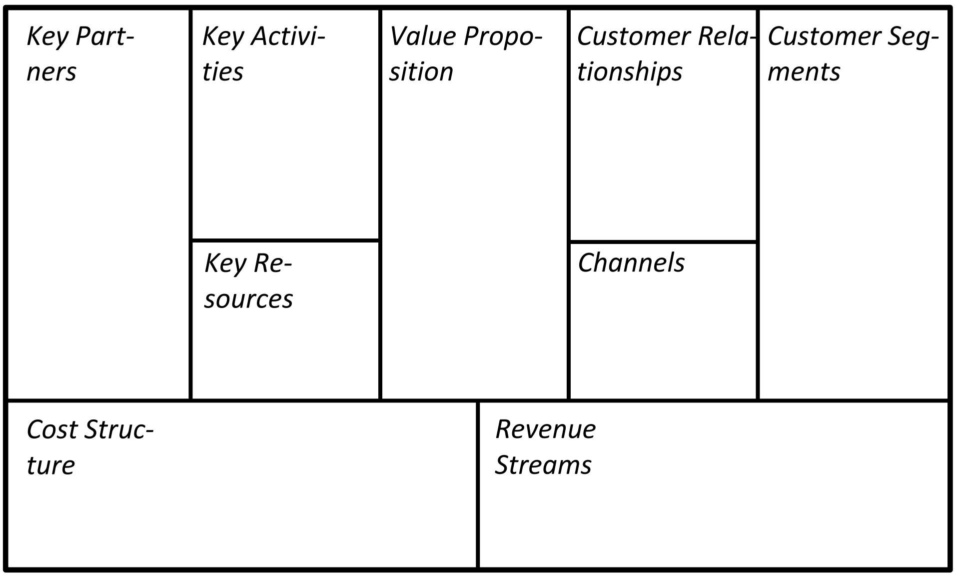

Figure 9. Business Model Canvas (Osterwalder and Pigneur, 2010)

At the same time that generic business models, such as razor blade, were in demand, there was also a call for industry specific models both for existing and emerging businesses. O’Reilly (2007) published views on the use of the Web 2.0 business model in the software industry. He began his investigation using fresh examples. His conclusions were not only relevant for Web 2.0 companies but also for firms at large:

- *Services, not packaged software, with cost-effective scalability,*
- *Control over unique, hard-to-recreate data sources that get richer as more people use them,*
- *Trusting users as co-developers,*
- *Harnessing collective intelligence,*
- *Leveraging the long tail through customer self-service,*
- *Software above the level of a single device*
- *Lightweight user interfaces, development models, and business models*

Business model excellence includes the same dilemma as operational excellence, i.e., success involves a risk of creating rigidity. Based on their case study, Doz and Kosonen (2010) suggested that top management requires three meta-capabilities to achieve the renewal of a business model of the firm: strategic sensitivity, leadership unity, and resource fluidity. The Industrial Internet is one concept discussed in this dissertation, and the way several practitioners define Industrial Internet, takes already position on some of the elements of the Business Model Canvas.

2.3 Digitalization and strategy

There are a growing number of digital strategy models offered by consulting companies, an increasing number of digital strategy projects ongoing in firms, and active publishing of new academic papers about the topic to sustain momentum. Is digitalization a phenomenon that is captured by the analysis of the external environment with the tools suggested by strategic schools, or can the strategy be developed based on digitalization? Does digitalization indeed change the rules of how value is created? The assumption has been that digitalization touches knowledge and value creation in a new way, which is a potential source of a systemic impact on the economy or on the strategy of a firm. Digitalization also questions what markets can be considered large, like Chris Anderson is describing in his concept Long Tail[12], when Internet due to its global coverage can transform local niche businesses into sizeable global market opportunities. The economic principles in the Long Tail are not new but technology has changed

[12] http://www.wired.com/2004/10/tail/, retrieved 6.9.2016

the application of those principles, which has an impact to business strategies, which might be also relevant in B2B (Brynjolfsson et al. 2006).

None of the strategic schools recognized the platforms as playing a role in strategy formation. Open innovation, crowds, and ecosystems are also elements that have been increasing in scale and impact due to the information network. The concept of a network economy is older than Uber. Platforms and open innovation are reviewed in later sub-chapters. The link between business models and the Industrial Internet was thoroughly examined from different perspectives in the article by Porter and Heppelman (2014) in which they endorsed the new era of competition due to smart, connected products and also suggested a path for progress: monitoring, control, optimization, and autonomy. Porter and Heppelman (2014) also argued that the Five Forces could be used to understand the industrial dynamics of digital technologies. This normative checklist was provided for strategists:

- Which set of smart, connected product capabilities and features?
- How much functionality should be embedded in the product and how much in the cloud?
- Open or closed system?
- Full set of smart, connected product capabilities and infrastructure internally or outsource to vendors and partners?
- What data to capture, secure, and analyze to maximize the value of offering?
- How to manage ownership and access rights of product data?
- Should distribution channels or service networks fully or partially be disintermediated?
- Change its business model?
- New business by monetizing product data through selling it to outside partners?
- Scope expansion?

Digitalization also provides a platform for different concepts for the firm itself. Häcki & Lighton (2001) argued that orchestration plays a key role in a network economy. They also provided evidence of network companies that outperformed their non-network peers. The network economy discussion lost momentum due to an interest in platform thinking, even though network effects are fundamental for both platforms and open innovation. Porter and Heppelman (2015) joined the discussion of how digitalization impacts the operations of a firm when value is created by data. Using analogies from the software industry, they discussed collaboration (externally and internally) in lieu of hierarchical structures. During transitions, they suggested stand-alone business units, centers of excellence, or cross-business steering mechanisms. Porter and Heppelman (2015) also suggested the role of a Chief Data Officer to manage data aggregation and analytics on the corporate level.

2.3.1 Platform strategy

A forklift can be a platform. A firm that manufactures forklift trucks can choose the core platform of the truck (e.g., frame, control system, and driver ergonomics) and design interfaces for partners (e.g., power train, attachment, wheels, and hydraulics). This is a type of modular thinking that has been common in industrial development for decades. Platforms have also been important contributors of efficiency for internal operations. In many car companies, different brands share the same platforms (and components), and the motivation has been sharing development and production or sourcing costs by economies of scale. Sawhney (1998) suggested that product platform thinking can also be expanded to brand, process, globalism, and customers.

Information technology brought platforms to the next level by enabling the development to be location independent. Also, the core product, software, enabled real-time delivery economically anywhere. This also expanded the concept of platform products. Can a platform be built based on niche knowledge, such as knowledge of the wear and tear of a bearing? Gawer and Cusamo (2002) wrote an interesting book analyzing three firms that became platform leaders, Intel, Microsoft, and Cisco, and three firms that were potential platform leaders, Palm, DoCoMo, and Linux. Compared to earlier efficiency driven modularity, the book described platform strategies that had a symbiotic nature in which the platform owner and complementors depended on each other, such as a memory chip and a computer. Their conclusion was that to pursue a platform strategy, the firm must be able to manage four levers. Scope of the Firm involves the ecosystem, and Product Technology involves the way interfaces are designed and intellectual property is managed. External Relationships include the designs of the consensus/ control and collaboration/competition mechanism with the complementors, and Internal Organization includes the designs of structures, processes, culture, and mindsets when some of the complementors are competitors. Later, Gawer and Cusamo (2008) offered two paths for leadership: Coring (if the industry does not have a platform) and Tipping (winning the platform war through market momentum). The paths have different technology and business choices.

Kenney and Pon (2011) posed a relevant question: if there is an emergent platform in the industry, which platform is it? Their case study focused on the smartphone industry, and the potential platform was the OS. The conclusion was that there is a dominant OS-based design and that Apple leads the platform race; however, due to a convergence phenomenon, a disruptive new logic could emerge, possibly from someone like Facebook. Like most products, product-based platforms have logical commoditization risks. Technological products have addressed commoditization both by advancing the product and/or attaching services to it. Services can also be attached to platforms, but can service become a platform? Suarez and Cusamo (2009) argued that services can play a major role in mitigating the commoditization risk of product platforms. Cloud computing, which is also reviewed later, introduced platforms as a service concept. Weinhardt et al. (2009) used Salesforce.com as an example of this development. Earlier firms invested in proprietary Customer Relation Management (CRM)) systems or used modules of other systems, such as Enterprise Resource Planning (ERP), for that purpose. Salesforce.com changed the merging Cloud technology, software, and service concept. Zysman et al. (2015) highlighted the essence of algorithms and their relation to Cloud platforms. They called this change toward service the Algorithm Revolution.

2.3.2 Open innovation as a paradigm in the development of a firm

Open innovation, or one its forms, crowd, is not only a business paradigm but also reflects societal change. Innovation beyond corporate or other borders as a phenomenon was certainly not invented in recent decades. Western civilization experienced a similar innovation during the Athens centrum. ICT technology transformed the globe into the real-time Athens square, and Chesbrough implemented open innovation into management discipline, which has been criticized not because of the content but for its novelty, as suggested by Trott and Hartman (2009). Chesbrough's (2006) definition of Open Innovation is:

> *"The use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand markets for external use of innovation respectively."*

This means that the target can be a firm's products or services, internal operations (primary or support processes), or business models. Regarding its relevance to strategy formation, Vanhaverbeke and Cloodt (2014) contended that the overriding suggestion in the strategy literature is to rely on internal resources for development. This statement does not take into account that the tacit knowledge in a value chain has been transferred as input for internal innovation. Open Innovation also raises the question of whether the wisdom of crowds can be superior to (Surowiecki, 2005) the company's internal experts.

Open Innovation can be organized by following the traditional principles of subcontractor relations, whereas the other extreme includes fully open crowd sourcing concepts. The characteristics of organization can include firm-driven ecosystems, industry trade organizations, commercial incubators, university organized platforms, etc. Crowdsourcing as a concept for products, services, specific problems, vendors, customers, capital, ideas, or complete systems solutions is based on the notion that volume, diversity, and collective intelligence offer additional value. Malone et al. (2010) stated that a collective intelligence system can be developed by designing it using components that they called genes. They illustrated the evidence using Wikipedia, Google, and Linux as examples. Several public buildings are a result of architectural competitions; it was not called crowdsourcing, but it had the same characteristics. Howe's (2006) article "The Rise of Crowdsourcing" suggested crowdsourcing as an alternative for outsourcing. Competitions take specific forms, such as Hackathons, in which private programmers spend a weekend developing a solution to a problem provided by an industrial firm. Hedenborg, the CEO of a Finnish factory automation supplier, Fastems, commented that their Hackathon provided nine product development initiatives in three different disciplines.[13] The participants were both software students and professional companies.

What drives Open Innovation as a tool for better competiveness? Is it richer content, cost, speed, or something else? The content is self-evident based on one of the Open Innovation principles in Chesbrough's (2003) article, which points out that no one company possesses all talent, and there are also radical ideas that might be outside of the field or industry of the firm. The ability to obtain external knowledge might depend on the autonomy of the people in the experiment. Teece (2007) argued that there is a trap in Open Innovation if Open Innovation is seen as an alternative to integrating the knowledge that exists within suppliers, customers, and complementors. He also contended that unique assets and resources are not enough for a sustainable competitive advantage without unique dynamic capabilities. In his ecosystem framework, he introduced Analytical Systems, which include Learn and Sense, Filter, Shape, and Calibrate

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[13] http://www.organisaatio-sanomat.fi/hack-the-factory-toi-fastemsille-ideoita-teollisen-internetin-soveltamiseen/ retrieved 7.7.201

opportunities in addition to the external existing and new knowledge. Cohen and Levinthal (1990) developed the concept Absorptive Capacity, which they defined as “the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities.”

Open Innovation can also involve cost issues. In crowdsourcing competitions, the hours spent on the solutions are not related to the winner’s prize; however, the transaction cost for the incumbents that manage the network of startups or events as well as the indirect cost of the organizer might be high. Christensen et al. (2005) elaborated on this in their case study related to technology development and concluded that the relation and the cost differ depending on the maturity level of the technology. Felin and Zenger (2014) concluded that the cost related to communication in Open Innovation is decreasing due to platforms and standardization as well as due to communication technology development.

Speed translates to cost; unlimited resources can either speed the development or delay the total process if not managed correctly, as the complexity increases when the number of people increases in a project. Gupta and Sounder (1998) stated that there is a growing importance for reduced cycle times in product development; they also showed higher user involvement in short-cycle product development. Dedehayir and Mäkinen (2011) suggested that in the systemic industry context, increased technology based clock speed intensifies time-based competitions in related sub-industries.

Open innovation is structured, expanded, and accelerated by the innomediaries. Innomediaries can assist in all phases of innovation (Orientation, Exploration, Selection and Engagement), but their roles vary in different phases (Roijakkers et al. 2014). Roijakkers et al. (2014) also concluded that some of the innomediaries offer services based on the expertise of their own personnel, whereas the other type of innomediaries search and match clients with innovative companies using search engines. Some of the portals are in the global job market, such as www.freelancer.com, and some focus on individual disciplines, such as www.design.com.

If Open Innovation is already a new paradigm, what will delay expansion? Obvious answers are a lack of understanding, knowledge, processes, and attitudes, such as “not invented here” syndromes. The nature of the barriers most likely differs depending on the object of Open Innovation. Chesbrough (2010) stated that one of the mental difficulties in the business model of innovation is that new business models might be in conflict with the firms’ existing technology. This makes business model innovation more difficult, whether it is internal or uses Open Innovation principles. Huizingh (2011) suggested that Open Innovation expansion has similar characteristics to the diffusion of innovation, and the followers are reluctant to copy Early Adopters, especially if it requires organizational changes. The slow emergence could also be explained by cultural readiness, as suggested by Savitskaya et al. (2010) in their case study on China.

One major obstacle in Open Innovation expansion is the Intellectual Property Rights (IPR), whether it is an excuse not to change or a justified concern of valuable intellectual property leaking to current or potential competitors. Economically, it is a question of whether sharing provides a greater return than keeping the knowledge in-house. It is a more abstract question than calculating the rate of return for an internal R&D investment. West and Gallagher (2006) studied the question in an open-source software context and pointed out that sharing innovations with vendors can lead to better products; they also promoted mechanisms for commercializing the “spillover” innovations. Arora et al. (2001) asserted that the technology market is growing, which makes the “spillover” option a real option. As attractive as the intermediate markets for the IPR might be, they are also more complex to manage than ordinary security markets. Trading IPR also involves changes in traditional intellectual property management (Chesbrough and Ghafele, 2014).

2.3.3 The enabling technology behind digitalization

Digitalization in this dissertation is understood as a process in which data is collected, transmitted, stored, processed, and used for value creation. The input can originate from people when they translate observations, judgements, or thoughts in writing or from sensors that collect factual measurement data. In digitization, the information is coded as a string of ones and zeros in different parts of the process. Coding information is common, but ADC (Analog Digital Converter) began the modern expansion. In the early 1980s, it was used in military applications and was expanded to the civilian market. Its usage further accelerated in the mid-1990s when ADC became a mass market component in different consumer applications (Robertson, 2006). There are numerous digital technologies, but only the fundamental ones are briefly described in this sub-chapter. They are used in digital systems or concepts that drive the potential disruption from a technology point of view, which was investigated in this dissertation. The systemic concepts are described in sub-chapter 2.3.4.

A transistor by Bell Labs in 1947 (Early, 2001) was one of the first key components in the future digital system. It was a simple, small device that could either act as an electronic switch or as an amplifier. The capacity of the transistor began to increase when the integrated circuit, which utilized semiconducting silicon, was invented by Texas Instruments in 1958 (Kilby, 2000). The next step was the microprocessor, which made it possible to use digital data as input and to process it according to programmable instructions. The microprocessor was not invented by Intel, but the Intel 4004 microprocessor from 1971 (Betker et al., 1997) is perceived to be the first commercial microprocessor. It paved the way not only for computers but also for other parts of a digital system as an embedded component.

Memory is needed for storing data either temporarily or for long periods. The first hard discs were invented by the IBM lab in 1956 (Praxley, 2007) to be used as part of their mainframe computer. Thereafter, there have been physics-based innovations of the discs or innovations in the production technology, which has enabled the growth in capacity (measured in bytes, which is equivalent to 8 bits), the decrease in the physical size of the device, and consequently, the reduced cost of storing data.

Peripherals, such as sensors or various user interfaces, are fundamental for the system to interact with the outside world. For entering data or viewing results, there have been innovations, such the keyboard, the mouse, and the touchscreen. The technical development of sensors is more important from an industrial perspective. The process industry measures various factors of the process by sensors in order to control the process in a definite way. The importance of the sensors increases when they can be connected wirelessly to the external systems. This has enabled telemetry, for example, in which problems with a working machine can be solved remotely before they have occurred. Systems improve by increasing the amount of sensors that feed the critical data with a high reliability. The cost also decreases, which further accelerates market penetration. A robot is an example of a product that could not have been developed without digital technology. A robot needs sensors for safe navigation and for the input to make the right decisions, which are made by computer algorithms. Robotics has catalysed the development of actuators. Work machines require several actuators with micro movements to operate unmanned. There is also the additional challenge that both the machine and the load can weigh tens of tons.

Algorithms are the brain of the system. They present the rules of system operation and are coded with a computer language, known as the software. The history of software is relatively brief. IEEE software publication place the introduction of the software in late

1983 or early 1984 (Ebert, 2008). Thereafter, the development has been rapid, and there are different generations of computer languages as well as clusters of languages. Some of the software programmes are platforms, and some are specific to an application. Software technology is an interesting topic, but the relevance to this dissertation is that software is the core enabler of the systemic impact of several digital technologies.

Wireless technologies decoupled various applications based on location constraints. As disruptive as innovations by Bell, Edison, Hertz, or Marconi were over 100 years ago in radio technology, more recently, GPS and GSM were the enablers of modern digitalization. GPS is a technology that utilizes satellites that orbit in space, which originated in the U.S. Department of Defence. The commercial usage was originally initiated by the Joint Office as a Navstar GPS program in 1973 (Stotts et al., 2014) that shared technology with civilian stakeholders. In hindsight, it is easy to conclude that the program succeeded, as GPS has become a de facto global platform for commercial applications that utilize location information. GSM technology was developed by enterprises and universities that were developing technologies for mobile communication in Europe. At the same time, there were competing technologies from the U.S. and Japan. The scale impact occurred because major European countries were able to agree on the GSM standard (Hillebrand, 2013), which later also became a global standard. The economics and relevance for GSM and GPS was that they both became global technologies, and that the industry leaders chose them as platforms to develop applications for various industries. GSM paved the way not only for voice but also for data transmission. Data transmission has had rapid developments in speed and cost. Both technologies were also linked to industrial and consumer businesses.

There are several other technological components in digital systems. The systemic impact of the individual components begins with the features, but the cost development has become even more pivotal, creating an increasing number of new applications. Cost reductions are the result of innovations in production technology and increasing volumes. The increasing volume originated from the consumer business, but more and more the same components are also used in industrial applications. The development has followed Moore’s law:

> "The number of transistors incorporated in a chip will approximately double every 24 months."[14]

Moore's law has been reasonably accurate since the introduction of the Intel 4004. Development will continue, but the expert's opinions are not unanimous regarding precisely how it will follow Moore's law in the future.

2.3.4 Digitalization as a systemic phenomenon

If the technological components and their features, cost, and impact are relatively factual, the situation is more complicated for the systemic impact. When purchasing the next generation of a microprocessor, the capacity, cost, and functions are known. It is far more complicated to buy one Industrial Internet, even though there are service providers that claim they can deliver it. Technology based concepts are often transferred to businesses by the consulting department of technology companies or standalone consulting companies. The list of digitalization concepts chosen for this dissertation is based on the rank of the concepts researched and promoted by those companies, and that are also relevant for a machine-building industry. Other potentially disruptive digitalization concepts that emerged during the empirical research are discussed in the results section. Open Innovation as a potential paradigm changer has been reviewed in the strategy section, but it is also included in the list. The concepts differ based on their characteristics, and they can have interdependencies. The scope of the concepts is (in alphabetical order):

- Additive Manufacturing (also referred to as 3D printing)
- Big Data/Artificial Intelligence (AI)
- Cloud Computing
- Internet of Things
- Industrial Internet
- Model-Based System Engineering
- Open Innovation
- Robotics (or autonomous operations)

[14] http://www.intel.com/content/www/us/en/history/museum-gordon-moore-law.html?wapkw=moores+law, retrieved 6.8.2015

Additive Manufacturing

In manufacturing, there have been numerous technologies, such as machining, welding, bolting, gluing, casting, and their combinations. The difference in Additive Manufacturing (AM) is that the product or component is built by printing it layer by layer, making it three-dimensional, which is referred to as 3D printing. For AM technology to advance, the material coverage must be expanded (usually plastic), larger objects must be enabled, and there must be acceptable speed and unit costs. AM offers systemic changes; the physical supply chain of products can become digital, or a firm can have a business model of selling “recipes” for printing spare parts. It is also an enabler of speedier R&D via rapid prototyping. Engineering a current product to be printed is a quite different approach from designing a product that was originally designed to be printed, which is a challenge for engineering competences of the incumbents.

Future development has both product and supply chain paths. By combining the paths and services, it can catalyse the business model evolution (Cotteleer, 2014). Cohen et al. (2014) presented five disruptive attributes related to 3D printing: accelerated product-development cycles, new manufacturing strategies and footprints, shifting sources of profit, new capabilities, and disruptive competitors. Gartner’s prediction of spending on 3D printers is $13.4 billion in the year 2018, and the forecast for 2015 was $1.6 billion[15] D’Aveni (2015) examined annual patents in AM (from 80 to 600 in ten years) and argued this growth indicating the technology reaching a tipping point. AM is not only advancing by the high technology companies or system integrators (actors) but also due to users. The US Navy is printing drones on board vessels for intelligence.[16] On the civilian side, 27 companies in the port of Rotterdam formed an alliance to print four spare parts after a tedious selection process to be tested in real operations.[17] AM is not only driven by the competitiveness of firms; it also offers potential societal benefits (disruption for some), such as reducing dependence of current trading partners or delaying climate change due to a decrease in the unnecessary transportation of products.

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[15] http://www.gartner.com/newsroom/id/2887417 retrieved at 6.8.2015
[16] http://3dprint.com/85654/us-navy-3d-printed-drones/ retrieved at 6.8.2015
[17] http://www.maritimeprofessional.com/news/printing-rotterdam-port-274044 retrieved at 6.8.2015

Big Data/AI

Big Data involves the economical processing of large quantities of data. It is also viewed here as one of the steps toward Artificial Intelligence (AI). Interpreting data is common for humans and growingly also for machines. The change involves the unprecedented flow of data of human behavior, often internet-based, or data from sensors. At the same time, storing and computing data has become more economical, and there are better algorithms available.

Big Data has often been referred to as a new source of innovation; the analytics are somewhat different when making sense of human behaviors or predicting a machine breakdown. The following two statements are true of machine data: the amount and nature of the data collected increases rapidly, and data can be transferred wirelessly. Based on data from sensors, conclusions can often be validated by simulations or empirical experiments based on the laws of physics. The Artificial Intelligence of machines is related to machine learning or deep machine learning (Itamar et al., 2010). There is evidence of the effect of Big Data-driven business improvement but also large industry and firm variety how to capture the benefit (Brown et al., 2014); however, they suggest that data science requires a center of excellence to develop the required capabilities. Westerman et al. (2014) emphasized having the customer data in focus when developing data driven insights. Big Data alone is not the answer for future business success, as there is always some degree of judgment required, and therefore decoupled conclusions of the company or its culture can lead to strategic mistakes (Guszcza and Richardson, 2014). Also, the investments in AI will continue, as AI can be the vehicle used for transforming computing from productivity to content. The Watson IBM is a prime example in the healthcare business, where advanced analytics assist doctors in diagnosing cancer. Likewise, the software giant SAP is developing its HANA technology for better analytics from predicting football results to business intelligence. Modern technology can also follow older business models, such as with Google, which has been using the traditional newspaper business model but more effectively and globally (Huberty, 2015).

McAfee and Brynjolfsson based on their interview of 330 North American executives concluded that data-driven companies were more profitable (McAfee, Brynjolfsson 2012). They highlighted that the speed and variety of data has increased, which challenges deep hierarchical decision-making in data-driven environment. McAfee and Brynjolfsson (2012) came up with five management challenges into the transition to be data-driven: Leadership, Talent management, Technology, Decision making and Company culture.

Cloud Computing

The dominant process of private and public organizations in developing IT included following steps until recently: internal process development (as is and to be) and the choice of suitable software for application and implementation (possible pilots and rollouts). The cost and lead time was driven by scale, complexity, and the effectiveness of the process itself (feasibility studies, planning, decision making, and implementation). Long lead times meant that entities conducted parallel activities (old processes with the old tools and new processes with the new tools). The Cloud changed this. A firm can connect to the Cloud and receive a world-class process with IT support in weeks and can pay for the usage. It is obvious that as a model, it is more flexible than rollouts and more economical than depreciating the IT infrastructure cost each month. The US National Institute of Standards and Technology (Mell and Grance, 2011) has defined three service models for Cloud Computing: IaaS (Infrastructure as a Service), PaaS (Platform as a Service), and SaaS (Software as a Service), and four deployment models: Private, Community, Public, and Hybrid Cloud.

From a disruption point of view, the Cloud lowers the barrier for newcomers to enter the global business market, and it also offers economies of scale to SME's that were previously available only for MNEs. Several of the known new business model innovations are utilizing the Cloud as a technology, such as Netflix in broadcasting. Although the Cloud is a major source of disruption for the previous type of computing, it is also vulnerable to security risks. These issues require both technological solutions and new policies regionally and internationally (Kushida et al., 2015). Security risks can affect both public and business domains but also privacy at large. The Cloud has the same inertia attached to it as AM or AI, as it includes elements of which many incumbents have no prior experience or knowledge. Iyer and Henderson (2010) listed seven capabilities that are needed in the formulation of a firm's Cloud strategy: Controlled Interface, Location Independence, Sourcing Independence, Ubiquitous Access, Virtual Business Environments, Addressability and Traceability, and Rapid Elasticity.

Internet of Things

The Internet of Things (IoT) is related to the Internet. Experiments in building computer networks began in the 1960s in military and university circles. The explosion occurred in early 1990s with the invention of the World Wide Web. Free access was a prerequisite for the explosion according to Sir Timothy John Berners-Lee, who won the first Millennium Technology Prize in 2004 for his pioneering work with the World Wide Web:

> “The decision to make the Web an open system was necessary for it to be universal. Had the technology been proprietary it would probably not have taken off. You can’t propose that something be a universal space and at the same time keep control of it.”[18]

Thereafter, the Internet has experienced several enhanced technological innovations in the platform and especially with the applications that utilize the platform. The systemic impact will occur when people are connected globally at all times. It is easy to understand the magnitude of the value based on Metcalfe’s law from the early 1980s, which states that “the value of a network grows as the square of the number of its users grows” (Metcalfe, 2013).

While the Internet is the platform for people to become location-free and have real-time access to data, IoT involves connecting physical objects. Manyika et al. (2013) defined it as “the use of sensors, actuators, and data communication technology built into physical objects that enable those objects to be tracked, coordinated, or controlled across a data network or the internet.” HCI and M2M were discussed before the Internet, but the global scalable platform was missing. Some companies, such as Cisco Systems, use the Internet of Everything for the same concept. Kellmereit and Obodovski (2013) named five core application domains for the future of IoT: Connected Cities, Homes, Health, Cars, and Supply Chain. Gubbi et al. (2013) explained that web.3 (ubiquitous computing) uses intuitive queries and is based on Cloud technology to achieve the potential of IoT. This is also an example of the interdependence of the selected digitalization concept, as stated in the introduction of the sub-chapter.

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[18] Sir Timothy John Berners-Lee, http:/taf.fi/en/millennium-technology-prize/winner-2004/ retrieved 6.8.2015

Industrial Internet

IoT and the Industrial Internet as concepts are mixed both in academic and business literature and discussions. The core difference is that IoT has a stronger link to consumers, and Industrial Internet is linked to the value creation of a firm, which in many applications makes it more mission-critical. The ETLA report (Juhanko and Jurvansuu, 2015) presented a model in which the link between a consumer to smart, connected products and services was lifestyle-based (IoT), for a firm's data-based business models (Industrial Internet) and for the society frictionless services (= information society 2.0). GE emphasized the systemic nature by pointing out that the core aim of the Industrial Internet is connecting intelligent machines, advanced analytics, and mobile people at work (Evans and Annunziata, 2012). The same systemic character is mentioned in Porter and Heppelman's (2014) article in a farming context in which applying the Industrial Internet concept allows farm equipment manufacturers to move from equipment performance to farm output optimization. The earlier cited World Economic Forum (2015) Output Economy concept also described the progress of the Industrial Internet in which the last three phases represent an increase in the systemic level of optimization (Figure 5).

In their white paper (Bradley et al., 2013), Cisco estimated the value of the Internet of Everything (including the Industrial Internet) market as $14.4 trillion by the year 2022, and the almost equally influential drivers for value creation are: asset utilization, employee productivity, supply chain and logistics, customer experience, and innovation. Russo et al. (2014) suggested six questions that should be considered by machine builders to create value: how does data create new value, how fast will new business models emerge, how will industry structures change, how do we play in this space, what capabilities do we require to win, and how do we get started? Individual countries have also added the Industrial Internet to their agenda to develop or sustain industrial competiveness. German initiative Industrie 4.0 (Kagermann et al., 2013) is a good example, which notably indicates that real-time CPS platforms are changing the paradigm of industrial service. The US consumer business tradition might explain why the focus in US industrial initiatives has been from the beginning adding customer value. Also, the German investment in the Industrial Internet is reflecting the change from the manufacturing to customer in the national Acatech (Kagermann et al. 2014) research report published a year later than the original Industrie 4.0., which was called the Smart Service Welt.

Model-Based System Engineering

The focus of this dissertation is machine-builders. Even in standalone situations, machines are a result of multidisciplinary work. There is an ongoing evolution in the subsystems of a machine; material science creates lighter and more wearable structures, components are becoming more intelligent, and digitalization impacts how machines are controlled in several ways. The systemic complexity increases when a fleet of machines or machine interactions with upper systems (planning, maintenance, etc.) are taken into account. The development of a machine still follows the traditional disciplines as a foundation (mechanical, electrical, and software engineering), but digitalization has enabled new sources of input via sensors, new insight by algorithms that utilize Big Data, and a new set of tools. The tools include both methods such as simulations or crowdsourcing ideas as well as advancements in software for various disciplines, such as CAD tools. Model-Based System Engineering (MBSE) has evolved as a promising discipline to manage the growing complexity of the R&D of a machine builder. It can combine the physical world with software in an early development phase. Architecture is needed to enable the actor to create a dialogue between internal and external knowledge and to orchestrate the use of concepts, such as Open Innovation. MBSE is an effective method, but further standardization would lead to advancement with influential actors (INCOSE, 2007) actively using it. Garetti et al. (2012) argued that virtual prototyping is moving from digital knowledge to a digital lifecycle. This is an important concept in building new business models that are performance-based. Nichols (2013) suggested that systemic complex problems can be solved in the CPS environment by a smart and synchronised development methodology (from previous concurrent development), which is also a driver of business transformation. This methodology can include continuous iteration supported by virtual and real experiments, which is somewhat similar to Scrum (Schwaber and Beedle, 2002) ideology. MBSE is currently in an early phase, and technologies that can enhance it are still in development.

Robotics

In the context of this dissertation, robotics refers to work machines becoming autonomous. All work machines have features that assist the operators or protect the machine from failures whether caused by the operator, the machine, or the environment. Computers have played a major role in this process. For example, a sensor measures the temperature of engine coolant, and if the temperature is too high, software instructs the system to shut the engine down before it is damaged. These developments have resulted in the capability to optimize productivity, fuel consumption, tire wear, and other parameters to improve the lifecycle economics of the machine. The next level of intelligence for machines involves interacting with the environment, including taking instructions from production planning, communicating with the maintenance system locally or with a remote help desk, and interacting with the other machines to avoid collisions. Since machines were invented, operators have occupied the cabin and applied judgement. Replacing human judgement with an algorithm is the essence of robotics in this research. This is already common with machines in the process industry but not to the same degree e.g. in farming, mining or port operations. For security reasons, industrial robotics has separated the man from the machine, but advancements are paving the way for humans to cooperate with robots in industrial applications.

When a decision-maker's objective is to switch to automation, it is most likely due to the anticipation of a better financial return than can be obtained by continuing to invest in the manual alternative. The technology is relatively novel, and there are concerns about reliability and safety, which can become better or worse. At the same time, it can be expected that the underlying technologies are still rapidly progressing. Automation causes unemployment for machine operators, but it might be more environmentally friendly; different benefits for different stakeholders. To reduce the inertia in automation and unmanned operations, that is related to the undesirable societal impact of unemployment; various innovations that enable humans to work with robots should be promoted as suggested by Brynjolfsson and McAfee (2012).

Robotics is also a field in which development in consumer businesses converges with industrial businesses. There are similar underlying technologies, such as machine sight or navigation. A self-driving Google car and the service robots in hospitals have more of an impact on the attitudes of the public than the welding robots in the 1980s. BCC research has forecasted that autonomous robots make up the largest category of smart machines (others are expert systems, neurocomputers, smart embedded systems, and intelligent assistants) with a $13.9 billion annual market.[19] Cyber security is a core issue in all digitalization concepts, but autonomous machines are directly vulnerable. Kohler and Colbert-Taylor (2015) stated that cyber hacking and cyberterrorism are fac-

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19 http://www.bccresearch.com/pressroom/ias/global-market-smart-machines-expected-reach-$15.3-billion-2019, 12.8.2015

tors accompanied by legal issues that affect the timing of the expansion of autonomous vehicles.

Summary

Concepts within digitalization are interlinked, and several concepts are systemic in nature. Human behaviors drive the speed of the emergence of digitalization, which is not only influenced by rational benefits but also by usability and the user interface. There is not necessarily consensus regarding how the impact of the disruptive nature of individual concepts differs from industry to industry or for the potential timing. This dissertation has focused on disruptiveness in the machine-building industry, which serves global ports and terminals. Whether or not views of the value chain differ between enablers, actors, and users was also investigated. Some of the concepts are likely to be disruptive based on recent advancements and the economics of technology; for other concepts, technology must continue to advance or become more economical to cause a disruptive impact. It is also likely that the point of technological advancements or economics differs between industries. As indicated by the research question, the uptime is critical for the value chain investigated, which implies that most likely, the way Uber disrupted the taxi business would not automatically be applicable in mission critical processes, though there are conceptual leanings from Uber.

Westerman et al. (2012) introduced a matrix in which they defined the digital mastery level on the vertical axis as dependent on digital capability, and the horizontal axis was dependent on leadership capability. Applying this definition, they developed four levels: Beginners, Conservatives, Fashionistas, and Digital Masters. Based on the research data, they applied the matrix to several industries, which is illustrated in Figure 10. In this figure, enablers would be closest to high technology industries which are on the Digital Mastery level. Manufacturing was placed on the Beginner’s level.

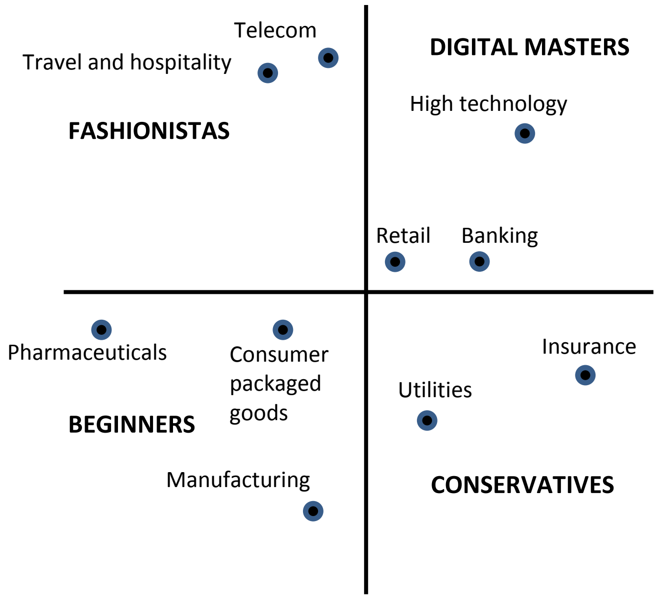

Figure 10. Maturity by industry, (Westerman et al., 2012)

2.4 Synthesis on industry evolution, strategy formation, and digitalization

The phenomena and mechanisms investigated are part of the industry evolution; the theory sections discussed seminal theories that explain the dynamics of the industry evolution, such as the Five Forces (Porter, 1979), the role of the stakeholders (Freeman, 2015), or emerging theories of industry convergence. The nature of the evolution was also investigated, which involves stepwise or disruptive continuous improvement. The focal theories are S-Curves (Foster, 1987), Technological Trajectories (Dosi 1982), Sustaining and Disruptive Technologies (Christensen 2011), or Diffusion of Innovations (Rogers, 2003).

As the investigation focused on disruption or paradigm changes, the economics view is Schumpeterian (2012) in that larger disruptions in economies are linked not only to the technology or economy but also to politics and society at large. The basic elements of the factors of production are labor, raw materials, and capital. Knowledge labor is in key role in digitalization, which has strong links to knowledge-based value creation, which is illustrated by concepts such as Outcome Economy (World Economic Forum

2015). Capital and perhaps the more risk-seeking Venture Capital are expected to play roles in the development.

The catalyst in Schumpeterian (2008) disruption (Creative Destruction) is the entrepreneur. In this dissertation, they are represented by the individual firm. A major way for a firm to cause disruption is related to innovation, which is often referred to as radical innovation in disruption. The intent, direction, plans, and resources of innovation are based on strategies of firms. Strategy formation was reviewed based on the 10 schools of strategies in the classification system developed by Minzberg et al. (1998). The platform is a new element that has emerged in the digital era in economics and strategy formation. Platforms are also closely linked to Open Innovation and Crowds, which were included in the discussion of network economy. Five Forces (Porter, 1979) is very value chain based and Crowds or networks are not conceptually included.

Firms are key players in B2B business. The strategy formation and decisions regarding resources are made by management. The decisions are influenced by collected beliefs, such as Industry Recipes (Spender, 1989), Dominant Logic (Prahalad and Bettis, 1986), and the governance and culture or individual beliefs that have an impact on management cognition, which include Bounded Rationality (Simon, 1991), Prospect Theory (Kahneman and Tversky, 1979), and values. Implementation is likely to be affected by the same beliefs as well as factors such as leadership style and capabilities, which include Absorptive Capacity (Cohen and Levinthal, 1990) and Dynamic Capabilities (Teece, 2007).

Digitalization is a systemic phenomenon, and its ability to enable disruption is likely to vary based on different theories of economics or strategic management. In addition, the disruption potential of individual digital concepts varies. Digitalization concepts were reviewed based on current literature and practices with the assumption that they can potentially cause disruption within the limits of the research question.

The theory discussion, whether it is linked to economics, industry evolution, strategy formation, or individual technologies, examined elements that drive progress as well as elements that inhibit progress. The balance of these forces has an impact on speed and direction. The forces are easier to analyze individually; however, larger impacts are most likely due to the systemic impact of the forces as a whole.

The summary of this literature review is illustrated in Figure 11. All potential drivers in the yellow section include sub-drivers that can work as inhibitors or accelerators. They are based on the characteristics of the driver itself, or they can be caused by societal and political factors or various beliefs that have been reviewed. The model uses the Five Forces (Porter, 1979) and Stakeholders (Freeman, 2015) as one theory and convergence as a different type of theory to explain industry dynamics. Radical innovation represents the means, Digital Business Models, and Networks, Crowds, Platforms as specific phenomena involved in digitalization. Firm, strategy, and management represent resources. Capital is specifically linked to Risk Capital. Digital technologies are AM/3D, Big Data/AI, Cloud, IoT, MBSE, and Robotics tools. Their systemic impact can be continuous improvement, quantum leaps, or disruption, which might be different in products, service operations, and business models of an industry.

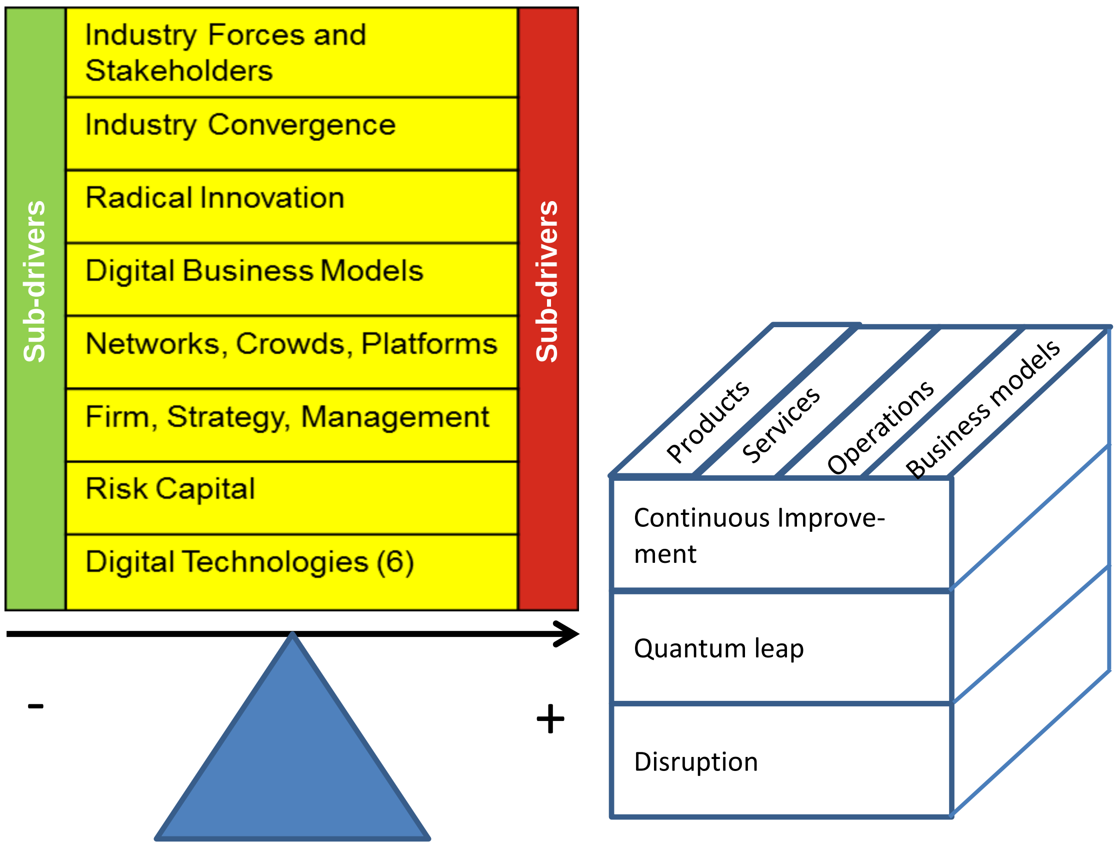

Figure 11. The research object

3 Methodological foundation

Considering the ways digitalization has impacted media and retail businesses, it is fair to state that a similar disruption or paradigm change has not occurred in the machine-building industry. This does not exclude the pockets of value creation disruption that already take place or some of the mechanisms of potential disruption that are similar in machine-building industry as in industries in which the impacts of digitalization are already visible. The purpose of the inquiry was to increase understanding; is disruption likely to happen, what will be disrupted, which factors drive or inhibit the disruption, and is the view on disruption different in the value chain. The focus of the inquiry includes innovations whose characteristics and performance are factual, but disruption depends on how the innovations, tools, or methodologies are applied in the future, which is a result of the decisions made now by the management or by the choices people do as employees in the firms or privately as consumers. "Better" technology does not always win in the market place, which occurred in the Betamax vs. VHS case. The characteristics of the investigation guided the applicable frameworks based on the philosophy of science, practical methodology, and the research design, which are discussed in this chapter.

3.1 Research philosophy

Positivism and hermeneutics form the dividing worldviews of science for this dissertation. The positivistic worldview assumes that the findings are true and objective, the hypotheses are verified as facts or laws, values are not applied, and the research results are not dependent on the researcher (Guba and Lincoln, 1994). The hermeneutic worldview seeks understanding and posits that the essence of the relation between the researcher and the environment and the lack of absolute truth does not make the research results unscientific (Gadamer, 2013).

The positivistic worldview of science can address issues of discoveries that enable digital applications. Magnetoresistive random-access memory, which enabled the emergence of the hard disc drive, is based on laws of physics; however, Moore's law cannot explain the cost or capacity of the memory chips in the future in a way that would meet the scientific criteria of positivism. As the majority of technologies that can enable potential disruption are already commercially available, the focus of this research was not to predict the future development of these technologies but to increase understanding of the impacts on business, which is similar to the ethos of hermeneutics.

The epistemology and ontology of future studies is another perspective in this research. The fundamental question is whether the future is predetermined or whether there are multiple futures that are results of today's decisions. Moreover, does the goal of a desirable future drive these decisions? There are several views among scholars that support the openness of the future, and concepts such as Futuribles (De Jouvenel, 1967) and Futures Map (Kuusi et al., 2015) are used. Godet (1994) added action to his concept of Strategic Prospective, which underlines action orientation rather than fatalistic thinking as a base. Popper (2002) also stated in his harsh criticisms of historicism that "the future depends on ourselves, and we do not depend on any historical necessity." Several possible futures are also the essence of scenario thinking as a methodology. This does not mean that the future would not be impacted by history or by the current state of affairs. Van der Heijden (2002) addressed the issue by presenting a diminishing amount of the predetermined issues and a growing share of uncertainty as a function of time –measured as distance from current affairs. Using this framework, he identified three ways to predict the future based on distance into the future: forecasts, scenarios, and hope.

As the desirable future includes an assumption of value according to Niiniluoto, knowledge seeking has several commonalities with design sciences (Niiniluoto, 2013). Based on the use of knowledge, research can be categorized into descriptive and normative research (Olkkonen, 1994). The objective of normative research is to guide future development, and therefore design science can be considered normative according to Olkkonen (1994). Malaska (2013) referred to research of the future as futurology, which includes basic research and philosophy of science questions about researching the future, future studies that involve applying rigorous methodologies, and foresight, which applies research of the future to making better decisions.

In his book, Creswell (2003) suggested a framework that was used to guide the methodological choices of this research, which is presented in Table 1. Although it simplifies the schools of the philosophy of science, it offers a current view that considers the dilemma between positivism and hermeneutics.

Postpositivism	**Constructivism**
• Determination • Reductionism • Empirical observation and measurement • Theory verification	• Understanding • Multiple participant meanings • Social and historical construction • Theory generation
Transformative	**Pragmatism**
• Political • Power and justice oriented • Collaborative • Change oriented	• Consequences of actions • Problem-centered • Pluralistic • Real-world practice oriented

Table 1. Four worldviews (Creswell, 2003)

The research question does not fall into the postpositivism category based on earlier arguments about positivism. The transformative view has a strong link to political science, and therefore is not an ideal guiding framework, either; however, the four characteristics of pragmatism suit the research question. Creswell also pointed out that pragmatism is not committed to one view in the philosophy of science. Thus, there are elements of constructivism in this research. The objective was not to identify a framework or model that explains or predicts disruption or its mechanisms; however, if findings that can be presented in a descriptive framework emerged during the research, the characteristics could be viewed as related to the worldview of constructivism.

Digitalization has been described as a set of systemic technologies, as it simultaneously impacts the business environment, stakeholders of the firm, and the way value is created. Digitalization can also lead to new types of products, services, operations, and business models. Dussauge et al. (1992) stated that generic technologies can have numerous applications in various businesses and industries. In a broad sense, digitalization is not a paradigm itself; however, based on the definition of the use of a paradigm (Kuhn, 1996), as discussed in Chapter 2, there are multiple practical paradigms, e.g., business models applied by enablers, actors, and users, which are related to digitalization. Still, some paradigms involve a broader context, such as whether economies will be more open or closed. Paradigms can guide scientific work despite the lack of a standard interpretation according to Kuhn (1996); the same logic is evident when developing a business. Identifying solid causal truths regarding digitalization as a paradigm changer in the machine-building industry is unlikely, which creates challenges in presenting the results of the findings. System thinking offers a viable alternative. Forrester (1994) stated that system thinking can be applied to system dynamics. In the same article, he (Forrester, 1994) argued that systems thinking and soft operations research fit well together in the conceptualization phase of researching system dynamics. He also asserted that the rise of soft operations research partly occurred because it can address issues of physical and social systems simultaneously.

3.2 Mixed methods

The obvious benefit of mixed methods is the triangulation of qualitative research with quantitative methods. For this dissertation, qualitative methods were the Delphi interviews and case descriptions whereas quantitative methods were used for the survey. All three methods are discussed in their respective sub-chapters. The validity and reliability of the methods are reviewed in chapter 5.3.

The ethos of this dissertation involves hermeneutics, and there was an intrinsic assumption that the object of inquiry is too complex to achieve a solid understanding; however, if the mixed methods overlap, are related to the research question, and generate unique perspectives, triangulation and a holistic understanding can be achieved. Greene et al. (1989) evaluated the aspects of using mixed method designs and identified five purposes: Triangulation, Complementary, Development, Initiation, and Expansion*.* Creswell (2003) classified the research strategy of the mixed methods into Sequential, Concurrent, or Transformative. During development, one method feeds other methods, which could be considered similar to Creswell's (2003) Sequential category. Expansion seeks to extend breadth, whereas initiation is related to the discovery of new perspectives. Greene et al. (1989) analyzed how mixed methods are integrated as part of an analysis or as part of an interpretation. Out of 57 mixed research projects they evaluated, they concluded that almost half had no integration and that almost 80 % of those with integration were part of the interpretation.

Using the classification system of Greene et al. (1989) and Creswell (2003), the research design of this dissertation utilized triangulation and expansion for the mixed method design. The process was partly sequential and partly concurrent so that the findings from an earlier phase could be used in fine-tuning the following phases. The sequential and concurrent phases of the research design, and triangulation and expansion are illustrated in Figure 12.

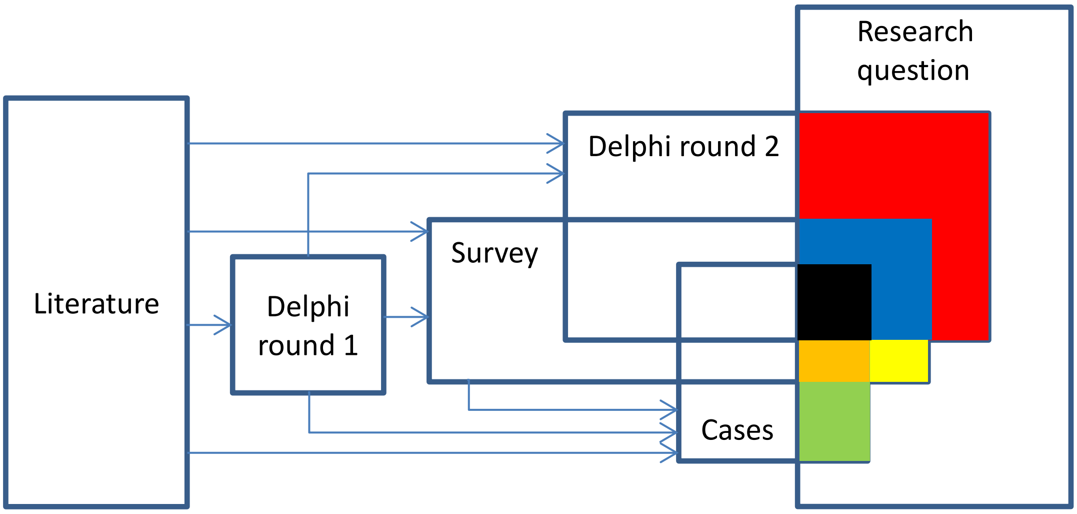

Figure 12. The research design

3.3 Delphi method

The purpose of the investigation was to understand whether there is emerging disruption enabled by digitalization in a machine-building industry that serves global ports and terminals as well as the mechanisms that drive or inhibit it. Important assumption is that dynamics is impacted by differences of the view in the value chain, which has been simplified to enablers, actors, and users. The source of empirical data was based on experts' opinions and their predictions regarding future development. One objective of the design of the Delphi interviews was a balanced distribution of the experts and their areas of expertise.

The Delphi method is not the only option for studying future developments. Other options include systems and evolution methods, scenarios, other expert methods, and the creative identification of weak signals (Kuusi et al., 2013). A rigorous system and evolution analysis would have required a large quantity of data over a long period, which reduced the feasibility of applying the methodology in a reasonable amount of time. Scenario research would have been an effective option. It was not selected because it can be applied later using the results from the Delphi methodology, as Mannermaa (1999) suggested in his book. Weak signals or important rare events, which Taleb (2010) referred to as “Black Swans,” could have been used to identify qualitative factors that can cause disruption. Digitalization is described as a complex systemic phenomenon. Taleb stated that “a complex domain is characterized by the following elements, both temporal (a variable depends on its past changes), horizontal (variables depend on one another), and diagonal (variable A depends on the past history of variable B). As a result of this interdependence, mechanisms are subject to positive, reinforcing feedback loops, which cause ‘fat tails.’” This dissertation assumes that the majority of enabling technology already exists and is economical enough to have a disruptive potential, and therefore the focus is on understanding managers’ decisions in applying the technologies. This also implies that the systemic loops referred to in Taleb’s definition are more important than identifying new “Black Swans.” There are also expert methods other than Delphi, such as various workshop methods in which a group of experts collaborate to solve a problem. The required professional and geographical aspects of the method would have been both impractical and expensive. Obtaining a holistic picture implied that some experts would be from competing organizations, and therefore the anonymity of the Delphi methodology was an integral requirement.

The Delphi method was named after the Oracle of the ancient Greek town of Delphi, and it got the modern methodology from the Rand Corporation, which investigated potential US industrial bombing targets from the perspective of a Soviet strategic planner in the 1950s (Dalkey and Helmer, 1963). Linstone and Turoff (2002) characterized the Delphi method as:

> *“Structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem.”*

One of the reasons to use the Delphi method according to Mannermaa (1999) is to manage large complex problems between disciplines that lack common experience, methodology, and language. Rowe and Wright (1999) stated that anonymity, iteration, controlled feedback, and statistical aggregation of a group response are essential features of the Delphi technique. Based on the researched cases, they concluded that Delphi can outperform statistical groups. They also argued that variations in the use of Delphi methodology increase the difficulty of verifying its validity. Originally, the Delphi process was intended to create an increasing consensus with a panel by repeating rounds (Linstone and Turoff, 2002). Kuusi (1999) argued that the panelists' arguments of their standpoints (for or against) over a straightforward consensus seeking are more useful in detecting future developments. Kuusi called this Delphi variant "Argument Delphi." There are also special techniques, such as the use of images to encourage panelists to form an opinion (Adelson and Aroni, 2002). Their study revealed that the use of patterns created stronger differences in the subgroups. The risk of using images involves a growing variance in the interpretation of the actual question that might void the benefit of user-friendliness that using images offers.

The Delphi technique has been criticized. The earliest and most cited criticism was from Sackman (1974), who based his critique on an extensive review of completed Delphi studies and concluded that the methodology should not be used until additional scientific procedures are incorporated. In his list of 16 conclusions, most are related to the applications of Delphi, such as in selecting experts or designing questionnaires. He criticized the forced consensus and suggested empirical experiments based on the methods of social sciences, which implied that the conventional Delphi method would move closer to positivistic worldview. Kuusi's (1999) response to Sackman's critique was that Sackman criticized Delphi based on opinion polls (transient invariances in opinion research), whereas the purpose of Delphi should be identifying relevant arguments for future development.

Using modern ICT technology improves the technical applicability of Delphi. Panels can be organized in which a large number of participants follow the Delphi process and its features. The development of preprogrammed algorithms enables real-time feedback. This development favors quantitative methods in analyzing the panelists' feedback. As quantitative methods were applied to the survey for this dissertation, face-to-face Delphi interviews were conducted to better understand the views of individual panelists.

The source of information for the Delphi method is the expert, which requires the researcher to follow specific guidelines. Experts must be selected in a way that he or she possesses the necessary knowledge to provide expert answers. The question or the argument must be formulated in a way that the answer contributes to the actual research problem. The research design must minimize the risk that the expert opinion reflects personal prejudices, biases, or distortion due to current events or any other beliefs that cannot be completely eliminated. For example, recent digitalization publicity could cause experts to overestimate the impact, which behavior is described by Availability Heuristics (Kahneman, 2003).

An important criterion for this research was the richness of data. For the Delphi rounds, this involved both the roles and backgrounds of the panelists. Kuusi (1999) offered a framework of the experts' roles in predicting future developments that can expand the richness of the data, which is presented in Table 2.

	Types of expertise
Scientists	Knowledge on invariance - permanent invariances of non-learning beings - transient invariances: habits, routines, and equilibrium points of learning actors
Decision-makers	Real and perceived capacity limits, perceived interests and routines, and real and perceived capability limits
Synthesizers	Relevant invariances, relevant capacity limits, relevant interests, and relevant capability limits

Table 2. Three types of experts on future developments (Kuusi, 1999)

In Kuusi's framework, the learning being may have a different behavioral disposition now than in the future based on experiences; the learning being also has intent and an active memory. The capacity is based on the resources available to act. According to Kuusi, real capability limits are boundaries of rational behavior. He also noted that when real and perceived capability limits are combined, the actor behaves rationally. Kuusi's (1999) capability statement is not derived from the competence of an individual or organization. Kuusi's General Theory of Consistency posits that a "learning being continuously changes its cognitive map in response to experiences of inconsistency." An important feature is that the decision-makers on a higher hierarchical level can move beyond the capacity and capability limits of a decision-maker of a lower hierarchy. A practitioner's interpretation of the synthesizer is that they master relevance by being able to operate both in the scientist's and decision-maker's space. To illustrate this role, in the interviews, they are visually placed in the presentation frameworks in between scientists and decision-makers, which is a different visual placement than in Kuusi's framework shown in Table 2.

The value chain was a background factor of this investigation. The value chain is a simplified version of Porter's (1985) value chain (Figure 7) and it only includes enablers, actors, and users. Eliminating logistics or any other part of the physical value chain reflects the focus on value creation that is based on knowledge enabled by digitalization. Therefore, the enablers are defined as the firms that supply digital technologies or related services. Porter's value chain (1985) is similar to the operations. Operation itself can be an object of disruption caused by digitalization. The users are the global ports and terminals. The framework of experts was designed by merging Porter's (1985) simplified value chain with the role of expertise in future development by Kuusi (1999). As both views consist of three elements, the size of the expert matrix will be 3x3.

3.3.1 Delphi round one

The digital technologies and concepts in economics and strategic management presented in Figure 11 were derived from the literature. The first objective of the Delphi interview round one was to determine whether the selection was relevant based on the judgment of the experts. The validation included all six technological concepts and the two concepts that are directly related to digitalization (Digital Business Models and Networks, Crowds and Platforms). The other five concepts were not included in the validation because they were either seminal theories used to explain industry evolution or fundamental components in economics, such as firms and capital. The first round of interviews either added or removed concepts from the pre-chosen 8 (6+2) concepts of the framework. The likelihood was low, as the concepts are rather generic in nature, but it is important to mitigate the prejudices that the researcher might have had when designing the framework based on the literature and research question.

The second objective of the interviews was to identify arguments that might explain factors that either accelerate or inhibit the concepts of the framework. The framework included six technological and seven economic/ strategic management concepts. The accelerators and inhibitors had to be in the same abstraction level in order to be able draw later on conclusions. The high number of concepts meant that the abstraction level was higher if the focus would have been one or two concepts. This was mitigated by encouraging the panelists to express concrete justification or examples when choosing accelerators or inhibitors. The concepts were referred to as drivers, and the accelerating and inhibiting factors were referred to as sub-drivers. The interviews were semistructured. The user interviewees in the first Delphi round were other than ports and terminals to include the expansion aspect (Greene et al. 1989). The reason for expansion is that there might be information in other industries that has not been learned in ports and terminals but that is or will be applicable to ports and terminals.

The round one interviews included 2-4 experts in each cell of the 3x3 matrix. For value chain selection, firms were required to meet the criteria defined in the research question, including the expansion in round one. Role section was relatively easy for decision-makers, as it can be narrowed down to owners, chairmen of the boards, CEOs, or those who manage a large business (from directors to executive vice presidents). The same logic was applied for the synthesizer, and the titles typically varied from CIO and CTO to various titles that indicate that the person is responsible for development related to the research question. Scientist selection was more demanding, as the number of potential persons even from one university was very high. The criteria for interviewees included publications or experience working with the industry in a specific part of the value chain that the role the scientist would represent. In all interviews the importance of the personal expert view was highlighted instead of "official" view of the background organization.

The process of the structured part of the first Delphi round was as follows:

1. Role in the 3x3 matrix
2. Research question
3. Research design (Figure 12) and research object (Figure 11)
4. Objectives of the interview (drivers and sub-drivers)

An important part of the research object brief was the conceptual distinction between continuous improvement, quantum leaps, and disruption and the description of the different technologies. The time and style of descriptions was adjusted to match individual interviews, as all experts chosen possessed high expertise in most concepts, and their expertise in individual concepts exceeded the expertise of the interviewer. The open portion of the interview allowed experts to express any perspectives that might be relevant to the research question that were not included in the framework.

Some of the participants were likely to be insiders in public companies, and some of the questions might be sensitive. Therefore, the interviews were not recorded. The interviewees were also assured that none of the memos would be distributed, no quotes with names would be used, and no results would be presented in a way that would reveal their identities. The interviewees would most likely have approved recording, but they would also most likely have filtered their views. Interesting views of potential disruption do not necessarily align e.g. with the current agenda of the firm, and recording was not done even if some details were missed in the written notes. Harvey (2011) concluded that this is a tradeoff that the researcher must choose for interviews when trust is of utmost importance. Walsham (2006) argued that recording has a disadvantage in that the interview might be less open or truthful. This would increase the risk of favoring arguments that are better suited to the organization of the respondent. The outcomes of the interviews included documented views on the disruptiveness of presented drivers and suggested sub-drivers.

3.3.2 Delphi round two

The objective of the second interview round was to rank the selected drivers, and the three most important sub-drivers that either accelerate or inhibit drivers. The suggested sub-drivers were derived from the literature and Delphi round one. The experts were permitted to present new sub-drivers as well. When a new sub-driver emerged, that sub-driver was available for the next interview. The pattern of the emergence of new sub-drivers and their order of rank provided additional data on the consensus patterns in the value chain. Delphi round two also included an open portion in which the experts could either elaborate on their rankings and suggestions of new sub-drivers or express their views of the research question regarding whether digitalization is disruptive for the machine-building industry, which part of value creation is mostly impacted, or which mechanisms cause disruption.

The selection of the population was done based on the same principles as described in Delphi round one with two exceptions. The size of the population was expanded to four experts in each of the cells to enrich both international coverage as well as the coverage of the firms and universities. Some of the experts were the same as in round one. The second difference was that the users were only from ports and terminals. For universities, this implies that the experts had researched transportation or logistics. This increased the focus on the research question. The interviews were not recorded based on the same reasons as the round one Delphi interviews.

For the structured questions, either VAS (Visual Analogue Scales) or Likert scales could have been used. The motivation to use order ranking was to encourage experts to think critically. The use of a Likert scale could generate average ratings, which would yield similar values for several of the drivers and sub-drivers. This result could have been avoided by eliminating the midpoint of the Likert scale, which according to Garland (1991) is effective for socially unacceptable answers. Fabbris (2013) showed that the mental effort further increases during order ranking than rating, which suggests that for order ranking, the choices should be below 10. The procedure can be simplified by concentrating first on the highest and lowest. For the drivers, this was achieved by ranking only six digital technologies and seven economic/ strategic management drivers. The selection of only the 3+3 most important drivers for the sub-driver ranking was partly done to simplify the mental effort, as Fabbris (2013) argued. The second reason was to maximize the interview time so that issues that the expert judged to be most relevant to the research question could also be discussed.

The experts were told that the logic of disruption is based on the Schumpeterian (2012) concept, which was reduced to the PEST model from which drivers were derived from digitalization (technology in PEST), economic/strategic management (Economy in PEST) literature, and Delphi round one interviews. Political and social factors were present (if deemed applicable) in the sub-drivers that either accelerated or inhibited the digital or economic/ strategic management drivers.

The process for the structured part of Delphi round two was as follows:

1. Briefing
2. Order ranking of technology drivers
3. Order ranking of economic/strategic management drivers
4. Technology (digitalization concepts) driver number one
    a. Suggestion of new inhibiting sub-drivers
    b. Order ranking (1,2,3) of the inhibiting sub-drivers
    c. Suggestion of new acceleration sub-drivers
    d. Order ranking (1,2,3) of the accelerating sub-drivers
5. Economic / strategic management driver number one
    a. Suggestion of new inhibiting sub-drivers
    b. Order ranking (1,2,3) of the inhibiting sub-drivers
    c. Suggestion of new acceleration sub-drivers
    d. Order ranking (1,2,3) of the accelerating sub-drivers
6. Repeating the same process as no. 2 and 3 technology and economic /strategic management drivers

7. Free comments

The presentation slides used for the panelists are shown in Appendix 2.

3.4 Survey

The first objective of the survey was to triangulate the results from the Delphi interviews for all digitalization drivers and economic/ strategic management drivers that are directly linked to digitalization (Digital Business Models and Networks, Crowds, Platforms). As the respondent's time spent on the survey was considerably less than the time spent by the interviewees, Digital Business Models were simplified to the Industrial Internet, which is assumed to be better known, and Networks, Crowds, Platforms were simplified to Open Innovation for the same reason. To enable triangulation, participation followed the same 3x3 matrix as the Delphi interviews. The objective was to achieve a minimum of 250 responses.

The survey also expanded the breadth and scope of the inquiry (Greene et al. 1989) of the Delphi interviews in three different areas. First, there was an expansion to the judgment of the explicit systemic impact of the digital technologies to firms' products, services, operations, and business models. The second expansion was the participants' judgments on timing if they perceived that the systemic impact of the digital technologies would be disruptive. The third expansion involved understanding how well the firms or research institutes are prepared for the potential disruption based on the respondents views on future development. This implies that a small investment may be adequate if the digitalization impact is perceived to be low.

The reason for the targeted size of the population is that it enabled conducting statistical tests using the background factors (independent variables), which in this case are the respondents' place in the value chain and the role of expertise in predictions of the future. A third background factor could be the respondents' judgments on how well their organization is prepared for potential digitally enabled disruption. Values assigned to the various technologies and concepts, and the impact to products, services, operations, and business models also offer the possibility to analyze dependencies using statistical methods.

3.4.1 Experiment

One issue related to surveys is a low response rate according to a study by Baruch (1999) in which data from 175 different studies was used. His result showed an average response rate of 55.6 %, but only 36.1 % in studies in which respondents were from top management or companies. For surveys, there are also unknown factors, including who actually completed the questionnaire and whether or not the respondents understood the questions in the same way. The design of this survey attempted to mitigate these problems using a method in which the respondents were recruited from seminars, either organized by conference companies, research institutes, or companies internally. Seminars were selected so that almost all audience members would represent one of the roles in the matrix. The survey began by presenting the definition of the concepts used in the survey, explaining the response process, and instructions regarding how to complete the expert matrix position. The objective was diversity in both companies and geography. This process design provided close to a 100 % response rate and fewer misinterpretations of the questions than in mailed questionnaires. One risk is related to the question of whether representatives in the seminars were from a relevant population. The study by Short et al. (2002) revealed that based on 437 studies, less than 20 % used random sampling. They also evaluated one study related to CEO performance and concluded that different sample strategies provided different results. This survey included a hybrid approach in which company internal seminars typically have a predetermined population, but open seminars have a more random audience. The obvious risk is that the nine cells could be either underrepresented or unevenly distributed. The matrix offers a possibility for comparison by aggregating the value chain roles or doing the same for the expert roles, which would both provide a group of three for comparison. The whole population could also be used as a statistical comparison group against the aggregated Delphi interview results.

A mixture of a structured scale and a VAS scale was used as a measurement tool, which was applied so that respondents first determined whether the impact of an individual question was continuous improvement, a quantum leap, or disruption. Under the chosen category, the respondents indicated the strength of the impact by placing an “x” on a continuous scale in which the furthest left is the weakest impact, and the furthest right is the strongest. During the analysis, the three categories were then divided into three sections so that continuous improvement in the first section received a value of 1 and last section received a disruption value of 9. The categories were marked with colors to differentiate between them, but there were no red, green, or yellow colors to avoid any impression of desirability. The Likert scale and its derivatives are predominantly used in business research, but VAS is most effective when a respondent has a strong view on a topic but some of the reasons might be difficult to explain. Based on the definition of VAS in research articles, it is mainly used in medical research, such as when patients must rate the degree of pain. The expansion of VAS to other sciences seems to be related to online surveys, which can partly be explained because the use of VAS with pen and paper has an extra phase due to recording the VAS result into a numerical value. In online surveys, this can be programmed as an automatic feature, and there are VAS engines available on the Internet. Neibecker (1984) studied structured scales and continuous scales with two test groups and concluded that there were no major differences in the results; however, he determined that the continuous scales might have better user interfaces, as they are less monotonous and also allow for more accurate answers than structured scales. The VAS results from this research were restructured; the raw data remains available for further research using also the detailed values.

The experiment proceeded in the following sequence:

1. Background (research question, definitions, process, instructions for the role)
2. Answering section one (impact to products, services, operations, business models) individually with a 30 second time limit for each judgment
3. After section two, the participants indicated disruption in any of the categories were instructed to have a view how long it takes that the disruption has reached a status that it is a normal way of doing business, 60 seconds
4. In section three, the instructions were repeated, and thereafter, participants indicated their views on the disruptiveness of individual technology and economic/ strategic management drivers (120 seconds).
5. Finally, the participants rated the readiness of their organization in 30 seconds.

The data collection was formatted with exact timing. The same presentation slides were used, and each slide had the same script to minimize variance between the experiments. The total duration of the experiment was 20 minutes. The survey form is shown in Appendix 3.

3.4.2 Analysis

The survey data was filtered and completed before the analysis. During filtering, samples that were missing any background information (independent variables) were excluded. The final question was answered using the VAS scale (which had guiding numbers shown in Appendix 3) to indicate his or her organization's preparedness for the potential disruption, which is an interesting result, per se; however, the answer was also used as additional background information. This was accomplished by dividing the VAS scale in three equal sections so that the answers close to 0 were neutral, answers closer to -2 were regressive, and the answers closer to +2 were progressive.

The pen and paper method was used for the survey, and after filtering, the data was typed into the Excel database so that each row represented one respondent. After the initial input, all data points in the database were checked twice to minimize marking or typing errors. Completion was done by replacing the missing value in the sample with a value that was the average value of the variable given by respondents in the same role/value chain matrix. Completion reduces variance, and it is selected to be applied based on the total amount of missing values in the whole population.

After completion, whether the data followed a normal distribution was verified, as this impacts the choices of analysis. This was done using the Shapiro-Wilk test (Shapiro and Wilk, 1965), which according to Razali and Wah (2011) is the most powerful of the four normality tests they evaluated as long as the population size is above 30. The Shapiro-Wilk test as well as other analyses and visualizations were completed using the Microsoft Excel add-on statistical tool XLSTAT[20].

The role of expertise in future (Kuusi, 1999) creates different perspectives. The object of inquiry was to understand how the views differ based on where the respondent is in the value chain, and the role of expertise is used to enrich the perspective. Also, the additional independent variable, the preparedness of respondents' organizations for the potential disruption, might explain the given values. This creates a risk of generalization of the results if the size of sub-populations differs, as some of the sub-populations can either dominate or be under-represented. For generalization, the size of all populations should be between 10 and 20 (tight control); otherwise, it should exceed 30 (Roscoe, 1975). Forcing equal representation later on would create a risk that the new samples would not be comparable with old samples. The generalization risk can be mitigated by balancing the sub-populations in which each sample is assigned a coefficient that balances the contribution of each sub-population in the entire population. To obtain the coefficient for individual samples, the total weight of the sub-population is divided by the number of samples in the corresponding sub-population. In further analyses, selected methods can utilize the coefficients when calculating weighted averages or vari-

[20] https://www.xlstat.com/en/solutions/base

ances, for example. The data formed 27 sub-populations when using three independent variables (3x3x3).

The final step before presenting the results was to ensure that the interaction effect did not distort the interpretation of the results. The interaction effect (Dawson, 2014) shadows the true impact of the background factor as another background factor (also called a moderator) that affects the same value of the inquiry. The background factors of this inquiry were role, the place in the value chain, and perceived investment impact. The presence of the interaction effect in the balanced data was determined by running a two-way ANOVA test.

The survey results are initially reported as individual results. The interpretation of the results is included in the discussion and conclusions Chapter 5 in which the results are compared to both the literature and the results using the other two methodologies.

3.5 Cases

The objective of the case descriptions was to illustrate that there are existing or emerging disruptive phenomena in the scope of the research. The descriptions indicate future developments through analogies, and they stem from De Jouvenel's (1967) claim that the future must be plausible based on the current state of affairs. Analogies do have shortcomings, which Martino (1993) listed as: lack of inherent necessity (history was not based only on physical factors), historical uniqueness, historically conditioned awareness (do your homework well), and causal analogy (things are not normally the same in all respects). He also emphasized the need for holism when using analogies, as technological change is a result of technological, economic, managerial, political, social, cultural, intellectual, religious-ethical, and ecological dimensions, which is a similar viewpoint as PEST (Aguilar, 1967) and its derivatives regarding changes in the business environment of a firm. In this dissertation, analogies serve a hermeneutic purpose to increase understanding rather than to predict causality.

Case research is a widely used method in management science, and case methodology has been an integral part of the research of multiple highly cited articles and books (e.g., Chandler 1990, Christensen 2011, Gawer, and Cusamo 2002). The number of cases needed is based on the goal of the inquiry. A study by Benbasat et al. (1997) on the applicability of case research in information systems showed that if the aim is descriptive, a multiple case approach is recommended. Yin (2014) listed sources for case research data: documentation, archival records, interviews, direct observations, participant observation, and physical artifacts. Case studies have similar sampling issues as other methodologies, but the methodology is chosen based on the aim of the investigation. Eisenhardt and Graebner (1997) discussed sampling in the theory building that utilizes case research:

> *"*The purpose of the research is to develop theory, not testing it, and theoretical (not random or stratified) sampling is appropriate. Theoretical sampling simply means that cases are selected because they particularly suitable for illuminating and extending relationships and logic among constructs.*"*

The sampling in this study followed the view of Eisenhardt and Graebner (1997), especially because the role of the case descriptions involved triangulation and expansion. The criterion for the cases was that the firm was either conducting or planning (published) to conduct business utilizing digital technology to create value in a novel way. Value is also created in a space between the current actors and users, and the case actor is not a direct competitor of the digital enabler of the case. The value potential must be considerable in comparison to the investment needed. In the case descriptions, the structure of the industry is described as well as how the case has created new value and how it is away from actors (either from the current business or future growth potential). The case data was collected from public sources but validated by the representatives of the case firms or by the representative of actors impacted by the cases. The detailed case design was completed after reviewing Delphi one round and the preliminary results from the survey, which follows the sequential approach of mixed methods (Creswell, 2003).

The selected cases include Enevo[21], Trimble[22], and XVELA[23]. Enevo is a firm involved in waste collection, Trimble is involved in farming (the business case has several similarities with the case presented by Porter and Heppelman (2014)), and XVELA is involved in container shipping and handling. Detailed descriptions will be presented in Chapter 4.

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[21] https://www.enevo.com/
[22] http://www.trimble.com/
[23] https://www.xvela.com/

4 Results

The results are presented by following the same mixed methods logic as in the previous chapter, and they form stand-alone sections. The comparison of the results by different methods is in the discussion and conclusion (Chapter 5), which is the inherent strength of the mixed methodology research design. The user in this enquiry has been a global terminal operator. Therefore, the first sub-chapter, 4.1., presents the characteristics of the global container handling industry in order to create a background against which the results can be understood.

4.1 Global container handling industry

The generic industry is transportation, which has a sub-segment—cargo transportation—to separate it from passenger transportation. The focal mode of transport is sea transportation, even though land transportation is briefly discussed as part of the supply chain. Over 80% of global trade is seaborne (UNCTAD, 2015). The alternative mode to long-haul ocean shipping is air freight, whereas the short-haul shipping alternatives are transport by road, rail, or river. In sea transportation, the transported goods are liquids, gas, bulk, and break bulk. The containers are steel boxes used to carry the cargo, and are standardized in length, width, and height; the most common size is 40 feet long, 8 feet wide, and 9.5 feet high, the volume of which determines the maximum dimension of the goods to be loaded into the container. The majority of the containerized cargo is break bulk, although even bulk and liquids can be transported in containers. A reefer container is a special container with an integrated cooling unit to keep perishable goods (e.g., food) in ideal condition during the voyage.

The transportation system has two main actors: the shipper and the consignee. The shipper or consignee can be a primary producer, factory, trading company or individual consumer, depending on the function of the transported goods.

Ocean shipping originated hundreds of years ago, when the sailing ships were carrying spices from Asia to Europe. The loading and unloading of ships was manual work. Based on this dissertation, one can argue that the invention of the container in 1956 on the East Coast of the United States (Levinson, 2006) was a disruptive innovation in sea transportation. One of the interviewees in the first Delphi round commented that disruptive innovations rarely satisfy fundamentally novel needs but rather satisfy old needs with a fraction of the cost. The container eventually met the criteria. Using today's language, one could say that the container was a platform that enabled disruption of the transportation system. With this view, the network effects were important—the number of actors who adapted to the new method and the degree to which freight was containerized. One important characteristic was that the container set the international standards that complementors were able to use in their development—ship, truck, rail wagon and container handling machine builders. The container was a very important decision to a port, as the weight of the container—tens of tons—made it impossible to handle with manual labor, leading to the need for mechanization of ports and, consequently, the pioneering innovations in container handling equipment. The end result of the innovations made transportation costs of many goods so low that the goods could be produced wherever it was most economical, regardless of the final place of usage. The innovations also created inertia, where the cost of changing the container as the platform of the transportation system had become beyond justification.

The user in this dissertation is a port operator in the service business. The needed infrastructure (e.g., quay, buildings, power supply) is often leased from the port authority. The main supplier for the port operator is the equipment manufacturer which provides the equipment needed for the operation. For running the port, the operator needs an array of services like ICT services, building and equipment maintenance, and security. The operator can opt for most of the services to be provided internally or by external vendors. The container operator—one of the port stakeholders—serves the shipping lines in the sea transport system and the trucking and railroad companies in the land transport system. If the operation is transshipment, the containers normally arrive in large vessels and are redistributed to continue transport by smaller vessels, and vice versa. Customs, freight forwarders, and labor unions are other typical port-specific stakeholders.

Industry has always been international due to the nature of shipping. The shippers and consignees are extremely fragmented, but the shipping lines, ports, and equipment suppliers have been consolidating over the years. The five largest shipping lines account for 48.7% of the global market (Alphaliner, 2016), while the five largest terminal operators represent 49.7% of the market (Drewry Maritime Research, 2014). In addition, the five largest equipment suppliers provide 87% of industry cranes and 66% of mobile equipment; three companies were present in both categories (Schäfer, 2014). Some of the shipping lines also operate terminals, which typically are also open for the other shipping lines. The five largest shipping lines appear in Table 3, and the five largest terminal operators in Table 4. The container flows are driven by consumer markets, and the highest growth occurs when there is a growing middle class. For example, in 2013, 54% of the world's containers were handled by Asian ports (Drewry, 2014).

Rank	**Operator**	**Existing capacity / million TEU**	**Market share**
1	APM-Maersk	3.1	14,7 %
2	MSC	2.7	13.0 %
3	CMA-CGM	1.8	8.8 %
4	COSCON	1.5	7.4 %
5	Hapag-Lloyd	0.9	4.5 %

Table 3. Five largest shipping lines (Alphaliner, 2016)

Rank 2013	**Operator**	**Throughput / million TEU**	**Market share**
1	Hutchison Port Holdings	76,1	11.8 %
2	APM Terminals	68.0	10.6 %
3	PSA International	61.7	9.6 %
4	Cosco Group	59.9	9.3 %
5	DP World	53.7	8.4 %

Table 4. Five largest terminal operators (Drewry Maritime Research, 2014)

The business environment for the shipping lines, ports, and equipment manufacturers can also be analyzed using the same framework, PEST (Aguilar, 1967), which was utilized in the Delphi interviews. Political connections to the maritime industry are strong. Merchant shipping, and an own navy to protect the sea trade have strong roots. Functioning ports have equally key functions in the foreign trade of a nation. Historically, ports were run either by governments or municipal organizations, but one strong trend over recent decades has been privatization; the global terminal operators have taken the operational role. The largest operator, Hutchison, is running terminals in 52 ports located in 26 countries across all continents.[24] However, the public authorities have kept their control through the terms of the concessions—often over 20 years—that they have granted to operators running their terminals. The concerns about climate change, environment, and safety are embedded in the political goals that end up in the legislation and regulation that impacts the maritime industry. Ships and the port equipment use fossil fuels, and carbon directives, engine emission regulations, and fuel taxation are measures that politicians can use to mitigate the impact. The rising cost of noncompliance, like oil leakage, also drives behavior to use technologies that are less oil-dependent. Environmental permits for greenfield ports call for stricter procedures than those of the existing ports. Ships, shipyards, and ports are also hazardous workplaces, and various types of safety standards are common. Ports are also the places where the goods not listed in the manifest are flowing (e.g., drugs, arms, explosives, radioactive and chemical materials, illegal human immigrants), which have both direct and indirect impacts on maritime stakeholders.

The economic impact of the ocean shipping and port handling costs are relatively low in relation to consumer goods transported in the containers. Therefore, the efficiency is not driven by fragmented shippers or consignees; rather, the cost is levied into the retail prices. However, shipping is a volatile business, and the shipping lines have large investments in capacity. The competition has kept earnings at a relatively low level, and the EBIT margin has varied between 5-10% between 2006 and 2013 for the major companies (Schäfer, 2014). Shipping lines have mitigated this volatility by forming alliances to, for example, share capacity in ships. In 2012, the size of the container liner business was $225 billion (Schäfer, 2014). The port business is location-driven; if a port is near a large consumer base, it already has a structural advantage. The operational success factor for the port operator is to turn the ship fast and economically, as

[24] https://www.hph.com/en/webpg-87.html, retrieved 13.1.2016

the ship is the largest investment in the system; 18.000 TEU ship cost approximately \$185 million[25]. It is equally important that the turnaround time is predictable, which allows the ship to travel at an optimal speed in order to save fuel. The revenue for the operator comes from the volume of containers multiplied by the handling fee per container; the global market size was \$57 billion in 2012 (Schäfer, 2014). The four main elements in the cost side for manual operation are capital cost of the equipment, drivers, fuel, and maintenance and repair. Port operators are making far better profits than the shipping lines; the average EBIT margin varied between 20-30% for the major players between 2006 and 2013 (Schäfer, 2014). Equipment suppliers can be categorized into regional or global; they can also be divided into general machine builders that also make port equipment, or specialized companies. The business model is building the equipment fleet in a competitive market in order to make the profit with spare parts. Various levels of service contracts slowly emerge. Distribution is a hybrid of direct sales and use of distributors. The size of the port equipment market was \$5.7 billion in 2013 (an increase of 10-15% after service revenue), whereas the EBIT margin has varied between 2-6% with major players between 2007 and 2013 (Schäfer, 2014).

The strongest social connection is employment. Indirectly, a functioning port supports employment through foreign trade in the same way that ineffective ports drive employment away. This critical role has made port workers' labor unions strong throughout the world. The maritime cluster—shipping lines, shipyards, ports, port service providers, port equipment manufacturers, subcontractors—is also a large source of direct employment. Importance for employment has made governmental subsidies in shipbuilding, for example, a common phenomenon. In Finland, the maritime cluster employed 47,000 people (Viitanen et al., 2003).

Port-related businesses encompass multiple technologies, but only the ones that impact the system are mentioned (i.e., ship size, electrification, automation, smarter machines, and ICT). The ship size is undoubtedly the largest driver of the dynamics, as it impacts the economy of the business, freight routes, seaside operations, ports, and the hinterland, and it drives both the size of the container handling equipment—particularly cranes—and all other technologies that can speed up the operation. Figure 13 shows the development of container ship size in the last 20 years.

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[25] http://www.bloomberg.com/bw/photos/2013-09-05/holy-ship#slide2, retrieved 13.1.2016

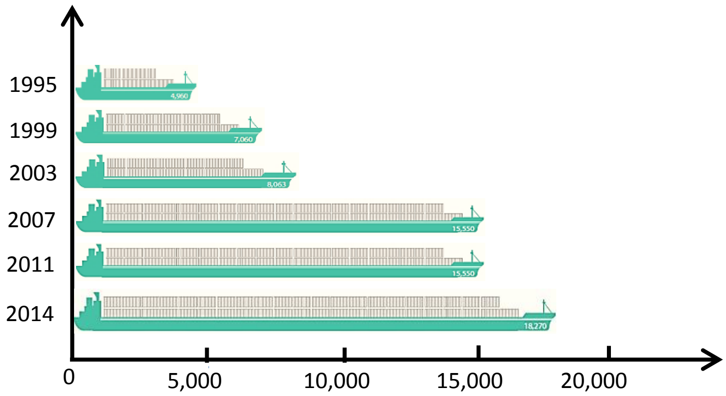


Figure 13. Ship size development in TEU's (Drewry Maritime Research, 2014)

Electrification is one technology trend that relates to the endeavor to reduce fossil fuels. It makes the local emissions insignificant, but the systemic impact is dependent on how the primary electricity is produced (e.g., oil, gas, coal, solar, wind). Electricity also offers potential to harvest the waste energy when lowering a container or braking mobile equipment, for example, when the waste energy can be stored into the batteries, similar to the process in hybrid passenger cars. Passenger cars, in fact, are the primary industry where heavier batteries are currently researched and developed. Local emissions are also important, as the ports are close to urban areas. Technologies that enable automation are driven in some parts of the world by labor shortages, in other areas by the cost of labor, and in some applications by safety; these drivers also exist at the ports. The first unmanned terminal was opened in Port of Rotterdam by European Container Terminals (ECT) in 1993[26]. Since 1993, the number of automated terminals increased from one to 26 in 2013, and at that time there were plans for an additional 30 unmanned terminals, which indicates that the market is breaking (Schäfer, 2014). The ship loading and unloading is still done by the operators, however. Smarter machines are present in the ports, but the situation is no different than in mining, construction, agriculture, or forestry sectors. The machine components have embedded software and sensors, and the machines can harvest the data for the purpose of internal control and optimization; they can also communicate externally, either locally or over the Inter-

[26] http://www.ect.nl/en/content/history, retrieved 18.1.2016

net. ICT technology is embedded in components, machines, fleets, and system levels, as well as within the processes of the firms that build the machines.

It is important to recognize that shipping has always been, and is likely to remain, fundamentally a commodity business (Lorange, 2009). This implies that despite the choices of specialized strategy, there is a prerequisite of cost competitiveness in products, services, and internal operations for the actors participating in shipping. It is fair to assume that many of the old recipes of continuous improvement still work. Digitalization is also a current topic in shipping, and the recent McKinsey and Company research report argued that digitalization is not only enabling better, safer, and simpler processes in shipping, but also reducing significantly costs in all phases (Hausmann et al., 2015).

4.2 Results from the Delphi interviews

The first Delphi interview round took place between October 20, 2014 and February 12, 2015 (comprising 92% of the interviews), and the second round interviews were conducted between October 19, 2015 and December 21, 2015 (comprising 95% of the interviews). The combined number of interviews was 60, from which 54 were face-to-face; and six interviews were online. Interviews lasted between one and three hours, with more than 80% lasting around two hours (the time predicted when agreeing to the interviews). The two-hour time was based on three test interviews conducted prior to the actual interview rounds. The list of participants of both Delphi rounds one and two are located in Appendix 4, and after each panelist there is a reference in which value chain perspective he or she was interviewed (E= Enabler, A=Actor and U=User). This was important as some of the panelists had been working during their career in more than one value chain area.

A general observation from the interviews was that expert behavior differed depending on the role of expertise on the future (Kuusi, 1999). Decision-maker interviews were clearly shorter than those of the scientists. Decision-makers expressed quite often the logic of uncertainty, but at the same time the need to make decisions based on what is likely to happen despite imperfect information. Scientists, independent of their location in the value chain, took longer than decision-makers to form their views on specific drivers or sub-drivers, despite the fact that their actual knowledge often was deeper than the knowledge of their decision-maker counterparts for that specific driver. Most of the scientists, however, offered valuable input to the research methodology even when it was not asked as part of the interviews. The synthesizer group was closer to the decision-makers in their ways of interacting in the interviews. This most likely can be explained by the fact that they were employed by the businesses, even though their functional responsibilities were close to research and development.

4.2.1 First Delphi interview round

First round participation based on the expert role in the value chain is illustrated in Table 5. Panelists came from seven different universities or research institutes, and 14 different companies, of which 12 were in global business. One-third of participants were not Finnish citizens.

Role/ Value Chain	Enablers	Actors	Users
Scientists	3	3	2
Synthesizers	4	3	2
Decision-makers	3	2	2

Table 5. The Delphi panel in round one

The first objective of Delphi interview round one was validating the six technological drivers that that were suggested by the earlier cited research reports (like Manyika et al., 2013) to have potential to cause industrial disruption. The suggested drivers were AM/ 3D printing, Big Data/AI, Cloud, IoT, MBSE, and Robotics. Validation included a possibility to suggest new drivers. The second objective was finding sub-drivers that either accelerate or inhibit the development of each driver.

The validation was an open discussion, where each driver was reviewed in the context of continuous improvement, quantum leap, or disruption. Review was not based on scoring or ranking but letting the panelist elaborate what his or her judgment of the impact of a particular technology. The researcher translated later the written views into the above mentioned three categories. A comment like, “I believe that 3D printing will change the rules how manufacturing companies create value” implied disruption category.

Out of the 24 interviews, 57 views were given that the driver could be disruptive in the context of the research question, 41 that the maximum that the driver could reach is a quantum leap in competiveness, and only five that viewed the driver as unable to achieve more than continuous improvement. The span for the individual drivers extended from two to 16 views being disruptive. The driver that got only two disruptive views got 14 views being a source of a quantum leap. Based on the results all original drivers were included in the order ranking process in the Delphi round two. One panelist proposed mobility as a new technological driver with a context of firms' resources being location free. It was not taken to Delphi round two on the basis that mobility is inherent feature of the Networks, Crowds, Platforms which is one of the economic / strategic management drivers.

Sub-drivers were also derived from the written comments where the panelist elaborated his or her judgment of a particular technology. A comment like "3D printing will be disruptive technology as soon as metal based materials can be printed" implied the inhibitive sub-driver, low number of printable materials for AM/3D printing. Some of the sub-drivers were suggested in the context of more than one driver; data security risk e.g. was suggested in the context of Big Data/AI, Cloud and IoT. Sub-drivers with the same content could have been suggested both as inhibitors or accelerators, but that did not happen.

Some suggestions of sub-drivers formed almost Hegelian thesis-antithesis relationships, like the one relating whether users open their data (i.e., open = accelerates; not open = inhibits). The same example can also be characterized as following Boolean logic even in individual use cases; the user opens its particular section of the machine data or not; the user opens all of its machine data or not. Following the user data example, the likely expert view for that sub-argument in the Delphi round two is a heuristic judgment of the average state of affairs; majority (minority, most, only some …) of the users are likely to refrain from giving access to their data based on my judgment of the benefits of the technological driver that I am aware of. It appeared that the inhibitive sub-drivers were more often attached to behavioral aspects (like beliefs), whereas accelerative sub-drivers were easier to quantify (e.g., short development time).

More than 30 inhibitive and 50 accelerative sub-drivers were proposed. All those that were named more than once were merged onto the list from literature and research reports. In that merger, sub-drivers that had the same content but different names were placed under one name. The merged list of technological drivers and sub-drivers is presented in Table 6.

	Inertia sub-driver	Accelerator sub-driver
AM / 3D printing	Limited size of the object Slow printing speed Low # of printable materials High investment cost Lack of competences Management beliefs Investment in current infrastructure	Digital distribution (e.g. spares) Manufacturing recipe as IPR Unique mass production Sustainability Manufacturing close to usage New product features
Big Data / AI	Lack of relevant history data Data security risks Data ownership confusion Data ownership conflict of interest Management beliefs Lack of competences Privacy concerns	Reduce of human errors Knowledge scalability Diagnose speed Prescriptive potential Core element in digital B2B business models Emergence of platform tools Advancement in cognitive computing Users open their data
Cloud computing	Data security risks Investment in legacy systems Lack of competences	Enabler for new business models Quantum leap in operational productivity Emergence of platform solutions Low cost of computing High supply of partners Lower barrier of computing
Internet of Things	Data security risks Lack of standardization Lack of systemic understanding Lack of competencies Non sensored Installed fleet Cost of data transmission Availability of data transmission Management beliefs	Systemic productivity New source of customer insight Emerging platforms Digital entrants to equipment business Inceptive to crowd Enabler of new business models
MBSE	Incompatible legacy systems Legacy processes Lack of competencies Management beliefs	Reduced # of errors in development Short development time Low development cost Enabler of crowd knowledge Enabler of customer engagement in development
Robotization	Legislation lagging behind High capital cost Lack of infrastructure Social disruption Technological risks High switching cost Manned design paradigm	Systemic productivity Low wear, tear and collision costs Good LCC predictability High safety Sustainability Compensation of labor shortage (incl. labor unrest)

Table 6. Results from Delphi round one, technological drivers

The process of validating the economic / strategic management drivers was the same as with the technological drivers. As described in the methodology chapter, the validation included only those two drivers that are directly related to digitalization (Digital Business Models and Networks, Crowds and Platforms). The other five drivers of the Figure 11 were not included in the validation because they were either seminal theories used to explain industry evolution or fundamental components in economics, such as firms and capital.

Out of the 24 interviews, 13 views were given that the either of the two proposed driver could be disruptive in the context of the research question, 14 that the maximum that the driver could reach is a quantum leap in competiveness, and only three that viewed the driver as unable to achieve more than continuous improvement. Based on the results both drivers were included to the list of other five economic / strategic management drivers as illustrated in the Figure 11.

As a note, the round one interviews also yielded comments about Convergence, Radical Innovation, Five Forces, Stakeholders, and Capital. Convergence was mentioned several times to explain strategic management mechanisms and to explain potential disruption, which endorsed the argument for it to be in the list for Delphi round two. Radical Innovation as a disruptor concept was viewed to be based on the content of the innovation itself. Capital discussion was pre-dominantly around the potential impact of “Silicon Valley” types of Venture Capital on the asset-heavy industries like machine-building. The role of capital more often was viewed as a catalyst of a disruption that has already started, rather than the initiator of that process.

Just as with the technological drivers, the majority of the interview time was spent on discussing sub-drivers that can either inhibit or accelerate the potential disruptive impact of the economic/strategic management drivers. The proposed sub-drivers were merged with the sub-drivers of the literature, the same way as with technological sub-drivers, and the results appear in Table 7.

	Inertia sub-driver	**Accelerator sub-driver**
Five Forces (six)	Rivalry between existing competitors Cost driven customers High entry barrier industry Long established stakeholder organizations Oligopolistic market	Digital entrants to traditional industries Substitutive business models Value driven customers Value driven suppliers Influential Early Adopters Suppliers passing middle-men Active 6th force

	Inertia sub-driver	**Accelerator sub-driver**
Industry convergence	Industry organs Industry beliefs, strong dominant logic Cultural barriers Industry specific financial KPIs	Platform supply Management rotation Business model diffusion General digital technologies Consumer business behavior into B2B
Radical innovation	Legacy competences Legacy processes and systems Legacy leadership and management Return on continuous improvement Risk adverse business culture Conservative industry Lack of absorptive capacity	Software intensity Access to crowd knowledge Experiment culture Influential Early Adopters New level of customer insight Powerful development tools
Digital business models	Data security risks Data ownership confusion Fixed legacy systems and processes Lack of dominant theory Incumbents active resistance Lack of trust in virtual environments High barrier industry	Quantum leap in productivity Real time opportunity Asset light Influential Early Adopters Slow growth of existing business Startup emergence
Networks, Crowds, Platforms	Lack of capabilities Management beliefs Lack of systems and processes Lack of trust in virtual environments Conflict in IPR	Platform availability (discipline) Unrestricted capacity Fixed cost light Startup emergence Diginatives to firms Open source hardware Self-fulfillment motives of knowledge workers Crowd intelligence effect
Firm, Strategy, Management	Strong Industry beliefs Next quarter pressure Leadership from the past Well established dominant logic Complex organizations Hierarchical organizations Incrementalism	Bandwagon, Hype, Halo Management consulting focus Slow growth of traditional business Management rotation Emerging digital strategy frameworks Experiment culture Degree of external engagement
Risk capital	Missing financial track record Inexperienced management Impatience	Crowdfunding Asset light High upside Low interest rates Success stories

Table 7. Results from Delphi round one, economic / strategic management drivers

Additional observations from the Delphi round one

The World Economic Forum (2015) suggested a path to Outcome Economy that was seen in Figure 5. That view was also similar to what Porter and Heppelman (2014) described—from products to systems of systems. The first observation relates to those concepts from several perspectives in the free comments during the Delphi round one.

- There is a high complexity of optimizing components (diesel engine) or machine performance because it consists of so many subsystems;
- A small amount of critical knowledge from upper levels has high value leverage if it can be coupled to lower lever development;
- Decoupling of level or decoupling of value chain is always a potential source of disruption;
- Decoupling opportunity can attract out-of-industry players (DHL starting to print some of the product as a service was named as example of decoupling part of the physical supply chain and while still satisfying the need of physical goods);
- Creation of a higher level delivery has an advantage of little to no competition (Kim and Mauborgne, 2005), but also has a risk if customers of the current value chain are not optimal or ready for the new type of offering.

Those types of comments that arose from the first round Delphi interviews were used to construct a preliminary framework that looks at disruption the same way as the World Economic Forum report (2015) or Porter and Heppelman (2014), but suggests the paradox of complexity and value if the layers can be decoupled. The preliminary framework is illustrated in Figure 14, which also provides guidance to the case design.

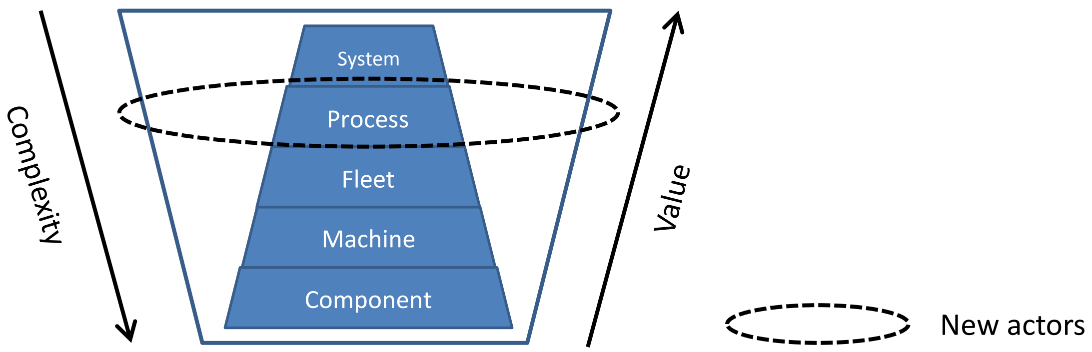


Figure 14. Preliminary finding on systemic characteristics of disruption

The second observation was the emergence of four groups of concepts. Cloud, MBSE, and AM/3D printing were perceived as **tools** in digitalization. They were powerful, with different features attached to different applications, but ultimately they were perceived (according to some of the comments) as commodities available for everyone. Iot and Robotization were perceived as the second group -**phenomena:** connectivity and autonomy, respectively. Therefore, it was suggested that they might contain true disruptive nature. The disruptive nature of Networks, Crowds, Platforms, and Big Data/AI, on the other hand, differed. Crowds and platforms were suggested to be one feature of a network economy paradigm, moving the power to crowds and users. This shift of power was suggested to create a leadership challenge for the players in the current value chains. The most important discussions about Platforms was whether they will be vertical or horizontal, and how many Platforms there can be in without losing the benefits of the network effects.

The third group, Big Data/AI, in this context appeared to be its own category as the **key enabler**. Many comments, like “the business is getting data-centric,” were mentioned. Big Data was only partly attached to AI and machine learning. AI (together with AM) was expected to still have strong technological advancement, and the roles of algorithms and software as the carriers of value were mentioned. The fourth group was the value model or **business model.** Industrial Internet was mostly referred to as a concept without generic meaning, whereas Industrial Internet as defined by General Electric was referred to as one Digital Business Model. Another specific Digital Business Model suggested was an IPR fee for printing spare parts.

The third observation was related to comments about timing. The most distinctive it was with **tools** and the **key enablers.** Cloud and Big Data were deemed to be technologies that are already matured. MBSE was referenced as a methodology/tool that still is advancing, but whose current usage is below the current potential. AM/3D printing and AI were expected to have the largest disruptive potential depending on technological advancement. There were also some comments on the objectives of the impact. Operations and products were more often mentioned in a quantum leap context, and business models in disruption. Disruption in service meant both operational discontinuities and the changes of business models.

4.2.2 Second Delhi interview round

The number of panelists increased from 24 to 36 from the first Delphi round. They represented the 3x3 background matrix evenly, which meant that each role/value chain cell contained four panelists. Five panelists from round 1 were also interviewed at the second round. The second round was represented by nine different universities or research institutes and 22 companies, of which 19 were in global business. Two companies and three universities had more than one panelist, but not from the same cell in the matrix. Panelists came from 11 different countries, and 60% were not Finns.

The first objective of the Delphi interview round two was to rank order technological and economic/strategic management drivers from the Delphi round one. The second objective was to find possible new inhibiting and accelerating sub-drivers, and then rank order the three most important ones. The third objective was to detect differences on views on the drivers and sub-drivers between enablers, actors and users. As a last analysis there is a grouping of the same kind of sub-drivers that are either inhibiting or accelerating technological or economic / strategic management drivers as whole.

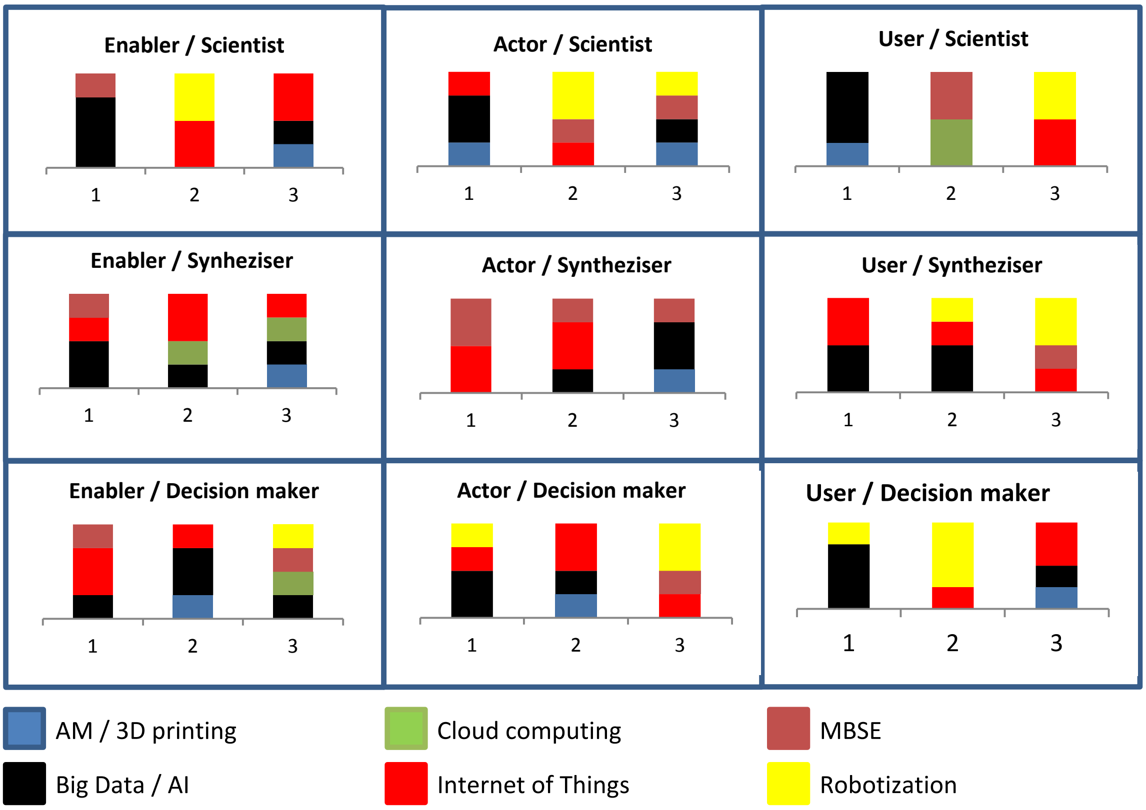
4.2.2.1 Technological drivers

The results of the order ranking of the technological drivers appear in the table 8.

Driver	Number 1 rankings	Average ranking	Variance
Big Data / AI	18	1,9	1,3
IoT	9	2,4	1,6
MBSE	5	3,9	3,0
Robotization	2	3,7	2,3
AM / 3D printing	2	4,2	1,7
Cloud computing	0	4,9	1,7

Table 8. Rank order of the technological drivers in Delphi round two

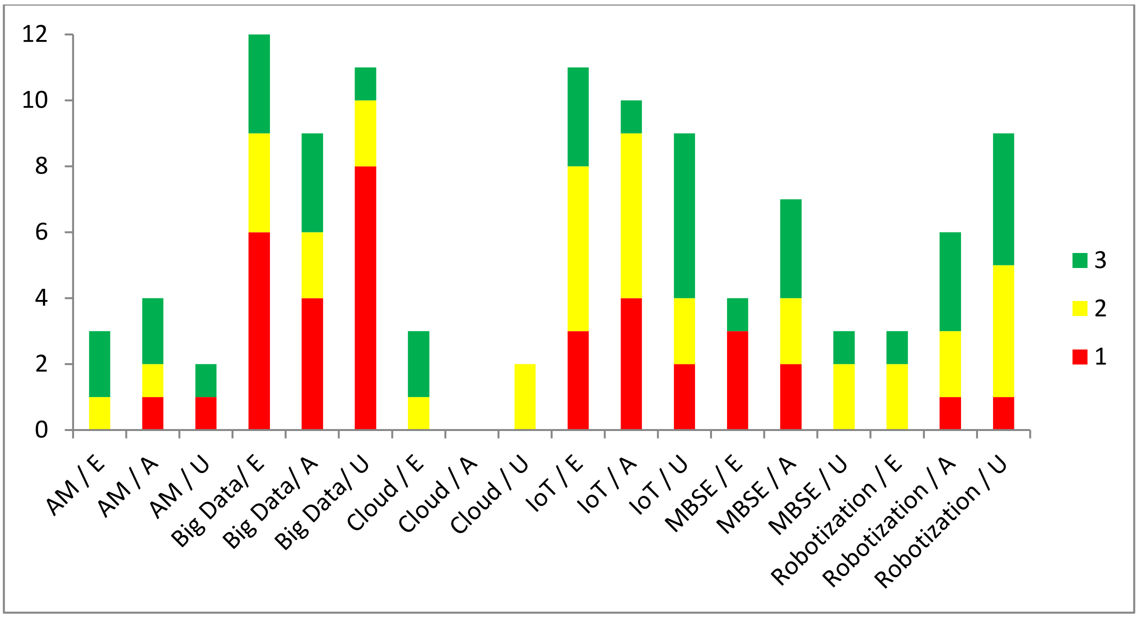
The results in the Table 8 represent the rankings of the panel as whole. Figure 15 presents the results visually so that each cell consists of four panelists' three highest ranked technological drivers and different colors represent technological drivers. As an example, one enabler/ decision-maker ranked Big Data / AI as number 1, two enabler/ decision-makers ranked IoT as number 1 and one enabler/ decision-maker ranked MBSE as number 1 as potential technological disruption driver. The same logic applies to number 2 and 3 rankings and for all nine cells.



Note: Y- axes is number of respondents and X – axes is rating.

Figure 15. Three highest ranked technological drivers in the Delphi panel in round two

In the third analysis, the technological drivers are aggregated by the value chain, as shown in Figure 16. Each driver shows how many number 1, 2 and 3 rankings (marked with colors) it got from respective value chain members, like the first column in the figure indicates that AM/3D printing got one number 2 ranking from the enablers and two number 3 rankings from the enablers. The Figure 16 indicates that Big data/AI and IoT received support independent from their places in the value chain. MBSE had commonalities with enablers and actors, and Robotization had the same kind of pattern between actors and users.



Note: Y- axes is number of respondents and X – axes is the place in the value chain/ driver

Colors indicate rating

Figure 16. Three highest ranked technological drivers in the Delphi panel in round two by the value chain

When the participants were assessing the three most critical technological drivers, they came up with 30 new sub-drivers that either inhibited or accelerated the driver. Table 8 illustrates all the new sub-drivers suggested, listed in the order of appearance (i.e., interview number), including the main driver, inertia (I) or acceleration (A), and how many order rankings (1, 2, or 3) the sub-driver achieved after the appearance. The growth of sub-drivers started to saturate in the middle of the interview round, and turned more sporadic thereafter. The order ranking of new sub-drivers is analyzed based on its pattern in order to judge whether the result would have been different if the sub-drivers would have been available from the beginning.

Inter-view	Sub-driver	Driver	I	A	1	2	3
1	High product cost	AM / 3D	x		1		1
1	Platform tools	MBSE		x		1	
2	Logistics companies start printing	AM / 3D		x			
5	Ethical considerations	Big Data/ AI	x				1
5	Market for intelligent data missing	Big Data/ AI	x			1	3
6	Advancement in 3D technology	AM / 3D		x	1	2	
7	Legislation lagging behind	IoT	x		1		1
8	Lack of systemic understanding	MBSE	x		3	3	1
9	Systemic productivity	MBSE		x	2		1
11	Industry beliefs	Big Data/ AI	x		2		5
11	Lack of business model change	Cloud	x				1
11	Drives collaboration	Cloud		x			
12	Legacy knowledge in systems	Cloud	x				1
13	Lack of use cases	IoT	x		1	2	4
13	Cost of technology	IoT		x		3	3
13	Hype (unrealized)	Big Data/ AI	x			1	1
13	Safety	Big Data/ AI		x			1
14	Market for intelligent data emerging	Big Data/ AI		x			
16	Deployment risk	Robotization	x		3		3
16	Lack of standardization	Robotization	x		1		1
16	Delivery capabilities	Robotization		x	1	4	1
17	Lower cost of analytics	Big Data/ AI		x		1	2
18	Lack of competence	Robotization	x			2	
19	Power of visualization	MBSE		x	3		
20	Advancement in user experience	IoT	x		1	1	1
21	Silo organizations	MBSE	x			1	2
21	Data ownership conflict of interest	IoT		x		1	
22	Real time knowledge	IoT		x		1	
29	Used cases	Big Data/ AI		x	1	1	
30	Technology becoming mature	IoT				1	

Table 9. New technological sub-drivers from the Delphi round two

Sub-driver analysis is done for the top three drivers from Table 8 by presenting first the three most important inhibitive and accelerative sub-drivers based on the view of the panel as whole. The ranking of sub-drivers was done by giving three points to each sub-driver that was ranked as number 1, two points for number 2 ranking, and one point for number 3 ranking. The analysis states the percentage from all points the sub-driver received. Some of the closely related sub-drivers are clustered.

After ranking sub-drivers are elaborated with respective free comments that arise in the Delphi interview round two. As a final sub-driver analysis the degree of consensus in the value chain is evaluated. The sub-drivers of the three lowest ranked drivers are analyzed as group at the end.

Big Data/AI

Three clusters of inhibitive sub-drivers got 79% of the points for Big Data/AI:

- Beliefs, 26% (management and industry beliefs)
- Data 31% (confusion and conflicts of ownership, security)
- Competence, 22%

Industry beliefs, which came from the interview number 11 was the only new sub-driver that could have had any material difference in analysis. It collected eight percent of the points in the consecutive interviews, and beliefs as an inhibitive driver probably would have been even stronger if industry beliefs had been available from the beginning.

The accelerative sub-drivers for the Big Data/ AI were not clustered, and five individual sub-drivers achieved 75% of all points:

- Prescriptive potential, 22%
- Knowledge scalability, 15%
- Users opening their data, 14%
- Advancement in cognitive computing, 12%
- Reduction of human errors, 12%

Twenty-seven out of 36 participants elaborated on the importance of Big Data/AI in the disruption during their free comments on the choice of order of the sub-drivers from Table 6 or 9. Three new generic topics emerged from those comments: complexity, progress, and content. Increasing complexity was mentioned in several interviews, and it was described as the need for simultaneous optimization in several levels of a system that are also interlinked. This development was perceived to exceed the human ability to cope with it, and therefore tools like Big Data were described to have disruptive potential. Big Data was mentioned as one contributor to AI development, but at the same time it was acknowledged that AI is still in its infancy stage compared to its potential to disrupt industries. The key individual point in AI was that exception handling is still dominated by human judgment. Free comments related to development of machine learning and adaptive systems came more from the AI driver discussion than from robotics. The third emerging Big Data/AI topic, content, stemmed from an industry or discipline perspective. “General industry Google” was not perceived likely, but instead many comments about discipline-based, data-driven platforms were made. This was coupled with the scalability (e.g., the friction of bearings in rotating machines as a source for a data-driven niche platform). The same justification was made for data-driven industry platforms. One comment summarized the content view: “*All the right answers are today accessible to anyone; you have to know the right question, which ability comes from the content knowledge.”*

Consensus is analyzed so, that if any of the value chain member’s percentage of points of the sub-driver differs more than five percent units from the average percentage of that sub-driver, it implies non-consensus.

In the inhibitive drivers, there was non-consensus in the following sub-drivers (clusters):

- Data (E= 35 %, A= 22 %, U=39%)
- Competence (E= 23%, A=26%, U=17%)

The non-consensus in accelerative sub-drivers was with:

- Prescriptive potential (E=18% %, A=17 %, U=29%)
- Knowledge scalability (E=11%, A=24%, U=11 %)
- Advancement in cognitive computing (E=24%, A=6%, U=5%)

Internet of Things

Four inhibitive sub-drivers or clusters got 81% of the points:

- Lack of systemic understanding/ competence, 38%
- Management beliefs, 17%
- Lack of standardization, 15%
- Data security, 11%

The lack of used cases got seven percent of the points even though it appeared in interview number 13; those points were mainly away from the lack of standardization.

Three accelerative sub-drivers got 75% of all points:

- Enabler of new business models, 27%
- Systemic productivity, 23%
- New source of customer insight, 19%

The cost of technology got eight percent of the points, and because it appeared in interview 13, it would have attracted more points, which would not have been taken away from any specific alternative. There was no any material new information about IoT in the free comments.

In the inhibitive drivers, there was non-consensus in the following sub-drivers:

- Lack of systemic understanding/ competence (E= 29%, A=28%, U=57%)
- Lack of standardization (E=17%, A=23%, U=4%)

The only non-consensus accelerative sub-driver was the new source of customer insight (E=30%, A=13%, U=11%).

Model Based System Engineering

MBSE got its position in the final top three due to receiving more number one rankings than Robotization. The other justification for its high ranking came from free comments, where a number of participants stated that the disruptive part of Robotization is in AI, machine learning, or algorithms, rather than machines getting smart enough to operate without drivers.

Three inhibitive sub-drivers or clusters got 88% of all points in MBSE:

- Lack of systemic understanding/ competence, 49 %
- Legacy processes, 24%
- Management beliefs, 15%

Three accelerative sub-drivers or clusters got 77% of all points in MBSE:

- Productivity (systemic or based on the shorter lead times), 37 %
- External engagement (crowds and users), 27%
- Power of visualization, 13%

Visualization became available in interview 27 but still rated 13%, which likely have been higher if it had been included from the beginning.

The free comments yielded some additional viewpoints to MBSE. Most notable was that modeling is one tool to manage the increasing complexity in AI, which benefits the current tools as well as accelerates the utilization of AI. It was also referred to as an enabler of simulations and higher level algorithms. The second topic was about engagement, both internally and externally, and MBSE was mentioned as a platform that uses visualization and simulations as methods. MBSE was the only technological factor that had role-based patterns where the benefit was more seen by synthesizers (and somewhat by scientists), regardless if they were enablers, actors, or users. A few of the interviewees did mention that design systems are lower-cost investments than ERP systems, and therefore most of the decision-makers have little understanding of the benefits. One interviewee also stated that modeling the current knowledge is the best investment both in the short and long term.

In the inhibitive sub-drivers, there was non-consensus in the following sub-drivers of MBSE:

- Legacy processes (E=8%, A=29%, U=33%)
- Management belief (E=33%, A=10 %, U=6%)

The non-consensus in accelerative sub-drivers was with:

- Productivity (E=46%, A=40%, U=17%)
- External engagement (E=21%, A=24%, U=44%)
- Power of visualization (E=21%, A=7%, U=17%)

AM/3D printing, Cloud computing, and Robotization

AM/3D printing got two number one ratings as seen in the Table 8. Almost half of the panelists acknowledged in their free comments that AM might be, for industrial production, the most prominent disruptive technology when the technological barriers have been solved; however, during the interview, respondents did not rank it higher as the timeline was uncertain and longer in the future. The inertia in the sub-driver ranking was predominantly divided into two categories: technical immaturity for large scale production (size, material, speed), and management beliefs. One panelist expressed a view that there will be hybrid technologies (conventional attached to AM) during the evolution. The common denominator for the other free comments could be described as weak signals. Comments served also as concrete explanation to elaborate the choice of more abstract arguments (drivers or sub-drivers) as stated in methodology section 3.3.1. These types of comments were:

- “DHL has started to use 3D printing as a tool in their delivery.”
- “In spring 2015, 50% of recruitment in manufacturing in US required 3D skills.”
- “3D revolution is not driven by a paradigm of how you print existing designs but how you design when things can be printed.”
- “3D printing is a powerful technology to impact current trade imbalances.”

Cloud had the highest consensus among the technological factors. It was perceived as the dominant technology in computing, but as a standalone was not disruptive. Even those few who lifted it into ranks 1-3 viewed the disruption to only be based on simultaneous business model innovation. Also, the ones who did not rate Cloud highly acknowledged that it has changed the paradigm of computing (e.g., cost, availability to anyone, scalability). Some saw security as inertia; others viewed that world class Cloud suppliers provide better security than even good companies can achieve internally.

Robotization or autonomous processes had medium disruptive results. The dominant view of robots in the industrial context was evolutionary, and Robotization was seen as technical progress for productivity. This was supported by the sub-driver analysis. The inertia was technical, (23%, technology or deployment), financial (29%, capital or switching cost), or social disruption (18%). Social disruption in the technological development has been an issue for as long as technology-based productivity has replaced human work for different jobs; this disruption is both a leadership and cost issue. Also, the accelerative sub-drivers of Robotization were similar to past automation development (productivity 32%; addressing labor cost of availability 25%). Ten panelists expressed free comments on Robotization; five of the comments were pondering the question whether the end game is intelligent robots working together or slaves to a smart Cloud. There was not a strong view on this idea, but it was perceived as a vital question for development. Three panelists emphasized the medium steps in automation, like remotely operated machines, where the machine is intelligent but the planning and exception handling is managed by a human operator. One panelist, however, pointed out that mixing manned and unmanned operations creates new types of security risks. The remaining comments were related to changing industrial job profiles, from field to office.

Interrelated technological sub-drivers

The last analysis was trying to detect sub-drivers that impact to several technologies. This is achieved by three steps: first counting points of the exact same sub-drivers (such as data security), then analyzing whether there are easily available a more generic grouping where more than one sub-driver can be combined; low # of printable material in AM and technological risks in Robotization can be categorized technical barrier as an inhibitive sub-driver. The final step was counting the points based on the new grouping. The new aggregated technology related sub-drivers can be seen in the Figure 17 in rank order; eight aggregated sub-drivers constituted 92% of the inhibitive sub-drivers and 91 % of the accelerative sub-drivers. The summary of the results of technological drivers is shown in Figure 18.

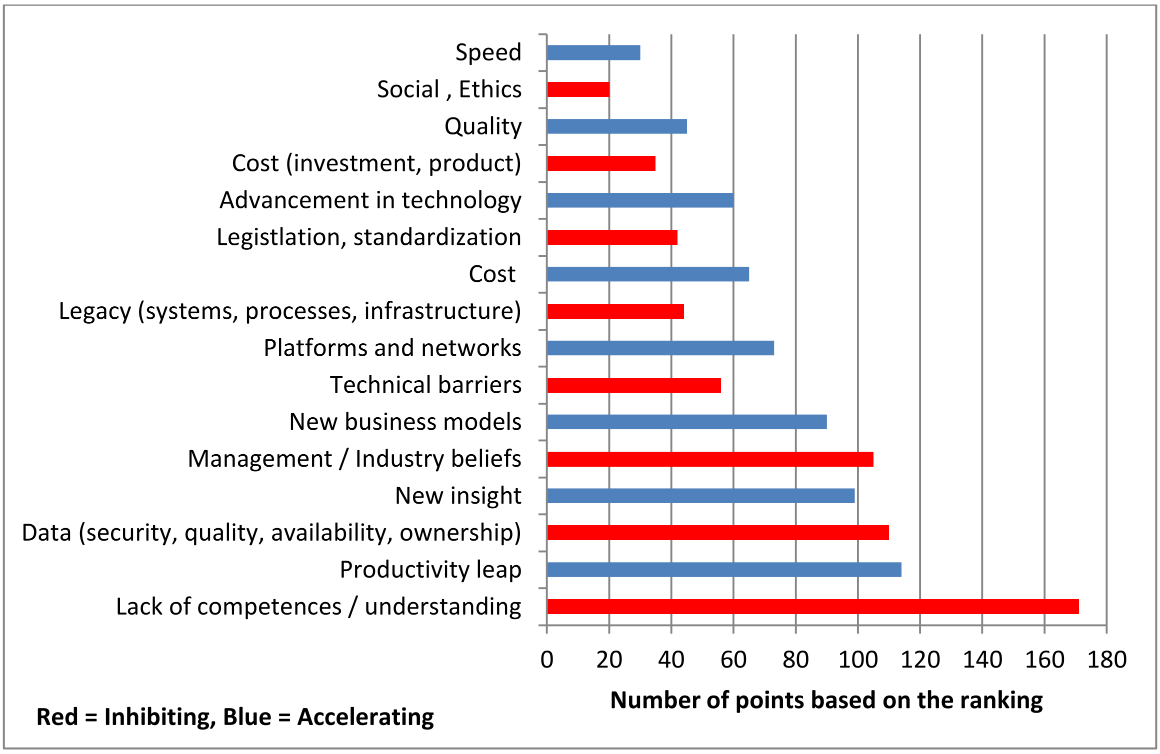


Figure 17. Top eight aggregate technological sub-drivers

Big Data/AI			Management/Industry beliefs	Prescriptive potential
E	A	U	Data (security, confusion, owner-ship)	Knowledge scalability
			Competence	Users opening their data
IoT			Lack of systemic understanding and competence	Enabler of new business models
E	A	U	Management beliefs	Systemic productivity
			Standardization	New source of customer insight
MBSE			Lack of systemic understanding and competence	Productivity (including lead times)
E	A	U	Legacy processes	Enabler of external knowledge
			Management beliefs	Power of visualization

Note: The colors represent consensus. Green means consensus with the value chain members who have green color. If one of the three disagrees, red means that the one who disagrees has stronger support from the green ones and weaker support from the yellow ones. In the driver section, E = Enabler, A = Actor, and U=User. With sub-drivers, the logic is that the bottom square is Enabler, the middle square is Actor, and the upper square is User. The inhibitive sub-drivers are located in the left column and the accelerative sub-drivers in the right column.

Figure 18. Summary of the technology drivers by the value chain

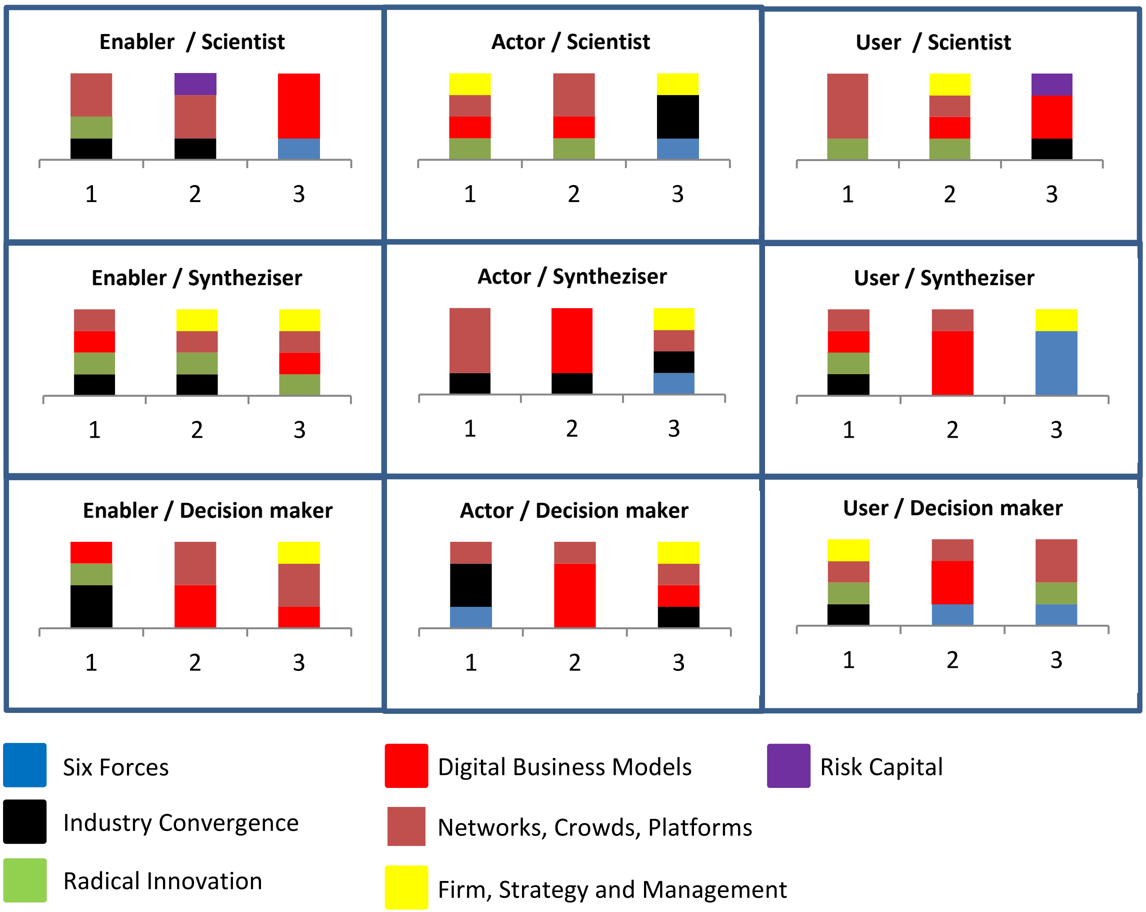
4.2.2.2 Economic / strategic management drivers

The results related to economic / strategic management drivers have been analyzed with the same procedure as the results related to technological drivers. They are also presented the same way as the technological drivers in the previous sub-chapter. Therefore, the procedures of the analyses, or instructions how to read the results are not repeated in this sub-chapter. The results of the order ranking of the economic / strategic management drivers appear in the table 10 representing the rankings of the panel as whole.

Driver	Number 1 rank-	Average ranking	Variance
Networks, Crowds, Platforms	13	2,2	1,4
Convergence	9	3,8	4,4
Radical Innovation	7	3,8	3,3
Digital Business Models	4	2,7	1,4
Firm, Strategy, Management	2	4,1	1,7
Six Forces	1	5,2	2,7
Risk Capital	0	6,4	1,5

Table 10. Rank order of the economic / strategic management drivers in Delphi round two

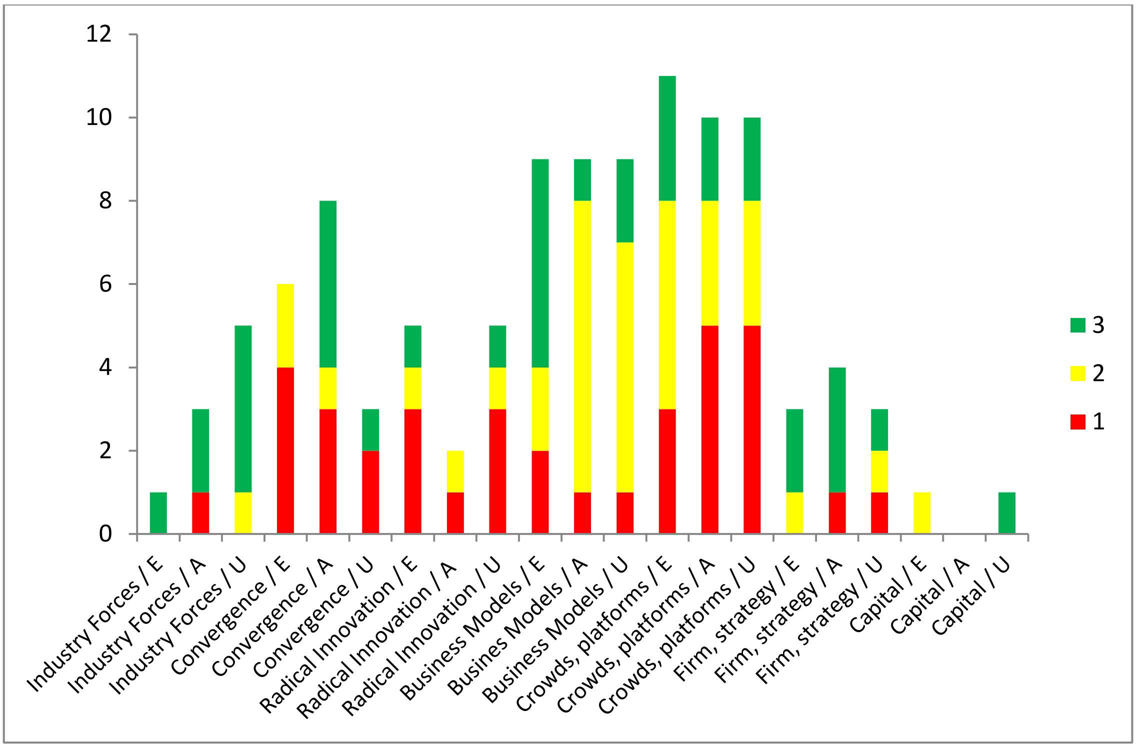
Figure 19 presents results visually so the order ranking of each of the nine cells can be seen separately.



Note: Y- axes is number of respondents and X – axes is rating.

Figure 19. Three highest ranked economic / strategic management drivers in the Delphi panel in round two

The aggregation of the economic/strategic management drivers by the value chain can be seen in Figure 20. There was a high consensus on the importance of Network, Crowds, and Platforms. Similar consensus existed with Digital Business Models, including agreement that its disruptive nature was less than that of Networks, Crowds, Platforms. Convergence and Radical Innovation formed the only material differences by the value chain. Both were perceived important, but Convergence was more favored by enablers and actors, whereas Radical Innovation was favored by enablers and users.



Note: Y- axes is number of respondents and X – axes is the place in the value chain/ driver

Colors indicate rating

Figure 20. Three highest ranked economic / strategic management drivers in the Delphi panel in round two by the value chain

The panelists suggested 31 new economic / strategic management sub-drivers that can be seen in Table 11.

Inter-view	Sub-driver	Driver	I	A	1	2	3
1	Long term orientation	Radical Innovation		x	1	2	
1	Diginatives to firms	Firm, Strategy, Management		x			
5	Privacy concerns	Networks, Crowds , Platforms	x			2	
7	Lack of domain knowledge	Convergence	x		2	1	2
7	Different product cycles	Convergence	x		1	1	
7	Platform availability (industry)	Networks, Crowds, Platforms		x	2	5	4
11	Successful history	Firm, Strategy, Management	x				
11	Visionary leadership	Firm, Strategy, Management		x	5	2	
13	Ability to move management be-tween industries	Risk Capital		x			
14	Legacy systems and processes	Networks, Crowds, Platforms	x		2	3	5

Inter-view	Sub-driver	Driver	I	A	1	2	3
15	Incumbents active resistance	Networks, Crowds, Platforms	x		2	1	2
15	Software intensity	Digital Business Models		x		1	2
17	Lack of intelligence in algorithms	Digital Business Models	x				
19	New level of customer insight	Digital Business Models		x	3	2	2
19	Client vs. market focus	Firm, Strategy, Management	x				
21	Silo organizations	Digital Business Models	x		2	2	1
21	Pressure from financial market	Digital Business Models		x			
21	Pressure from financial market	Firm, Strategy, Management		x			
21	Use of several platforms	Networks, Crowds, Platforms	x		1	1	1
26	Based on small invoices	Digital Business Models		x			
26	Disappearance of distance	Firm, Strategy, Management			1		1
27	"Conservative users"	Digital Business Models	x			3	
28	Lower transaction cost	Networks, Crowds, Platforms		x			
31	User engagement	Networks, Crowds, Platforms		x	1	1	

Table 11. New economic / strategic management sub-drivers from the Delphi round two

The rank order of the Table 10 for the sub-driver analysis of economic / strategic management drivers is altered to be for the top three: 1. Networks, Crowds, Platforms; 2. Digital Business Models; 3. Industry Convergence. The justification for Digital Business Models moving upward is the second lowest average ranking and equally low variance as with the number one, Networks, Crowds, Platforms.

Networks, Crowds, Platforms

Three inhibitive sub-drivers constituted 72% of points for Networks, Crowds, Platforms:

- Management beliefs, 26%
- Lack of capabilities, 23%
- Systems and processes (both legacy and lack of new), 23%.

The late sub-drivers' legacy systems and processes (came from the interview number 14 and collected 11 % of the points) and incumbents' active resistance (came from the interview number 15 and collected five percent of the points) were the only ones who could have impacted to the analysis. The points of sub-driver, legacy systems and processes were later mainly away from lack of processes, which is still a similar sub-driver and thus was aggregated. Incumbents' active resistance sub-driver started to reduce points from both of the process sub-drivers.

Three accelerative sub-driver clusters for the Networks, Crowds, Platforms achieved 77% of all points:

- Emergence of platforms (discipline and industry), 32 %
- Cost (fixed cost, transaction cost, capacity), 24%
- Crowd intelligence effect (including users'), 21%

Thirty-one out of 36 participants ranked Networks, Crowds, Platforms into top three and 26 participants also elaborated on the topic further in their free comments. Other than the original or emerged sub-drivers, free comments fell under four different themes: diversity, users, eco-systems, and culture. Diversity was strongly attached to the external knowledge in innovation. The comments highlighted that even large companies have many subject matter resources; group thinking might lead to low diversity, which can be mitigated by the methods of Open Innovation. Users' opening their data was described as a disruptive enabler when users open their data beyond suppliers. Eco-systems were discussed in two contexts: they are very different from the value chain, and managing them requires very different management styles and capabilities. Culture was also referenced from two very different angles. Some comments were close to management beliefs and related to the internal culture as a barrier to benefiting from the external world (other than directly from the value chain). The other cultural comments were more philosophical, posing the question of whether openness and transparency as concepts are shared in different national cultures, which most likely they are not—a relevant issue for multinationals. The free comments also contained a number of direct views on the open/close paradigm, and they were similar in tone: "Open systems will, at the end, win."

In the inhibitive drivers, there was non-consensus only in lack of capabilities (E= 27 %, A= 27 %, U=13%).

The non-consensus in accelerative sub-drivers was with:

- Emergence of platforms (E=28%, A=24%, U=45%)
- Crowd intelligence effect (E=8%, A=29%, U=18%)

Digital Business Models

Three inhibitive sub-drives or clusters got 78% of all points in Digital Business Models:

- Industry barriers (including incumbents' active resistance), 37%
- Legacy systems and processes, 23%
- Data (security and ownership), 18%

Silo organizations first came up in interview 21 and started to collect points thereafter, ending up with 9% of the points. Silo organization points were away from industry barriers. This suggests that silo organizations as a sub-driver might have been in importance close to those in the top three if present from the beginning.

Three sub-drivers or clusters constituted 72% of the accelerative sub-drivers:

- Cost benefits (productivity, capital), 33%
- Influential Early Adopters, 17%
- Slow growth of existing business, 15 %
- New levels of customer insight, 12%

New levels of customer insight originated in interview 19 and collected 12% of the points, mainly from productivity; this suggests that it would have ended higher in the list.

From the free comments, new perspectives were found to form 4 themes: winners, timing, supply, and used cases. The winners discussion pondered the issue if the startups could win incumbents by using Digital Business Models. The challenge was perceived to be in high industry barriers and in the need for assets. Progressive incumbents or adjacent systems suppliers (e.g., type GE; ABB, Siemens) who possess some of the critical technologies were named also as potential disruptors. The need for both digital and domain capability (as with AI) was named as a prerequisite to winning with Digital Business Models.

Timing comments mostly supported the opinion that there will be a pivot point for the growth of Digital Business Models; forecasting the exact timing, however, is not likely. The essence of the supply comments was that Digital Business Model in machine-building is currently more marketing than supply. Therefore, the importance of the used cases is high, and was elaborated upon in many discussions. This is a bit of a Catch-22, as everybody hopes for the occurrence, but nobody is willing to move. One specific view was that an oligopolistic market structure may lead users to attract new suppliers with Digital Business Models in order to enhance the competition.

In the inhibitive sub-drivers, there was non-consensus only in data (E= 13 %, A= 17 %, U=24%).

In the accelerative sub-drivers, there was non-consensus in:

- Cost benefits (E=20 %, A=43 %, U=35%)
- Slow growth of existing business (E=19 %, A=22 %, U=6%)

Industry Convergence

Four inhibitive sub-drives got 83% of all points in Industry Convergence:

- Industry beliefs (includes Dominant Logic), 32%
- Industry-specific financial steering, 22%
- Cultural barriers, 15%
- Lack of domain knowledge, 14%

Three accelerative sub-drivers got 88% of all points:

- Business model diffusion, 41%
- Consumer business behavior merging into B2B industries, 32%
- Generic digital technologies,15%

From the free comments, some themes were repetitive: speed, platforms, consumers, and individual companies. Speed was related to industry beliefs and specifically to clock speed; most examples were phrased like: “What is fast development time – real time or 2 years?” Platforms were attached to generic digital technologies from a disruption perspective—especially discipline-based. Also, industry overlapping ecosystems were mentioned. Most of the consumer elaboration related to application business concepts (apps) or rising user interface expectations in B2B driven by the people’s private experiences. Individual company initiatives, like earlier examples of DHL in 3D printing or Amazon in logistics, were referenced in industry convergence.

In the inhibitive sub-drivers, there was non-consensus in the following sub-drivers of Industry Convergence:

- Industry beliefs (E=36%, A=35%, U=17%)
- Industry-specific financial steering (E=19%, A=27%, U=11%)
- Cultural barriers (E=14%, A=13%, U=22%)
- Lack of domain knowledge (E=17%, A=6%, U=28%)

In the accelerative sub-drivers, there was non-consensus only in business model diffusion (E= 36 %, A= 48 %, U=33%).

Radical Innovations; Firm, Strategy, Leadership; Industry forces; Risk Capital

Free comments indicated that disruption by Radical Innovations is more isolated events than a result of a predictable pattern. Within these limitations, the inertia in Radical Innovation was mostly explained by 3 sub-drivers: legacy leadership and ownership (26%), good returns by continuous improvement (21%), and risk-adverse business culture (19%). The sub-drivers that accelerate Radical Innovation were experiment culture (29%), influential Early Adopters (21%), and the new level of customer insight (19%). The dominant view in the free comments resembled Christensen's Innovators Dilemma (2011): continuous improvement is a low risk activity which almost always pays back. Another view was that digitalization increases raw material for Radical Innovation (e.g., sensors, computing, behavioral data, opinion data), which theoretically increases the chance of Radical Innovation as an event. There were also reminders that Radical Innovations are often low tech. The last category of comments related to business definitions or business models, and those comments emphasized that part of radicalness is redefinition (e.g., moving into higher systemic levels, as discussed earlier; or Blue Ocean type (Kim and Mauborgne, 2005) of thinking as discussed in the theory section).

Free comments on Firm, Strategy, Management were similar to those of Radical innovations, and centered on the inhibiting side around Christensen's (2011) view, and on the acceleration side around "Steve Jobs" (i.e., was the smart phone disruption because of Steve Jobs, the product, Apple as a company, or its strategy and capability to implement it). However, the overriding perspective was the same as in Radical Innovation: the firm is at the core of the changes inside of an industry, but is rarely a disruptor of the industry as a whole. One comment sums up the average: “Large companies do disruptive things only when forced to do so.” Sub-drivers that slowed down Firm, Strategy, Management as a disruptive driver were: successful incrementalism (28%), firm itself (e.g., authorial leadership and hierarchical, complex organizations; 23%), industry beliefs (23%), and short-term financial pressure (22%). The accelerative sub-drivers were somewhat the opposite: Visionary leadership (33%), experiment culture (23%), and slow growth of existing business (18%).

Industry Forces was an interesting driver; practically every panelist recognized it as “The Theory” explaining industry dynamics. The recognition was similar to stakeholder theory, and still the combination ranked second lowest as an economic/ strategic management driver to explain disruption by digital technologies. The dominant inertia sub-drivers were high-entry-barrier industry (35%) and cost-driven customers (31%), whereas three top accelerative sub-drivers were: Influential Early Adopters (37%), value driven customers (24%) and substitute business models (20%). One group of free comments was pondering the same question as in Networks, Crowds, Platforms: that the value chain is not equal to ecosystem, and the Industry Forces are strongly linked to the value chain. This was perceived as one weakness of the theory to explain network-based disruptions. The inertia of industry barriers was explained with the view that the substitute suppliers in consumer business are often startups, but in high-barrier industries they are not credible. The conflicting views propose that niche startups can steal pieces of value from incumbents, or—when united—even bigger pieces. Some comments stated that the highest value generation potential is not constant to any place in the value chain. Theoretical views suggested that Industry Forces explain S-curve leaps inside industries but not transformation between industries or systemic S-curve leaps. There were also comments about lack of theory in this area apart from emerging Industry Convergence.

Risk Capital was consistently viewed as a fundamental ingredient in the industry development, but it was not viewed as a primary driver for industrial disruption. Only two panelists ranked it in the top three, and the few free comments were along lines that for all types of capital needs, including Radical Innovations or disruptive business models, there is eventually capital available. However, commenters acknowledged that the right timing of the access to Risk Capital speeds up disruption.

Interrelated economic/ strategic management sub-drivers

All the economic /strategic management disruption sub-drivers were grouped into related categories the same way as was done with the technology related sub-drivers. The top eight sub-drivers constituted 96% of the inertia (when requiring that the sub-driver was present in a minimum of two drivers), and 92% of the acceleration. The aggregated sub-drivers can be seen in Figure 21. The concentration pattern is weaker than with technological sub-drivers. There are also similarities in technological sub-drivers and economic/strategic management sub-drivers. The summary of the results of economic/ strategic management drivers is shown in Figure 22.

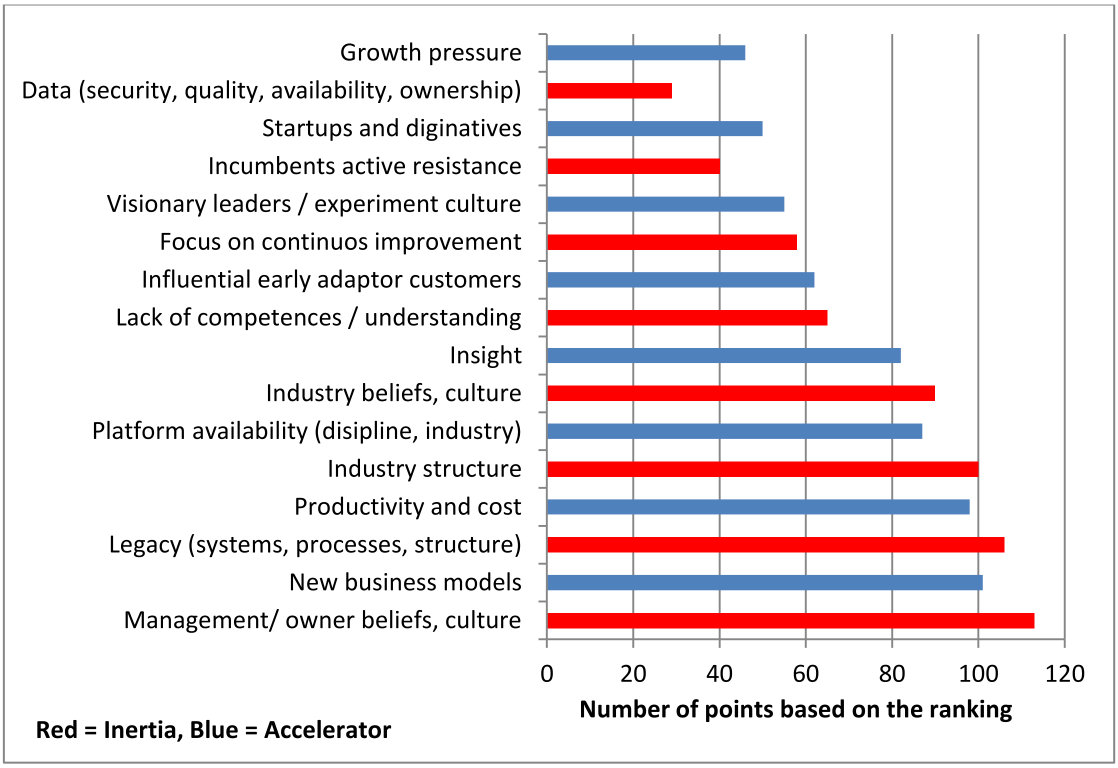


Figure 21. Top eight aggregate economic / strategic management sub-drivers

Networks, Crowds, Platforms			Management beliefs	Emergence of Platforms
E	A	U	Lack of capabilities	Cost benefits (productivity, capital)
			Systems and processes	Crowd intelligence effect
Digital Business Models			Industry barriers	Cost benefits (productivity, capital)
E	A	U	Legacy systems and process-es	Influential early adaptors
			Data (security, ownership)	Slow growth of existing busi-ness
Industry Conver-gence			Industry beliefs	Business model diffusion
E	A	U	Industry-specific financial steering	Consumer business and be-havior into B2B
			Cultural barriers	Generic digital technologies

Note: The colors represent consensus. Green means consensus with the value chain members who have green color. If one of the three disagrees, red means that the one who disagrees has stronger support from the green ones and weaker support from the yellow ones. In the driver section, E = Enabler, A = Actor, and U=User. With sub-drivers, the logic is that the bottom square is Enabler, the middle square is Actor, and the upper square is User. The inhibitive sub-drivers are located in the left column and the accelerative sub-drivers in the right column.

Figure 22. Summary of the economic / strategic management drivers by the value chain

4.3 Results from the survey

The survey was conducted to investigate five different areas of interest:

1. The systemic impact of the digital technologies and economic concepts (drivers) on firms' products, services, operations, and business models (objects)
2. Timing of the potential disruption by the object
3. The disruptiveness of the drivers
4. Preparedness of the respondent's organization for the potential disruption (investment)
5. Dependencies in independent variables, drivers, and objects

The same 3x3 background matrix was used in the survey as was used in the Delphi interviews, and the process was as described in the methodology chapter. The final number of seminars where the population was sampled was eight (two public, three invitation-based, and three semipublic, where participation was limited from a population that originally was open). The survey was answered by 305 persons. The participation profiles can be seen in Table 12. The participants came from 23 different countries and the number of non-Finns was slightly over one-third.

Role/ Value Chain	Enablers	Actors	Users
Scientists	11	10	2
Synthesizers	52	76	31
Decision makers	25	75	23

Table 12. Participation in the survey

Filtering samples with incomplete background information eliminated four samples (one enabler–decision-maker, one enabler-synthesizer, one actor-synthesizer, and one user-synthesizer). The samples that survived filtering were almost complete; less than 0.5% of the answers had unanswered data points. In most cases, only one data point was missing in the sample and therefore the data was completed in order to have other unique data points from those respondents as part of the analysis.

After completion, the data was tested with Shapiro-Wilk test and the results (see Appendix 5) indicate that the data does not follow a normal distribution. Table 12 reveals that sub-populations differ from each other, and balancing is required in order to increase the generalization of the results. The value chain is expected to be the main explanation for the results, and the sample sizes by the value chain vary from 53 to 150. The scientist sub-populations are so small, even before splitting them based on the investment behavior, that they are dropped away when analyzing differences in the value chain with the balanced data. Those samples are not lost, however, as some of the analysis is done by using the whole population. Leaving out scientists leaves 18 sub-populations for balancing, which results in 278 answers when counting the two other roles in value chain (see Table 12). Thereafter, 278 is divided by the number of remaining sub-populations (18), which equals to 15.45 - the total weight of the sub-population. To get the coefficient for an individual sample, the total weight of the sub-population is divided by the number of samples in the corresponding sub-population. In further analysis, selected methods utilize those coefficients (e.g., when calculating weighted averages or variances).

The last phase before analysis is the interaction effect test using the two-way ANOVA; the results are enclosed in Appendix 6. The description given by the XLSTAT states that adjusted R^2 express the proportion of the variability of the dependent variable of the model, and takes into account the number of variables used in the model. The first goodness of fit is for the whole population (see Appendix 6), and it indicates that the probability test is not met with Operations, Big Data, and Open Innovation. However, as only 6.9% and 9.5% of the findings in cases of Operations and Big Data can be explained, a *p*-value that is marginally over 0.05 is still acceptable. Open Innovation has a clearly higher *p*-value (0.142), but it also has a low explanation power by variance (8.3 %). The other test (Type III SS) explains how much the combinations of individual background factors (e.g., place in value chain, role, and investment) can explain variance in the dependent variable. The test analyzes this with both the combination of two background factors and with all three. The empty cells indicate that the interactions of the background variables have 0% chance of explaining the values of the dependent factor. Type III SS test is recommended if there is an assumption of interaction. The interpretation by the tool instructions is that lower *p*-value indicates that the factor has a larger contribution in the model explaining the variance by the variable examined. The results suggest that the combination of value chain, role, and investment together might have interaction in the cases of Big Data, Industrial Internet, and MBSE, but as the variance can only explain less than 14% of those variables, it cannot be concluded.

Results also indicate that individual factors are not very powerful in explaining most of the variance in data.

Before presenting results, three limitations can be summarized:

- Data does not follow normal distribution.
- Interaction effect does not shadow the impact of the background factors (independent).
- Background factors are only capable of explaining a small amount of variance in the dependent factors (drivers and objects).

The survey results form three categories. First is the whole population that uses unbalanced data with an assumption that some of the answers may lie in a larger population. A second category uses balanced data and is seeking differences and similarities between the value chain members. The third category analyzes dependencies between the factors (e.g., place in value chain, investment) and values (e.g., systemic impact or relative disruptiveness of technologies and concepts), and is mostly impacted by the limitations above.

4.3.1 Whole population

The first result is the systemic impact of digitalization (i.e., continuous improvement, quantum leap and disruption). The results of the impact by object can be seen in Appendix 7. The result is presented by plotting the values with XLSTAT univariate box plot. In that plot, the box contains 50% of all the values, whereas the vertical line in the box represents the median value. The lines outside of the box indicate the boundaries, which include 95% of the entries. If there are still individual points beyond those lines, they can be considered as improbable outliers. The x represents the average value of the population. Average and variance values have also been added in the same picture. The first result indicates the following conclusions:

- Data does not follow the normal distribution as the Shapiro-Wilk test indicated;
- Product is perceived having least disruption impact (lowest average and variance);
- Digitalization is expected to have quantum leap impact in operations of the firm that supplies machines (mean and 50% of the answers fit into quantum leap area with 3.1 variance);

- Potential disruption is most likely to take place in the services and business models (average strong quantum leap but also a high number of answers in disruption); business models have, however, the highest variance of all of the potential objects; and
- Level of variances appears to be high, indicating uncertainty within respondents.

Participants who judged potential disruption in any of the four objects also evaluated the timing (i.e., how long it takes that the disruption has changed the way of doing business) in three categories (i.e., less than 5 years, between 5-10 years, or over 10 years). Those results can be seen in Figure 23, which represents the relative shares of the timing by each object.

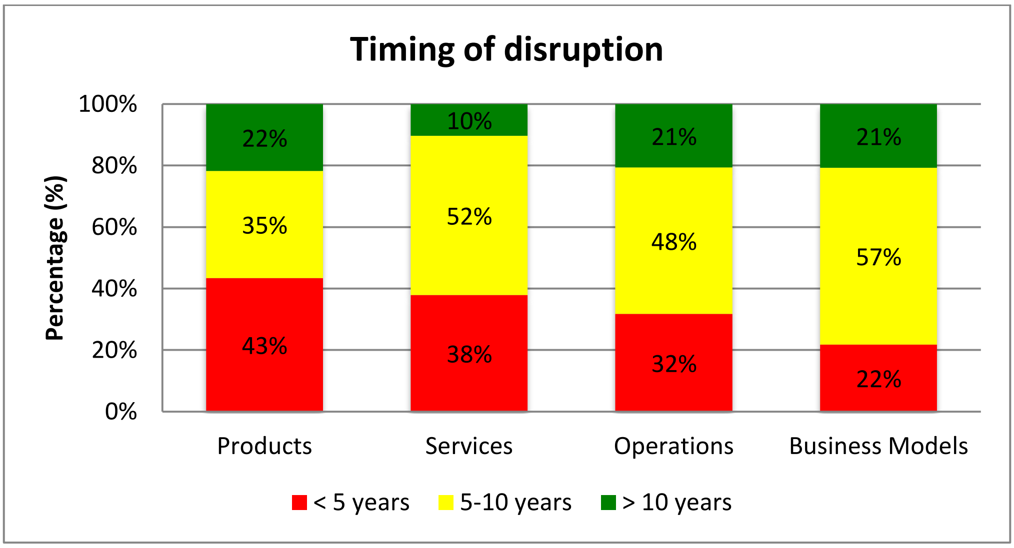


Figure 23. Timing of potential disruption by whole population, unbalanced data

The results reveal that although the disruption potential of the products is lowest, the time to introduce it is the shortest. Services have a high disruption potential and almost as short an introduction time as products -even faster if the timeline is under 10 years. Operations have a medium disruption potential and a relatively long lead time, indicating high inertia to change how a firm operates. Changing business models have a high disruption potential but the longest lead time to reach acceptance by the industry.

4.3.2 By the value chain

The first result by the value chain is the potential disruption impact by digitalization to products, services, operations, and business models. The used data is now balanced, but the procedure is the same as with the whole population; the results can be seen in the plot in Appendix 8.

There are multiple findings drawn from the plot:

- The relative position in the disruption (when looking the averages) is the same with all members of the value chain (i.e., products lowest, operations in the middle, and services and business models higher);
- In all of the objects, users have the highest variance;
- Enablers systematically see more disruption potential (average) in all of the objects than actors and users.

As the potential disruption is hard to judge, and variances are high, the second impact analysis is based on presenting how the views differ in the value chain with those participants who rated the concepts and technologies either weak continuous improvement, or strong disruption. This is based on the assumption that participants who assign strong value farther away from the middle point are more likely have clear arguments for their selections. Those results can be seen in Figure 24.

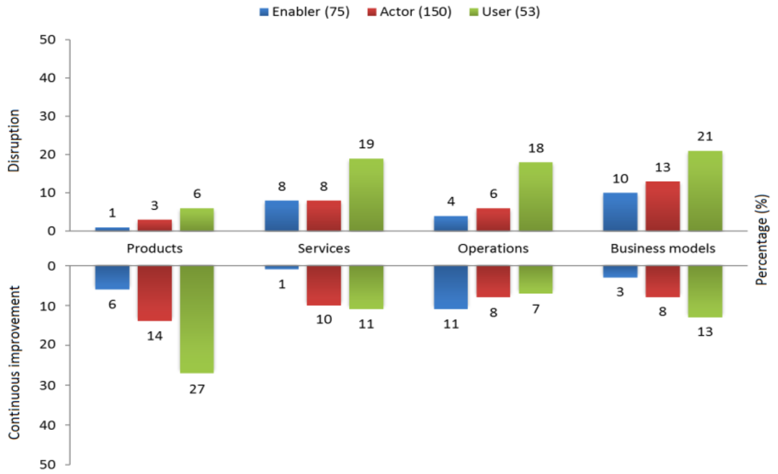


Figure 24, Weak and strong disruption impacts by the value chain, balanced data

This figure illustrates even more clearly that the disruption expectations are highest in services and business models, and fair in operations. According to this analysis, the users' view is clearly more towards disruption in all of the objects. Users also view that the disruption is not as likely to emerge from the products as enablers and actors believe.

The disruptiveness of technological and economic drivers was also analyzed by using XLSTAT univariate box plot; the results are enclosed in Appendix 9. The main observations from the plot are:

- The highest variance is related to 3D printing and Robotics;
- Enablers systematically viewed the disruptive impact of the combination of IoT/Cloud/Big Data to be stronger than did the users and actors;
- Enablers are more conservative than users in 3D printing and Robotics;
- Economic/ strategic management drivers (e.g., Industrial Internet and Open Innovation) attract generally higher average values than the technological drivers.

For the same reason as with impact analysis, technology and economic/ strategic management drivers are also analyzed based on the weak, continuous improvement, or strong disruption ratings; the results are presented in Figure 25. Also, here the high variance in 3D printing and Robotics is clearly visible, and users anticipate that these technologies might have a stronger potential impact than the rest of the population believes. Open Innovation was identified as an important disruptor by all the value chain members, but there is a equally sized opposition who perceives very small impact.

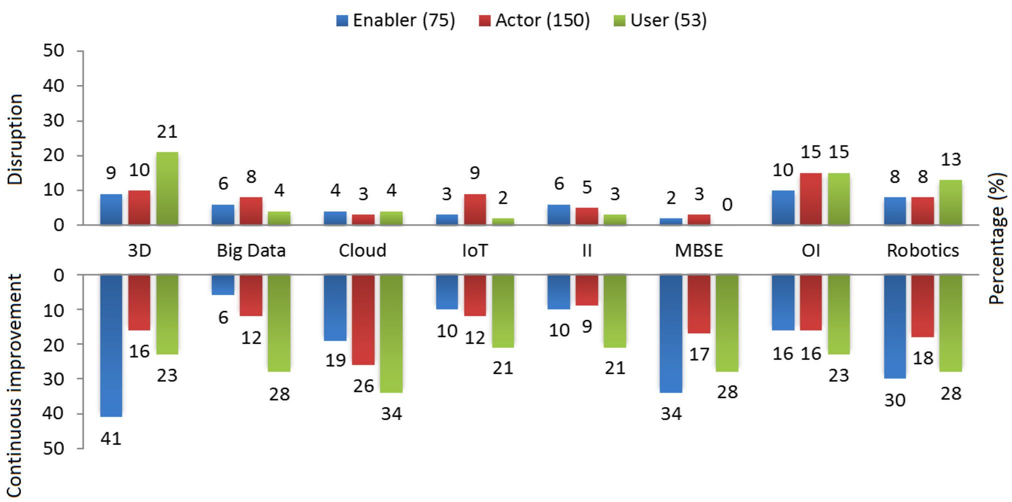


Figure 25. Weak and strong disruption drivers by value chain, balanced data

The third result by the values chain is the respondents' judgments on how well they are prepared with investments for the potential disruption by digitalization. This analysis also uses balanced data where the scientists are excluded. The results are presented in Figure 26. This data clearly indicates that the enablers believe that their company is taking progressive actions, whereas the users seemed to be equally unprepared, and the actors land somewhere in between, when almost half of the respondents share the view that their organizations' investment in the digital technologies keeps them in the current relative position compared to their peers.

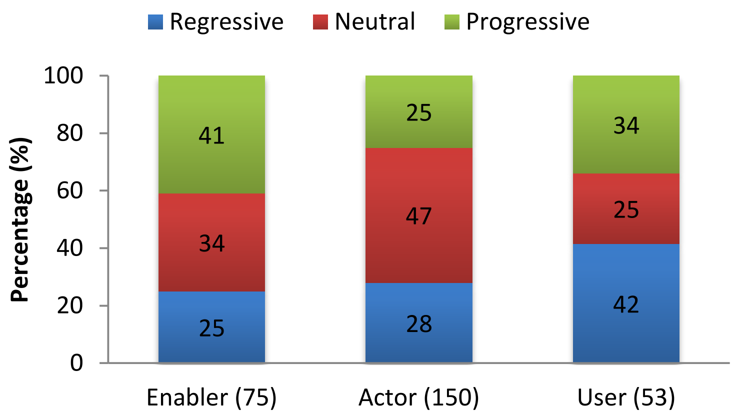


Figure 26. Impact of own digitalization investments, balanced data

4.3.3 Dependencies

Before analyzing dependencies, various statistical methods were tested, but only correlation and variance analysis appeared to be yielding results. The likely reason for this might be the high variance in the raw data.

Correlation was analyzed by using non-parametric Kendall's rank correlation method for both the balanced and unbalanced data. The Kendall correlation method can be used for large sample sizes, but Schmidt (1997) pointed out its wide use also in rank orders. The results for the whole population can be seen in Appendix 10. The results indicate that majority of the correlations have minor differences in the balanced and unbalanced data, but they are not significant enough to change conclusions. Therefore, only balanced data is used when analyzing differences in the value chain, which can be seen in Appendix 11. The correlation between business model and Industrial Internet is not taken into account as Industrial Internet is, de facto, a Digital Business Model. The conclusions from the tables in Appendix 11 are:

- Values given by actors deliver the weakest correlations between variables;
- All participants in the different parts of the value chain view connectivity (IoT) as a driver for Industrial Internet;
- Big Data/AI drives the disruption in all areas in the eyes of enablers;
- Big Data/AI, Cloud, IoT form a cluster for Industrial Internet from the view of enablers;
- Big Data/AI, Cloud, Iot form a cluster also in the answers given by users;
- IoT drives the disruption in all areas in the eyes of users (operations weaker);
- Open innovation drives the disruption in all areas from the perspective of actors and users.

Based on Shapiro-Wilk and univariate box plots, non-parametric methods would have been more ideal for analyzing variance; however, the use of weighting factors as were used in the balancing of the sample sizes complicates calculations when using rank-based comparison methods like Moods median test, as they use unbalanced data by default. Therefore, ANOVA—which is a parametric method—-shall be applied. Using ANOVA with non-normally distributed data has a risk of error if the population has a high number of outliers. This, however, is not as critical an issue as in the correlation analysis, because ANOVA is using averages of random samples from the sub-populations, and if the analysis is capable of creating a normal distribution for the sample averages of the sub-populations, it is also safe to compare the results between sub-populations. The error is more likely with small sample populations under 30, or if the variances of the subgroups are very different. As ANOVA is applied in the value chain, the number of participants by value chain varies between 53 and 150, which reduces the risk. The variance differences between subgroups are relatively small, as can be seen in Appendices 8 and 9. The ANOVA F-test determines whether there are differences between subgroups, and results appear in Table 13. The interpretation of the F-test is that if the corresponding *p*-value is less than 0.05 (Nuzzo, 2014), there is a statistical difference in the opinions between the subgroups (Figures are bolded in the Table 13).

Products	Services	Operations	Business models	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
0,030	0,099	0,661	0,386	**0,004**	**0,026**	**0,024**	**0,003**	0,154	0,203	0,448	**0,038**

Table 13. ANOVA F-test results

After the F-test, the data is handled with an ANOVA *t*-test. The results are shown in Appendix 12. As the object of the enquiry is to identify differences in the value chain, all combinations of the value chain where F-test showed less than 0.05 *p*-value are drawn. The diagram in Appendix 12 is illustrated with colors, so that if the *p*-value between two value chain members is less than 0.05, there is an expected difference in the view. In those cases, the one in disagreement who believes more in disruption (i.e., higher average in Appendix 8 or 9) is marked with green, and the one who believes less in disruption with red. If all disagree, the middle opinion is shaded with yellow (no such cases found). If the *t*-test did not recognize disagreement between value chain members, they are marked with blue, indicating that those members of the value chain share the opinion.

Main findings from Appendix 12 are:

- Users are more skeptical towards the claim that products are affected by the disruption caused by digitalization than are enablers;
- Enablers view 3D printing as less disruptive than do actors and users;
- Enablers perceive Big Data and Cloud as more disruptive than do actors and users;
- Users are more skeptical towards the impact of the IoT than enablers and actors are, but believe in Robotization being more disruptive than do enablers.

4.4 Cases

Case descriptions are part of the triangulation. They are, however, building on earlier cited thoughts of Jouvenel (1967) that the future has to be plausible and case selection by Eisenhardt and Graebner (1997) that “cases are selected because they are suitable for illuminating and extending relationships and logic among constructs”.

Two other methods collect data based on the judgment about future development. The cases illustrate that there is already ongoing disruption in the scope of the research, even if it is marginal compared to the size of the market from which the cases are taken. The construct by Eisenhardt and Graebner (1997) is what, in Figure 5, was referred to as Outcome Economy, or what was modified—based on the Delphi interview round one in Figure 14—to be more closely suited to the machine-builder. Every case describes the ultimate output of that business, how the value is created by existing industry, and how the new actor has redefined the value creation. In all cases, the value creation is at higher levels (as seen in Figure 14). The solution has to be based on the digital technologies within the scope of the research and the application of the technologies. As one last criterion, the case has to establish a quantum difference in cost/benefit compared to the current industry practices, and must have originally been a startup company.

4.4.1 Enevo

Enevo was established in Finland in 2010, using a new business model. They operate in waste collection (output) with minimal resources in the system. The actors in the Enevo case are companies that manufacture trucks or waste collection devices attached to the trucks, as well as companies that manufacture recycling and waste containers. The B2B user is a waste collection company that can be either private or public. The ultimate cost of waste handling is paid by businesses (cost of doing business) and citizens (cost of living, or component in taxes if waste collection is a public service). Enevo is the digital enabler that uses sensors, data transmission, positioning, analytics/algorithms, and cloud computing as digital technologies.

The waste collection system consists of waste bins and final treatment (e.g., land fill, recycling, energy), plus transportation and handling in-between. A typical process is that a truck with waste handling equipment picks up the content of the waste bins and delivers it for final treatment. The owner has made an agreement with the waste collection company that, for a certain fee, waste bins are emptied on a regular basis (e.g., once a week). Based on these fixed schedules, trucks have their route plans. This process results in both half-empty or overfilled bins are picked up, as picking is based on the calendar rather than on filling patterns.

Enevo's basic innovation is simple. The containers are emptied only when full, thereby optimizing the driving time between pickup points. The process is enabled by inexpensive sensors that are attached to the container and powered by a battery that has a lifetime of up to 10 years in typical conditions and use. The sensors send the information on the fill level of the container to Cloud, which-based on time series calculates the filling pattern and trend of that container, and therefore can predict when it will be full. That information can be used in route planning. This optimization has multiple logical values: the need for trucks and waste handling devices is less for every ton of waste handled. In the same way, the operational cost (e.g., driver, fuel, spare parts) from moving half empty bins or driving unnecessary distances disappears. According to Enevo, the productivity gain can be as high as 40%; conventional improvement is following a learning curve of a few percentages per year. The disruption logic is that a very small investment-in this case, inexpensive sensors and Cloud computing-can enable this productivity leap. Also, the improvement of the truck or waste handling equipment is incremental, as the basic solutions have existed for years. Enevo's solution is digital, and it can be scaled to fit any city that has a similar waste collection system.

The value creation needs a new business model, or at least a new procurement process, where the pickup fee is changed from days of pickups to tons of waste handled. Using that formula, the service provider can pass part of the savings along to the ultimate payer, and thereby increase its competiveness. The other part of the savings can be shared between Enevo and the waste collection company via royalties or discounts of a few cents per ton handled. In the case of recycling, the collecting company sells the raw material, such as paper, saving in the handling and logistics, thereby yielding better margins without changing the business model. If one can assume that the needed technology is mature and that everyone in the value chain saves, this should result in a major growth opportunity. But, there are also losers, and that logically explains part of the inertia. If the process requires less assets per ton, the need for trucks and waste handling equipment will go down as long as the entire system reaches a point where only productive moves are made and all growth of waste translates to the same growth of needed assets. This is also a difficulty for users who have heavy assets, including a high number of drivers on the payroll, if they have to compete with new entrants without assets, and who can apply the new method faster. It is certainly a difficulty for the drivers, as fewer of them are needed to perform the job. If the user is a municipal company, reducing drivers may be against public opinion. However, in many cases as the amount of waste is increasing and the fractions collected increase, the cost savings and efficiencies reduce the need to add new resources or invest in new equipment. In addition, in the private sector, the companies have means to increase their customer bases without additional investments. As the market is formed by a high number of end-users (i.e., businesses and citizens), the volume benefit is not realized if only a few of the end-users join the new system. Logically, one can project a pattern where Enevo's growth pattern has a link to Early Adopter logic. When more users (maybe, also, an Enevo-type competitor) enter the market, at some time there will be a point where users using the conventional methodology become non-competitive.

Interestingly, in the Enevo case, the actor (i.e., truck manufacturer or waste handling equipment manufacturer) is not even needed for this productivity leap despite the fact that the innovation reduces the actor's future market. For truck manufacturers, this possibility is not even visible in the beginning, as waste disposal is not a major application for trucks, and new innovations applied in this segment in a few countries does not show up in market volumes. However, there might other digital innovations for other applications where a similar mechanism increases the asset utilization and compound they might result in lower growth rates that the manufacturer is used to. That still might be overshadowed by the normal variance of the GDP growth and investment behavior. For the waste equipment manufacturer, the impact is more direct, but Enevo's solution is still outside of market scope and, in the beginning, impact to business volume is marginal. The reaction of the waste equipment manufacturer depends if they define their output as waste handling or waste equipment. If the answer is waste handling, they can try to copy Enevo, join Enevo, or buy Enevo. For Enevo, the strategic question is whether Enevo can be become an open platform for all the related players, if the status of the bin would be a platform that would enable developers, including Enevo, to develop additional value-adding services, such as recognizing fire before it occurs based on certain patterns of rising temperature.

The Enevo descriptions are taken from the company's web page and presentations that the company has made in public. The case description was read and commented upon by Mr. Pirkka Palomäki, COO and CTO of Enevo, who verified the logic being correct.

4.4.2 Trimble

Trimble's roots stem from 1978 in Silicon Valley based on the navigation and position technology, and they were an early applier of GPS. For the purpose of this research, the milestone for Trimble was when they established a joint venture with Caterpillar for advance guidance and control to be used in agricultural, construction, mining, and waste industries in 2002. Trimble's case industry example is farming, as it is also connected to business models that Porter and Heppelman illustrated in their article *How Smart, Connected Products Are Transforming Competition* (2014).

In this case, Trimble is the digital enabler, an agricultural farm tractor manufacturer is the actor, and the farm is the user. The simplified process is that the farm is planting seeds to be harvested later by using farm harvesting equipment. The output of the process is quality and quantity of the crop. For optimal crops, farmers need to know weather and soil conditions during the growing season as well as the precise application rates for chemical and fertilizers based on historical and real-time data. For optimal use of machinery, they need to know the real-time conditions of the machines; if the farm is large, that need extends to the whole fleet. Farm tractors might have low utilization rates outside harvesting season, but during harvest, uptime is mission critical.

Traditional farm output and machinery development has been only partially connected. The tractor development has followed the logic of any work machine development, performance, features, cost, and regulations that are directed to that particular machine or application (e.g., safety, noise, emissions). Performance could be improved with higher horse power, features and innovations (e.g., ability to counter difficult terrains), and product cost with selection of components and efficiency with the actor's operations. Reduction of operational costs, like fuel consumption have been a constant goal for the product development. The business model for machine-builders has been similar to that for razor blades, where significant amounts of the profit are made by selling spare parts during the lifetime of the machine.

Trimble brings the business to Outcome Economy (World Economic Forum, 2015), goes to higher abstraction level as illustrated in Figure 14, orchestrates the systems of systems (Porter & Heppelman, 2014), and is building industry-specific platforms that other players can attach to. They apply sensors, provide data transmission, positioning, analytics, and cloud computing as digital technologies, combine internal and external sources of data, and enable the user to monitor and control equipment based on the knowledge that they have created with digital interfaces like mobile devices. Their business model is based on software licensing (price per acre per year). They also offer users additional value-added services that are derived from the knowledge that they manage the system in the industry. Compared to Enevo, every farm gets the benefit, even if no other farms join the system. In order to obtain industry knowledge, growth of the number of users is needed.

The same way as in the Enevo example, this all can be achieved without involvement of the actor as long as the user provides access to the data and Trimble has access also to resources and knowledge that typically are possessed by the actor. In all instances, better utilization of tractors cuts part of the growth potential of tractors as long as their systemic development has reached maturity. The tractor manufacturers' options are: stay out, develop their own solution, or buy Trimble (which has become less logical, as Trimble operates in a high number of industries). Caterpillar and Trimble's joint venture is closer to acquisition, which has a consequence for Trimble, that in order to have Connected Farm as an industry platform, the other manufacturers have to cooperate with Trimble-Caterpillar JV. Compared to Enovo's example, the business redefinition is already ongoing. Precision farming is close to the concept of Outcome Economy (World Economic Forum, 2015), and other major actors like Agco[27] and John Deere[28] are active in changing the rules of how value is created in farming. The ecosystem around precision farming is not only driven by technological enablers like Trimble or actors like Agco, Caterpillar, or John Deere, but also by companies like Monsanto,[29] which comes originally from the agricultural chemicals market, but today is investing hundreds of millions of dollars into what they call Agriculture 2.0, which based on knowledge from agricultural data.

The data for this description was done by analyzing public sources like the company web pages, but the logic of the case description was validated by an industry expert of one of the leading actors in precision farming.

4.4.3 XVELA

XVELA is an internal company startup of the Oakland, California-based software company, Navis, which was acquired by the Finnish company Cargotec in 2013. Navis supplies software that enables container terminals to run their operations. XVELA is an example of an endeavor to build industrial platforms; the development of these platforms came up high in Delphi round two both as an accelerator of Network, Crowds, Platforms (Figure 22) as well as a generic accelerator of economic concepts that are sensitive for digitalization (Figure 21).

Navis has been an industry-specific ERP supplier where the value of optimization is location-specific (i.e., within the confines of the container terminal). Global shipping, as described in sub-chapter 4.1, is relatively simple in physical form, as global trade is enabled by goods moving inside of a standardized container. By the same token, however, the information attached to and enabling the movement of the container and its contents is highly complex, and there are many stakeholders in every supply chain transaction (e.g., shippers, forwarding agents, shipping lines, customs, terminals, consignees, port authorities, and various governmental departments). The emerging logic from Delphi round one (Figure 14) was the assumption that many of the disruptive digital innovations optimize systems at a higher level than actors have been doing. This is

[27] http://www.agcocorp.com/precision-farming.html
[28] https://www.deere.com/en_US/products/equipment/ag_management_solutions
[29] https://ag2point0.com/tag/monsanto/

the case also in XVELA, as optimization of a terminal is sub-optimization if you look it from the supply chain point of view. The amount of waste in global shipping is highly related to inefficiencies in information flow, and Cargotec has estimated that the lost value of its waste is $17 billion annually[30].

The traditional information flow is based on the exchange of electronic versions of documents between two trading partners at specific points in time (e.g., after the ship departs a container terminal). For example, a *bill of lading* is a document that is carrying the legal ownership from the shipper to consignee, and a *shipping manifest* contains the specifics of the cargo. A vessel *stowplan document* defines all of the containers on the vessel, their locations, and sufficient information for shipping lines and container terminals to exchange instructions as to which containers to discharge and load at a particular terminal. These documents are sent between parties in the supply chain, including governmental authorities, electronically; they adhere, for the most part to industry specific standards (e.g. EDIFACT), and are known in the industry as EDI documents. The crux of the problem is that information is sent to all stakeholders on a 1-to-1 basis and at specific points in time—it is not shared in real time amongst all the parties who require this information in order to make sound and efficient operational decisions.

Like with the Enevo case, the XVELA basic idea is simple. The shipping information would be loaded in real time into a Cloud platform that has analytics-based tools for optimization. Access to information includes security considerations ensuring that all data is safely shared amongst all the key stakeholders, while safeguarding commercially competitive aspects of the data. In this regard, security is more robust than what has existed to date with the sharing of EDI messages among the many parties in the supply chain. Cost factors that such a solution may impact include:

- Capital cost for vessels waiting to be loaded and unloaded;
- Extra operational cost (e.g., fuel) for the vessel when sailing at a higher speed than needed,
- Multiple handling of information in the value chain and by other stakeholders,
- Lower productivity of the terminal,
- Longer storage time for containers in terminals.

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[30] http://www.cargotec.com/en-global/investors/materials/other-presentations/Pages/CMD-2015.aspx, retrieved 3.5.2016

On the revenue side, better knowledge of information would increase vessel utilization and improve service, enabling performance-based pricing and rewarding good companies with premiums.

The business model alternatives for XVELA are monthly and usage-based. If Enevo needs a high number of users at the municipal level to achieve platform benefits, XVELA needs the same at a global level. Many of the potential users of the systems are consolidated businesses. If acceleration motives are in productivity and new business models, the inertia will likely follow the findings in the Delphi two round. Logically, a specific issue in this type of collaborative platform is trust (e.g., in Delphi sub-drivers, trust in a virtual environment), when competitors in the industry load their business data to the same Cloud platform. The same way as in the Enovo case, better asset utilization cuts asset-based business growth (again from actors) somewhat, but actors do not really have a say whether users join the system or not. All reductions in or automation of multiple information loading are reductions of the labor force, but the impact is from so many streams that it is not a major inertia. As major users of the system are large shipping lines, the inertia results from Delphi two round most likely apply (e.g., management or industry beliefs, legacy systems), but there are no specific research data on this. Users in Delphi interviews, however, were aware of XVELA when answering questions related to Networks, Crowds, Platforms; Cloud, AI, and Digital Business Models.

The strategic landscape for XVELA does have a few challenges. The first one is the speed of user acceptance and of reaching a critical mass of participation that will determine whether it can become an industry platform. The other challenge is potential platform competition. This, according to many of the free comments in Delphi round two, can lead to a situation where users join several platforms, and none of them achieve a true network effect. Potential industrial platforms could come from the same route as XVELA themselves: ERP software competence for ports and terminals. The other source of potential competition is any player that is in logistics software solutions. XVELA has a head start, however, and time will show its effectiveness.

This description was created by analyzing public sources, industry (sub-chapter 4.1), and researcher’s own industry knowledge. XVELA CTO Robert Inchausti also read the draft and confirmed that disruptive logic of the XVELA case is correctly written.

4.4.4 Summary of the three case descriptions

The three case companies all are digital, out-of-industry enablers (from actors point) whose solutions add major value compared to the historical productivity improvement of the case industry. The key characteristics of the value-adding output, relationship to platforms, business models, the use of digital technology, and scalability of the business is presented in Table 14, and it will be used as a framework when discussing results of the two other methodologies in the following chapter.

	Enevo	**Trimble**	**XVELA**
Origin (from case perspective)	New business model based startup	GPS technology (originally startup)	Internal startup of an ERP supplier
Output	Cheaper waste per handled ton	Better crop for a farm	Transparent, real-time cargo planning data for the entire ecosystem
Platform scope	Municipal+	Farm+	Global
Business model	License fee	License fee (+consulting)	Monthly fee and usage
Digital technology	Sensors, wireless data transmission, Cloud computing, Big Data /AI,	Sensors, wireless data transmission, Cloud computing, Big Data /AI, GPS	Cloud computing, Big Data / AI
Scalability	To similar waste systems	To similar farming methods	Global transportation
Impact to actor	Reduced growth rate in equipment based business	Reduced growth in equipment based business Chance to leverage	Reduced growth rate of equipment
Impact to user	Reduced cost, opportunity to new business models	Optimized output	Better productivity or lower cost Chance to leverage

Table 14. Summary of the three case descriptions

5 Discussion and conclusions

The ethos of this dissertation is hermeneutic, and the research question is related to a complex systemic phenomenon. The intent of the enquiry has been increasing understanding of whether the current value creation of the machine-building industry is going to be disrupted by digitalization and, furthermore, if there is a paradigm change, what types of technological and economic/ strategic management drivers cause the change. The underlying assumption has been that the consensus or disagreement about this future development in the value chain impacts the dynamics, and therefore the value chain has been a key component in the research design. This systemic complexity of the question triggered the use of relatively large number of technological and economic/strategic management perspectives. It also created a practical limit on how detailed the investigation could be without losing the holistic approach which is a critical attribute of the entire enquiry. The same reason drove the choice of mixed methods, which are not only used for triangulation of the results, but also for expanding the breadth that the different research methods cover. Apart from the three short case descriptions, expert judgment was at the core of the Delphi interviews as well as the survey.

The logic of the last chapter is that the discussion section covers the three areas of the enquiry: disruptiveness, value chain, and system perspective. In the first two, the findings of all three methods and the underlying theory are utilized. The systemic section is based on presenting the key findings in a system dynamic model. The conclusion section presents the contribution to industry evolution and strategic management as well as to practice. The analyses of reliability and validity of the results is done before ending the dissertation to suggest potential future research avenues.

5.1 Discussion

5.1.1 Disruption

It is challenging to judge the drivers of disruption without understanding the characteristics of the potential disruption. The proposition was that digital technologies enable technological and strategic management concepts which can disrupt the machine-building industry. This dissertation is not trying to prove the proposition, but rather to increase understanding about the mechanisms that might result from it. Proving the proposition would have encountered dilemmas in the spirit of the positivistic philosophy of science: How do we verify with measurement that the disruption has happened? How do we measure the exact starting point?

Disruption is, in this dissertation, defined as changing a paradigm of the industry. In the beginning, the definition of paradigm was done by citing Thomas Kuhn (1996), whose definition originated from scientific paradigms, but it also serves well in the industrial context:

> On the other hand, paradigm stands for the entire constellation of beliefs, values and techniques, and so on shared by the members of given community. On the other hand, it denotes one sort of element in that constellation, the concrete puzzle solutions which, employed as models or examples, can replace explicit rules as a basis for the remaining puzzles of normal science.

Theories in the second chapter dealt with content of the starting point, such as Dominant Logic (Prahalad and Bettis, 1986), Industry Recipe (Spender, 1989), and Business Model (Osterwalder, 2004). Other sets of theories looked upon the transformation mechanisms like Industry Forces (Porter, 1979), S-Curves (Foster, 1987), Technological Trajectories (Dosi, 1982), Disruptive Technologies (Bower and Christensen, 1995), Diffusion of Innovations (Rogers, 2003), and Industry Convergence (Hacklin et al., 2013). The third set of theories focused on the firms and people in management who initiate any change at a practical level: strategic schools and tools, Stakeholders (Freeman, 2015), Prospect Theory (Kahneman and Tversky, 1979), Bounded Rationality (Simon, 1979), and Absorptive Capacity (Cohen and Levinthal, 1990). The framework used to look at the system was based on PEST (Aguilar, 1967). It was originally developed as a tool to scan business environments, but it took simultaneously into consideration political, economic, social, and technological factors which were an integral part of Schumpeter’s (2008) seminal concept of the Creative Destruction, which also can be labeled changing paradigms.

Building on the notion of a heuristic starting point, one can draw from chapter 4.1 a list of beliefs that are in some form present with the practitioners of global container-handling.

- Users are conservative as they have high amount of capital tied up with the current assets which still have a long lifetime;
- Users are conservative as many of the them have a structural advantage to be in a location where high numbers of consumers and suppliers are located;
- Actor's business is driven by trade growth that has a positive outlook, and market share of new equipment is a result of competition whose dynamic is best explained by Porter's (1979) Five Forces;
- The profitability of actors is mainly created with the after-sales services, where the highest margin component is spare parts;
- Unmanned operations are still in their infancy stage, but their emergence is likely to accelerate;
- Out-of-industry startups do not possess credibility to seriously enter the business.

The disruption itself was empirically investigated in the survey and case descriptions, and it was also elaborated upon in many of the Delphi round two free comments. For analytical purposes, the potential impact was analyzed separately by products, services, operations, and business models; therefore, the discussion follows the same logic. It is, however, recognized that concepts like Service of Everything (Zysman et al., 2015) blur the boundaries of those categories.

Products

The survey result suggests that within the confines of this dissertation, products will not be the area where disruption emerges by digitalization. The minority, although they believed in disruption, also believed that the introduction time is shorter than in the disruption related to the services, operations, or business models. The interpretation is that both development work and radical innovation of products continue to change market positions between actors using mechanisms that are well-explained by Porter's (1979) Five Forces, but without changing the rules of the value creation of the industry. Also, new substitute products fit into the same Five Forces or general substitute theories in economics. There is also history-based evidence, that in global container-handling, there has been an array of new types of products or methods introduced at frequent intervals without industrial disruption as defined in this dissertation. Digital technologies are often generic, and more often than not originate from consumer businesses. Process computers that are needed for controlling the machines are available for all machine builders serving all industries. This makes it even harder to achieve product-based sustainable competitive advantage. Applying digital technologies faster than the competition can create temporal advantages that can be sustained if the actor is able to repeat its leadership in innovations.

The case descriptions validate the point from a different angle. In the cases where the disruptive impact was achieved without actors' involvement and with little or no coupling to the product, even the digital solutions impact the future market of the products. In the infancy phase of digitalization, machine builders were using own technologies that kept companies like Trimble away, as machine builders had proprietary components that they programmed by themselves. That development did not allow scaling or external innovation, and it did raise the barriers for the user who wanted to switch to another supplier. Also, one machine-one industry solutions meant that the R&D investment did not scale up, and consequently the progress was slow.

The actors' choices for the product is related to original sensoring (i.e., users can let sensoring to be installed to existing fleet by someone other than the actors), onboard computing, technologies that enable actuating functions based on computing, and technologies that enable data transmission to external systems. The biggest difference with the actors and companies in the case descriptions is the fact that the data machines collect from their performance, or from the process of which they are part, or from the environment where the process takes place, is a vital source of knowledge for development of new machines, but only for the actor. This does not take away the fact that in new machine development, boundaries of disruption are at the single machine level or location-based fleet.

The weakness of product-based industrial disruption can indirectly be derived from the small number of free comments on the role of the products in the Delphi interviews. One could summarize them in one comment: *Machines have become smarter, and they will continue to do so.*

Services

In the survey data, services were perceived to be slightly more potential object for industrial disruption than business models (Appendix 7). Figure 23 shows that 90% of the respondents of the survey, who judged disruption to take place in services, also judged that it will take place within the next 10 years. Predominantly, the “digital disruption” research reports of machine-building are close to this notion of the GE white paper (Evans & Annuziata, 2012). This might relate to logic that the objects of the service are multidisciplinary technological products, and the perspective of disruption is, often, how one of the existing incumbents could be the disruptor. In business seminars, the same notion is illustrated with one of the most referred examples: Rolls Royce and *power by the hour.*[31] It indicates that performance-based service (also defined as a new business model) is used by Early Adopters (Rogers, 2003); this case suggests that aviation has been the forerunner at the industry level.

For the digital enabler, it is different, and all the case firms can be defined as service companies: Enevo in waste management service, Trimble in crop optimization service, and XVELA in real-time cargo information service. Those services are only weakly coupled with actors’ products. Actors’ services historically are related to performance of individual products: spare part supply, maintenance and repairs, and by digitalization-more towards uptime services that utilize the data that the machine builder has from the real operation, merged into its design knowledge. Enevo and XVELA services do not interfere with those types of services. Their services, as well as Trimble’s, is in the space which is a natural adjacency for actors to grow as firms. Trimble is also in the actors’ service space, which is enabled by the knowledge of machines they have through the joint venture with Caterpillar.

As long as the service is attached to the actor’s own equipment, logically the disruption potential for the industry is limited. Service innovation even with that scope still has great profit and growth opportunity. The disruption mechanism impacting actors is more related to whether one player can service different brands, and whether the service is scalable. Trimble’s is also closer to this development. Trimble is trying to do both, as it is involved with the machine-building discipline with its connection to Caterpillar, and also applies the concept not only to agriculture (which was in the case description in sub-chapter 4.4), but also to other industries like mining and construction. The scalability increases with the rate by which value can be added remotely.

The free comments from the Delphi round two were along the same lines, with two expansions. Service operations are a target of quantum leap by digitalization that will

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[31] http://www.rolls-royce.com/media/press-releases/yr-2012/121030-the-hour.aspx, retrieved 16.5.2016

benefit the user and create competitive advantage for the actor. That builds on logic that domain knowledge lies with current actors who would not change the content of the service but just improve the execution. The other comment was also evolutionary, stating that one avenue to digital services is bundling it with capital. The leasing business has already contained various services built-in to the offering. It is not the same discussion as what was elaborated upon in sharing economy articles, other than the attitude for ownership might be changing in society at large. Platforms were mentioned several times in free comments, and most often they were linked to new types of services if the user would open its data, but that will be discussed more in the driver subchapter.

Operations

The impact of digitalization on operations is, according to the survey, stronger than on products but weaker than the impact on service/business models. If the impact is disruptive, it is perceived to take a longer time than if one initiates the change via a disruptive product innovation. There are a number of interpretations here. On the lower disruption side, one can argue that software has been an enabler of both continuous improvement and quantum leaps for a very long time. This is most evident in process schools, or re-engineering as Hammer (1990) called it. Processes that were supported by systems also cause inertia as discussed earlier in the qualitative findings. This most likely is related to why disruptive transformation was judged to take a long time even though there were no specific beliefs inhibiting it. Cloud computing that was analyzed as a driver often impacts operations. As earlier cited, Salesforce.com (Weinhardt et al., 2009) is a good example of one process as it changes the company-specific ERP solutions into common pay-per-use solutions where the best practice process is incorporated into the service. From the competitive angle, this commoditizes a key account process. For the actor, this might be a quantum leap in efficiency of one process, but it is undeniably disruptive to those whose industry is defined as key account management software.

Many digital technologies of enablers allow actors to impact users' operations. The case descriptions are such that actors are partially bypassed in the process. Digital technologies or related management concepts are often available for all value chain members; Open Innovation can allow very different development processes compared to closed innovation. These cases do not provide data on disruptiveness to operations of enablers or actors. However, there is evidence on the disruptive impact to users' operations. In Enevo's case, the waste handling company has to change its collection system as directed by analytics in the Cloud platform rather than using fixed routes. Trimble's results changes planning on the farm to be based on knowledge of the weather and other data-driven evidence. If the actor uses Trimble's service, it can use the platform to develop services for its users. In that case, the actor uses modules like positioning, fleet management software, etc. XVELA, for the most part, passes actors as it is not a value chain-based service, but rather is an omni-channel platform where all stakeholders can get knowledge to improve their operations. With XVELA, this can result in major operational changes for the users, like closing departments when data handling becomes automatic in the Cloud platform.

Delphi interviews were centered on disruption drivers. Keeping this perspective in mind, AM/3D printing was the only technology which was believed to have power to catalyze disruptive changes in operations of the actor. The current technological maturity is still inhibiting this tool, as will be discussed in the drivers' sub-chapter.

Business models

Business models were ranked as disruptive as services in the survey. The emergence of the disruption was also judged to take longer than with the three other potential objects of disruption. Most likely, this is due to the beliefs that are discussed attached to the inhibitive sub-drivers that are discussed in the next sub-chapter.

All the cases had innovative concepts that had potential as disruptive impacts. However, the companies' own business models were not disruptive. Their solutions enabled better planning and productivity leaps in operations, but their own business models to capitalize on these concepts were similar to the B2B software industry: a developer sells licenses to users. Many software products have become de facto platforms, like SAP in ERPs or Google in search engines. It appears that disruptive innovation can, at least in the beginning, be applied with an old business model such as the example of Google and a newspaper business model (Huberty, 2015). Even actors are bypassed in Enevo's and XVELA's cases; the user can use the solutions to develop new business models. Shipping lines can use performance-based pricing enabled by XVELA the same way as waste-handling companies can pass part of the savings from the Enevo solution on to its customers with performance-based contracts, and thereby change the rules of the waste business. Actors can also utilize the Trimble platform and offer performance-based contracts for users.

Free comments from the Delphi interviews supported the nature of the disruption in business models being close to the view of Outcome Economy (Figure 5) or moving up in systems (Figure 14), or the Systems of Systems (Porter & Heppelman, 2014). Business model innovation (Osterwalder & Pigneur, 2010) itself can be also a small step; the only element of the Business Model Canvas in Figure 9 that opens the door to Outcome Economy is the value proposition.

5.1.2 Drivers

What factors, enabled by digitalization, drive disruption in the machine-building industry serving global container handling?

The empirical input to the question is primarily originating from the results of the Delphi interview round two. The role of the survey was triangulation of the drivers. Technological drivers were the same as in the Delphi interviews, but economic/ strategic management drivers were reduced to two and simplified to Industrial Internet and Open Innovation. Reduction was based on a judgment that it would have been hard to judge seven economic/ strategic management concepts on top of six technological concepts in a short time. The selected two were based on literature concepts that have specifically attached to digital technologies. Both technological and economic/ strategic management drivers were also present in the cases, but in the discussion those will be only observations.

The logic of discussion is to group drivers as strong, medium, weak, and interrelated based on the results from the Delphi round two. Results are presented based on Delphi results, but are discussed using the other methods and literature. Part of the discussion concerns the sub-drivers that either inhibit or accelerate the impact of the driver.

Strong drivers

The results in sub-chapter 4.2.2 were based on rank ordering of the top three technological and economic/ strategic management drivers. In both categories, the top ranking was clear, and thereafter the consensus decreased. The strongest technological driver was Big Data/ Artificial Intelligence and strongest economic/ strategic management driver was Networks, Crowds, Platforms. The clear observation is that further development in both of these areas is beyond the machine-building industry, let alone individual players. That also suggests that some degree of Convergence of Industries is ongoing, even though it ranked in the economic drivers. Porter and Heppelman

(2014) also highlighted that smart connected products pose a question: *"What Business am I in?"*

Big Data/Artificial Intelligence

Big Data in the context of sense-making has, in this dissertation, been perceived as one development towards Artificial Intelligence when a vast amount of real-time sensor data is combined with other types of data to draw relevant business conclusions. That type of analytics is also a core enabler to Industrial Internet (Evans and Annunziata, 2012), which in this dissertation was later defined more generically as one Digital Business Model. The further acceleration of AI is driven by its business opportunities. Manyika et al. (2013) estimated the potential impact of automation of knowledge work in 2025 to be between $5.2-6.7 trillion annually. This type of relationship between technology advancement (push) and immediate market growth (pull) creates trajectories that impact industry structures, as Dosi (1982) suggested. Big Data/AI is also well-aligned with what Dussauge et al. (1992) discussed about generic technologies.

Is Big Data/AI also an enabler in strategic management concepts? As it touches the very principles of knowledge creation, one can easily conclude that it does have an impact on strategic thinking. I would, however, from the disruption perspective identify three particular concepts in strategic thinking: Business redefinition, Dominant Logic, and Core Competence. An argument for business redefinition is that Big Data/AI offers new sources of knowledge with which to redefine businesses. The concept is partly related to Design, Cognitive and Learning schools by Minzberg et al. (1988), with a strong entrepreneurial angle. It has links to earlier scholars' creative thinking (e.g. Hamel, 1996; Kim and Mauborgne, 2005) in strategy formation, which in today's language most often is referred to as business model innovation (Osterwalder and Pigneur, 2010). Business model change was also often mentioned in the free comments of Delphi round two as a prerequisite for technology to be disruptive. Link to Dominant Logic (Prahalad and Bettis, 1986) or Industry Recipes (Spender, 1989) is attached to the suggestion from Delphi round two comments that all businesses are becoming data-centric, as enabled by Big Data and advancement in AI. The logic for Core Competence (Prahalad and Hamel, 1990) is that if the previous thinking is correct—or if it is correct in machine-building—one could build a competitive advantage using a company based on core competence in data science, which Evans and Annuziata (2013) suggest as vital future competence. This logic is also similar to the view of Conner and Prahalad (1996) about the strength of knowledge-based choice versus opportunity-based choice. Big Data/AI, in that context, can be perceived as an amplifier of knowledge creation.

From this data-centric perspective, it is plausible that inertia for Big Data/AI expansion is related to data attributes (e.g., confusion and conflicts in data ownership and concerns of data security). Competence is not currently seen as an advantage, but rather an inhibitor, in building data-centric businesses. The single most important inertia was, however, the set of management and industry beliefs; there was consensus on that importance among enablers, actors, and users. Management beliefs are linked in Chapter two to Prospect theory (Kahneman and Tversky, 1979), Bounded rationality (Simon, 1979) , and Absorptive Capacity (Cohen and Levinthal, 1990), whereas industry beliefs are more tied with current Dominant Logic (Prahalad and Bettis, 1986) and Industry recipe (Spender, 1989) . The sources of Dominant Logic (Prahalad and Bettis, 1986) in Figure 8 also explain components that create industry beliefs' inertia. Transformation to data-centric business is also a large management challenge even if there would be no specific beliefs inhibiting as suggested by McAfee and Brynjolfsson (2012).

Sub-drivers that accelerate Big Data/AI were not so much linked to strategic management theory; rather, they had more the logic of enabling, benefit, or improvement. The top five sub-drivers in rank order were: prescriptive potential, knowledge scalability, process productivity, users opening their data, and advancement in cognitive computing. Big Data/AI was also the most disruptive driver in the survey, with the second lowest variance. It also clustered with Cloud and IoT, and correlated with disruption objects (enablers). All cases had Big Data/AI-based knowledge creation at the core of their business values.

Networks, Crowds, Platforms

This concept was judged to be the most disruptive digitally enabled economic/strategic management driver. It relates to network economy theories (including sharing), as well as to Open Innovation (Chesbrough, 2006) and various platform strategies presented in Chapter 2. The concepts also are interlinked. When Häcki and Lighton (2001) discussed the network effect they discussed the importance of platforms even before the rise of Cloud computing. Sharing is built on using platforms like Uber, but the paradigm question is also related to ownership (Belk, 2010; Bardhi & Eckhardt, 2012; Nicholas, 2012).

Open Innovation (Crowds) and Platforms are interlinked (e.g., in the discussion of intermediaries' roles) (Chesbrough, 2006). The same way to link to AI and Networks is present in the collective intelligence discussion by Malone et al. (2010). A prominent finding in the free comments from the Delphi round two was that open systems at large already gain market share with their own force, and they need platforms; at the same time, emergence of new platforms will further speed network usage. The other similar fundamental view was that Five Forces (Porter, 1979) does not well explain the systemic transitions in business and does not recognize platforms as players in that theory.

Just as with Big Data/AI, management beliefs were the major inertia for network economy to expand. The theories for the beliefs are the same, but the interpretations are most likely different. Big Data/AI has more understanding and belief questions related to its importance. Networks, Crowds, Platform also has beliefs that have undesirable attributes to management, as it challenges structures, culture, ways to operate, and management capabilities; that was the second-ranked inertia. The third-ranked inhibitive sub-drive, current systems and processes, is often the most used as it is based on facts. If a company has built its processes according to a traditional value chain and invested into IT systems accordingly, this poses an implementation dilemma even as the company would like to shift its operating mode towards network style. Emergence of platforms is the main accelerator of Networks, Crowds, Platforms. A secondary accelerator, flexibility with capacity and lower cost, is a normal, rational argument in any investment calculation.

Open Innovation was measured in the survey and it ended up higher than most of the technological drivers in the average rating. It got most very disruptive views (Figure 25) and at the same also more very weak disrupting views indicating a polarized view of the population. Open innovation is also perceived as a generic disruptor (impacting products, services, operations, and business models), the same way as Big Data/AI based on the correlation analysis.

All case firms had networks and platforms as integral part of their business. Trimble's ConnectedFarm concept needs the ecosystem to contribute data for Trimble to provide better crop output services. Enevo needs users to join its platform to raise the effectiveness of waste management. XVELA is a real-time cargo information platform whose value is partly based on the Metcalfe's logic (2013) of how many users the network is able to attract.

Medium drivers

IoT, MBSE, and Robotics were medium technology drivers. IoT was the second-ranked driver, and was closest to a phenomenon by the view of panelists with logic that device connectivity is increasingly enabled by multiple drivers like described by Bradley et al. (2013), and the growth takes place already, independent of individual industry or company barriers. Why IoT was clearly higher than Cloud may be because Cloud computing is more independent from firms, whereas in IoT, firms have an important role in designing the sensoring and connectivity, but even they cannot stop the logarithmic growth of connected devices. If Big Data/AI can create new knowledge, MBSE was seen as a tool to model both existing and new knowledge. MBSE was slowed by management beliefs which were explained by lack of systemic understanding as well as the benefits of the technology. Legacy systems were factual inertia. As such, MBSE did not have strong linkage to any theory, but it was rather a rational management choice of perceived value by investing in a given technology. It appeared that the judgment on robotics was connected to AI. The importance of robotics appeared to be linked to whether the panelist judged the intelligence to be in the upper systems or in the robot itself. If the view was that intelligence was in the upper systems, then the arguments were built into Big Data/AI and, in the case of robotics, also into machine-learning. The societal impact of unemployment in autonomous operations was also present as described by Frey & Osborne (2013) and Brynjolfsson & McAfee (2012).

IoT was the second most powerful technology driver in the survey. It was also clustering with Big Data/AI and Cloud. Trimble and Enevo platforms were based on the connected devices but XVELA source was more aligned with the planning systems.

Digital Business Models, Industry Convergence and Radical Innovation were medium disruptive economic/strategic management drivers. Digital Business Models was close to Crowds, Networks, Platforms in ranking and also had the same small variance in the second Delphi interview round. In the free comments, it was obvious that in machine-building, the most popular Digital Business Model is that introduced by GE as Industrial Internet (Evans & Annunziata, 2012) which was generally understood by the panelists as harvesting data from intelligent fleet of machines, processing that data into knowledge which is developed as a valuable algorithm (productivity, cost saving, safety etc.), packaging it as a piece of software, and delivering it as a service where the value is shared between the developer and user. This development was perceived to be inhibited by industry barriers, legacy systems, and the data itself (i.e., ownership and security). Digital Business Model innovation appeared to follow Rogers's (2003) Diffusion of Innovation theory, indicating the importance of use cases. Convergence theory in Chapter 2 was predominantly discussed as the merger of the ICT industry to other industries like media or health care. Attributes like clock speed, ecosystems, or diffusion of business models were also present in the free comments and discussion. More emphasis was, however, given to the convergence of machine-building and service industries when concepts like Service of Everything (Zysman et al., 2015) combine physical products, services, and business models, and whose transformation is ICT-enabled. Radical Innovation was medium high as a disruptive driver. The argumentation for it was more towards “Black Swan” (as the likelihood of inventing something as transformational as a container that was described in Chapter 4.1 is unlikely). The endeavors for Radical Innovation were often perceived to lead to quantum leap innovations that change market positions between existing players. To accelerate this experiment culture was perceived as a prerequisite.

Industrial Internet was used as a concept to illustrate Digital Business Models in the survey. It was perceived to be almost as disruptive as Networks, Crowds, Platforms, which meant it ranked higher than most of the technological concepts. As there were only two economic/ strategic management concepts in the survey, more conclusions on the ranking cannot be made. In the case descriptions, it can be argued that Trimble and Enevo are in the domain of Industrial Internet, whereas XVELA is a marketplace of knowledge, based on the real-time data.

Weak drivers

Weak drivers did not necessarily have weak correlations to company success, but based on the Delphi interviews they had weak explanation power as stand-alone to industrial disruption. According to this logic, Cloud was perceived to be the weakest technology; based on free comments by the panelists, it has become the de facto standard of modern computing, but also has been commoditized. If Radical Innovation was judged as a source of unexpected results, Black Swan’s (Taleb, 2010) AM/3D printing received similar comments as a technology. This most likely explains why it ranked as the second weakest disruption driver.

Cloud was also weak in the survey, but it clustered with Big Data/AI and IoT. MBSE was a medium driver in the Delphi interviews but ended up as weak in the survey as Cloud. In the Delphi discussions, the panelists appeared to approach MBSE from the concept of power of modeling, whereas it might be that in the survey the experts were judging it as a tool.

Weak economic drivers of disruption in reverse rank order were: Risk Capital, 6 Forces (Five Forces added with stakeholders) and Firm, Strategy, Leadership. The panel had very high consensus that Risk Capital does not cause disruption but is a powerful catalyst in the beginning to speed up disruptions. Six Forces was recognized as one of the fundamental theories of the industry dynamics as well as a practical tool in portfolio development. It was ranked sixth out of seven, but with higher variance than Risk Capital. The free comments highlighted its static nature, lack of platform, and eco-systems. Firm, Strategy, Management might have been ranked number one if the question would have been about innovation-based competitive advantage. Visionary leadership and experiment culture like those described by Ries (2011) were perceived to be tools to avoid strong industry beliefs or Innovators Dilemma (Christensen, 2011); the same way as they were prerequisites for Radical Innovation.

The relationship between weak drivers and the three cases is that originally the businesses had been startups, where experiment culture and visionary leadership of the firm played important roles in the beginning.

Interrelated sub-drivers

Delphi interviews were the only sources for sub-drivers. Inertia sub-drivers indicated why panelists do not believe that a technology or economic/strategic management concept is disruptive or why disruption is slower than it could be or what specifically slows it down. Accelerative sub-drivers did the opposite. Interrelated sub-driver is sub-driver that has been suggested to explain behavior of more than one driver. The top three technological interrelated inertia sub-drivers were: competence/understanding, data (security, quality, availability, and ownership), and beliefs (management and industry). Competence and understanding were related to Absorptive Capacity (Cohen and Levinthal, 1990). Data issues are logical and rational issues to be solved, but data ownership disputes reflect also a lack of understanding about how different parties capture the value from more open data-sharing. Various beliefs have already been discussed as part of theories related to management cognition and behavior.

Productivity, new insight, and new business models were the three most important technological interrelated sub-drivers that accelerate the digital disruption. Productivity and new business model are discussed, but insight has not been highlighted yet. Insight was discussed in the context of how IoT-based machine, operation, and environment data creates new engineering insights. Digitalization was also referenced to create new insight based on people being connected.

Some of the inhibiting sub-drivers of the economic/strategic management drivers were the same as with the technology. Top three interrelated inhibitive sub-drivers were: management/owner beliefs and culture, legacy (systems, processes, and structure), and industry structures. The culture aspect was somewhat stronger to complement the beliefs, but competence was clearly shared with technological sub-drivers. Industry structure (e.g., oligopolistic, old stakeholder organizations, established value chain) was referred to as natural inertia, but also acknowledged as a politically correct excuse to focus on continuous improvement. Some panelists linked this to Innovator's Dilemma (Christensen, 2011), as doing what the customers want and doing it a bit better than last time still pays off.

New business models, productivity/cost, and platforms were perceived as top interrelated sub-drivers explaining acceleration of the economic/ strategic management drivers. Overall, it appeared that Facebook, Apple, Uber, and Airbnb have made business model innovation a popular term. Productivity and cost represented the hard metrics that management is used to when making investment calculations. If industry structures were highlighted in inertia, platforms were one of the main topics breaking it. Platform emergence was perceived far more powerful than disruption by startup types of new entrants. That might also be a chicken or egg question (i.e., emergence of platforms allows startups to join as complementors), as Gawer and Cusamo suggest (2002).

5.1.3 Value chain

Does the view on drivers differ depending on where the company is in the value chain?

The data for comparison comes from Delphi round two and the survey. The technological drivers to compare are: AM/3D printing, Big Data/AI, Cloud, IoT, MBSE, Robotization, and economic drivers of Network, Crowds, Platforms and Digital Business Models. Sub-drivers were presented in the Delphi results, but there is no comparison data from the survey. The discussion is categorized into consensus or disagreement and is presented in order of ranking of the Delphi interviews. Context for the discussion is already-reviewed literature and the container handling industry. One factor that did not relate to any specific driver was the difference in the preparedness for digital disruption that was presented in Figure 26, which showed that enablers were best prepared, users worst, and actors in between.

Consensus

Big Data/AI was ranked the top technical driver in the Delphi interview, and tied for the top spot in the survey results with IoT. The averages were close with all the value chain members, and the variance was low with the exception of users in the survey. This result suggests that the machine-building industry serving global container handling is becoming data-centric, which enables disruption in the industry.

Network, Crowds, Platforms had equal position in the economic/strategic management drivers. In the Delphi interviews, it was the top economic/strategic management driver, with low variance and consensus in the value chain. Open innovation had a slightly lower average than Industrial Internet, but it attracted more than twice the number of very strong disruption views in the survey. There was a consensus on the position, but with higher variance than the other four top rankings. The empirical results and earlier literature on platforms (e.g., Cusamo & Gawer, 2002) or innomediaries (Roijakkers et al., 2014) suggest that platforms play a critical role in disruption, and they enable the power of Big Data/AI, using IoT based data or judgement from humans attached to Open Innovation or Crowd concept.

Internet of Things or connectivity was the second-highest technological driver in the Delphi interviews, but it had also low variance and consensus in the value chain. The survey judged its importance even slightly higher, with medium variance and medium consensus; users rated this slightly lower than enablers and actors. The small difference with users might explain that users perceive that they might already have some of the data by old-fashioned means like maintenance records. The conclusion of IoT, however, appears to be that it creates a new type of real-time data that has not been available earlier.

Digital Business Models ranked second in the Delphi interviews; it also had consensus for this position and a low variance. In the survey, it was almost ranked first, with a consensus in the value chain and low variance apart from the users. The interpretation with the users might be that their benefit from Industrial Internet is indirect. It depends on how the actor can translate the new data from IoT to knowledge, and how the benefit is divided. The lack of current supply did show in the accelerative sub-driver, Early Adopters (Rogers, 2003) with an interpretation that users whose existing purchasing patterns had been based on ample supply, faced in the introduction phase the opposite problem, and they might fear not having enough alternatives or being locked in the introduction phase of the new business model. The strong consensus on Digital Business Models indicates that the value chain is expecting that value will be divided with the players in the value chain differently than before, and that logic fits into the definition of a Digital Business Model.

The judgment of Cloud can be summarized that it is the new way of computing, but on a stand-alone basis—not as an explanation of disruption. This view had a consensus with the Delphi interviews and the survey.

Disagreement

The disagreement with the value chain was with MBSE, AM/3D printing, and robotics. In the Delphi interviews, MBSE was held to be the third most important driver for disruption; there was a consensus on this, but users judged it less critical as seen in Figure 16. The disagreement was smaller in the survey as seen in Appendix 9. There was, however, a disagreement between methods: the Delphi panel ranked MBSE clearly higher than did the experts who participated in the survey. The disagreement in the value chain is, perhaps, that MBSE as a tool for modeling complex things is more familiar with enablers, for whom it could be a business, and for actors that get a direct benefit from it. The difference in methods might be explained by the fact that in the interview, the panelists elaborated on the criticality of modeling, but it might be that in the survey, the tool shadowed the fundamental feature behind it.

Robotization also caused a disagreement in the value chain, but the pattern was the same by both methods. Enablers did not see it as disruptive, actors perceived it as a quantum leap, and users saw it as disruptive. The likely explanation for this is that the enablers are suppliers across the industries, and automatization is nothing new. Actors might also have supplied automation (e.g., to the processing industry) or even had their first references to unmanned operations in ports and terminals, and therefore see it as evolution. Actors seem to acknowledge that when a manned industry transforms to unmanned, suppliers' market shares will be divided with a new way. Robotization appears to be a paradigm change in the eyes of the users. As described in sub-chapter 4.1, the labor in port operations is a central role. It is a powerful stakeholder; the productivity of the port has a lot to do with the operator's judgment, and the competences both in the field and at the office support a manned paradigm.

Additive Manufacturing/3D printing got a weak rating as a disruptive driver. This view was consistent between the two methodologies; actors and users perceived it higher than did enablers. The weakness was elaborated on in the Delphi interviews (e.g., the concept is highly disruptive but the technological obstacles are high for the size and material used in the machine-building). Enablers' weaker view can be explained that, for them, it is a promising technology, and if it breaks through they still continue to deliver similar services to actors and users who will get the benefit of the technology. Actors' perspectives depend on the progress of the technology; if speed, material coverage, and cost can be solved, AM/3D printing can change both the design paradigm as well the production paradigm. Users who rated AM/3D printing highest see both evolutionary and disruptive benefits. How machines that handle containers are manufactured is not their direct concern.

Printing spare parts would change the dynamics, as argued in the industry sub-chapter; spare parts are the most profitable single component in the actors' offering. Global container ports and terminals are driven by consumer behavior (i.e., by goods that are in the containers), and an innovation which could make it possible to traverse the long distances by Internet in the form of printing code would disrupt transportation, if the speed of printers would be changed on an industrial scale. The conclusion for AM/3D is that it was the only technological driver that can become a Black Swan (Taleb, 2010) in a form that is still unclear today.

5.1.4 The systemic impact

How are disruptive drivers related to each other in the machine-building industry serving global container handling?

The process evaluated potential disruption drivers separately in the Delphi interviews and in the survey. The Delphi interviews with iteration ranked sub-drivers that inhibit or accelerate disruptive technological and economic/strategic management drivers. The case studies illustrated how there is already ongoing business, within the limits of this dissertation that contains some of the characteristics of disruption that is being investigated. The strength of mixed methods was applied in the previous sub-chapter where both consensuses with the methods and the value chain were used when the final ranking order was discussed.

The whole dissertation has assumed that the studied phenomenon is systemic, which was the perspective also expressed by many panelists. In order to increase the understanding about the systemic impact, the last phase of discussion uses system dynamics. This will be done by applying a Causal Loop Diagram (CLD) (Sterman, 2000). The CLD is a tool to represent the time delays and causal relationships between taking a decision and its effects on the system. The CLD visualize how causalities and delays build up the feedbacks and dynamics in a system level.

The illustration is based on the most critical conclusions from the results:

- Big Data/AI is the disruptive technology that enables new knowledge creation;
- Platforms accelerate the use of external knowledge;
- IoT feeds new engineering knowledge to Big Data/AI;
- Crowd and Open Innovation enable new judgmental knowledge.

Several causal relationships can be detected between aforementioned drivers. By representing these causalities in a single CLD it is seen that causalities form feedback loops. In the loop the decision is defined as investment in capabilities which were found critical in the research. The output is new product features, advanced services, efficiency of operations, or new business models. The dynamics between decisions and its output is affected by delay. In the model, the dependencies that might impact with a delay are marked with ǁ. The inhibitive or accelerative sub-drivers are added to CLD from Figures 17 and 21. The model can be seen in Figure 27, which can be defined as a heuristic system model explaining the characteristics of digitally enabled disruption in machine-building serving global container handling.

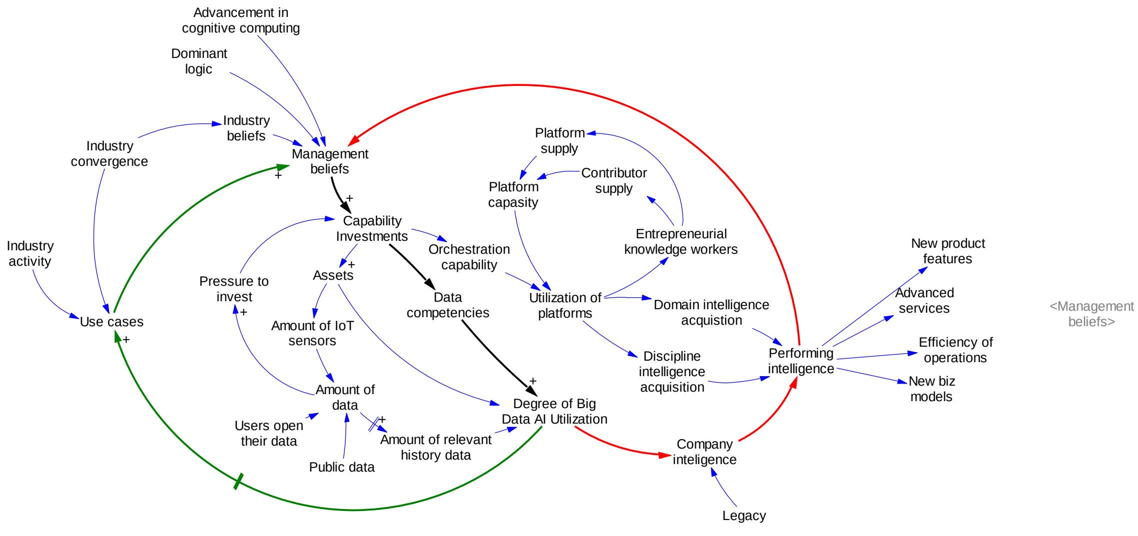

Figure 27. Big Data /AI and Networks, Crowds, Platforms described by CLD

Figure 27 reveals two loops that impact the firms' ability to create value. The measurable factors are utilization of Big Data/AI, which here predominantly present the growing IoT-based data and Platforms that bring the human network effect. Both factors are slowed down by management beliefs based on the results of the study. Management beliefs' concrete impact in this context is investment in capacity, which can be assets (e.g., licenses, servers, sensoring), and data competencies (e.g., training, recruitment of data scientists, subcontracting) in an IoT context. In a human network context, the investment is in orchestration capability based on the results of the study.

In IoT loops, there are delays (marked ll) in the loops, as some loops have time elements that are very difficult to shorten. Adding sensors increases history data very slowly. But with that logic, adding sensors now is a no-risk decision if believes that data is the core essence of competitiveness in the future, even you the business case in not known today. Management beliefs are impacted by the success of own use cases as well as use cases of own industry and other industries. Based on theory and results of the dissertation, management beliefs are driven also by other external factors. The combination of IoT (marked green) and human loops (marked red) drives the value creation in products, services, operations, and business models. Success has a strong but delayed impact on management beliefs, meaning that in order to lead the development, management has to first act based on a positive belief.

The human loop is more outside firm or industry control. Platform supply has already emerged, and it is accelerating through new innovation, both in disciplines (e.g., software engineering) and industrially (e.g., health care), as well as by multinational technology companies and startups in narrower spaces. At the same time, platforms attract small and large incorporated complementors, as well as knowledge workers who wish to be independent entrepreneurs. This exact impact of this development is more difficult to forecast than the impact of sensors.

5.2 Conclusions

The dissertation investigated the research question from a hermeneutic perspective in the philosophy of science, and used mixed methods. The main method was Delphi interviews. Delphi Round one validated six technological and two economic drivers that can enable disruption in the machine-building industry, which is serving global container terminals. It also, together with literature, yielded sub-drivers that either inhibit or accelerate development. The Delphi round two ranked the six technological drivers together with the original two economic drivers and an additional five economic drivers that came from the literature and were supported with comments in the Delphi round one. New sub-drivers were also added in the Delphi round two, and based on the saturation and pattern their significance was analyzed as if they would have been considered from the beginning. The survey investigated the object and timing of the potential disruption and triangulated the rank order results of the drivers from the Delphi round two. The logic of the Delphi and survey methodology was based on the value chain. The survey also increased understanding of the preparedness of the value chain members for the potential disruption. The third method in the enquiry was analysis of three short case descriptions. Their role was to illustrate that there are already ongoing disruptions whose mechanisms are under investigation. The critical conclusions were also illustrated in a heuristic CLD model.

The conclusions are based on the findings where the three methods have found similarities and consensus. As the survey expanded the methodology, some of its strongest findings are also presented as conclusions if they were supported by the literature. The conclusions are presented both for their theoretical contributions as well as their relevance to practitioners. In practitioners sub-chapter issues that had disagreement has more importance as it might indicate industry specific circumstances. The conclusions in chapters 5.2.1 and 5.2.2 are written in italics.

5.2.1 Industry evolution, strategy formation

Seminal theories within industry dynamics such as Industry Forces (Porter, 1979), S-Curves (Foster, 1987), Technological Trajectories (Dosi, 1982), Disruptive Technologies (Bower and Christensen, 1995), and Diffusion of Innovations (Roger, 2003) explain well how the dynamics work in established industries. Industrial Convergence is a prominent area that addresses how mechanisms that are familiar in ICT industry diffuse into other industries and sometimes form new industries. Business model innovation, used in this dissertation in the context of Digital Business Models, appears to work both in industry dynamics and as a factor in industry convergence.

The conclusions based on the empirical findings suggest the following three attributes to explain the potential disruption.

1. *New powerful technologies in knowledge creation (Big Data, AI, machine learning) and unpresented flow of data by connected devices (IoT) enable the move to higher levels of optimization like those described in the World Economic Forum about Outcome Economy (2015).*
2. *Industrial and discipline-based platforms emerge as new disruptive elements in value creation.*
3. *Platforms decouple old value chains that transform into networks, which are joined by startups and crowds.*

If the three attributes above are centric in the investigated disruption, then the empirical findings that inhibit or accelerate the development will have a focal role in strategy formation. Those drivers were similar in technological and economic / strategic management drivers, but in order to focus on the most critical ones as conclusions, those that have same types of meaning are combined. The acceleration in firms is based on investments, and productivity/cost was number one reason to do that. Investing in digital disruption led to the new Digital Business Models as the second most important explanation. New insight was the third most important reason (second as to technical drivers and fourth as to the economic/strategic management drivers), and recognizing the emergence of platforms was the fourth most powerful explanation (third with economic drivers and fourth with technological drivers).

Management/owners' beliefs constituted the most powerful explanation that inhibits the preparation for the digital disruption. The second most powerful explanation is industry barriers that include not only the structure of the industry but also the collective beliefs within the industry. The third strongest explanation was lack of competencies, including the lack of understanding of the systemic nature of the potential disruption. The two next most important sub-drivers explaining the inertia were legacy (e.g., systems, processes and structure) and data (e.g., ownership and security).

Redefining the language to be compatible with the strategy formation, the earlier results can be summarized as four statements. Decisions to invest are based on measurable rational economic factors. It has been recognized that digitalization contains new critical elements in the strategy formation (e.g., Digital Business Models, new insight and Platforms). Decisions not to invest appear to be based more on beliefs (management or industry) than measurable factors (cost of changing systems, cost of data security). Lack of understanding the characteristics of the systemic change and lack of competencies that it requires slows down the transformation.

Strategy formation literature was reviewed using the ten strategic schools by Minzberg et al. (2010). The first conclusion is that any of those strategic schools do not, alone, offer guidance through potential disruption. Using Minzberg et al.'s (1998) own framework in Appendix 1, the empirical results suggest that the external world in digital disruption is unpredictable and confusing. Both the findings from the research and Schumpeterian's (2008) view of Creative Destruction indicate that in disruption, the internal processes are natural that reflect larger societal changes than rational business planning is able to capture. Based on these assumptions, there are three suggested conclusions for strategy formation:

1. *Firms have to be able to mitigate the management beliefs in the firm and industrial level to be able to capture the potential of digital disruption.*

   It appears that the mechanisms that were present with three interviews in the introduction (Chapter 1) or examples like Kodak, do repeat themselves. This conclusion is within the Cognitive School.

2. *The change in business environment appears to be systemic and complex, and therefore strategy formation by learning is effective.*

   This is close to the Learning School or the ideals of the Lean Startup (Ries, 2011) and it requires either entrepreneurship by a visionary leader and/or a culture that fosters experimentation.

3. *Digital Business Models, when applied with a network model, are a major change in traditional industries, and they challenge firms' current capabilities.*

   This implies that apart from learning, a major competitive advantage can be obtained if, during the transformation, unique capabilities can be created, which is along the lines of resourced-based theory in strategy formation (Conner & Prahalad, 1990).

5.2.2 Practitioners in machine-building industry

The conclusions from a practical perspective are validated in the machine-building industry that is serving global container operators. It does not exclude learnings that are applicable also to machine-builders that have other types of users whose business environments have similar characteristics. The previous chapter had conclusions about the mechanisms of disruption where the value chain members were in consensus. Those conclusions can well be used also as guidance for practical strategy work. The specific conclusions here are related to issues of the object of disruption that were studied only in the survey and elaborated on by the case descriptions, or by such results that had disagreement in the value chain. Conclusions are written in the perspective of the actor in italics.

1. *Service is the most relevant object of the disruptive impact of digitalization within the limits of this enquiry.*

Service can be viewed from two perspectives: major growth opportunity and source of competitive advantage (quantum leap) and service that changes the need to be satisfied into higher systemic levels as described in the Outcome Economy by World Economic Forum (2015), which is a source of industrial disruption.

The first perspective can be categorized in the same way as what GE calls Industrial Internet (Evans and Annunziata, 2012), which is one Digital Business Model. Based on the results, users are ready for it but somewhat reluctant to open their data, which is needed for the business model to emerge. Some users do open their data, which creates new use cases, which impact management beliefs; then, after the innovator and Early Adaptor users, the Early Majority also gets interested (Rogers, 2003). The new business model also opens the door for new entrants like the component suppliers, system suppliers like ABB, or digital enablers like Trimble to enter the business as seen in the precision farming example.

The second perspective relates to a new upper level service that makes the whole lower level operation or process dramatically more effective. This implies that growth in services with the new business model is a prerequisite for the incumbents to grow as companies as the systemic productivity leap in assets reduce the growth rates of machines as long as a new equilibrium has been reached. All three cases were characterized by this perspective.

Compared to literature and findings in the empirical research, it can be argued that actors' business environments have been more stable in the past than ongoing digital transformation enables it to be changed. This is the logical reason why Porter's Five Forces (1985) in the industry dynamics, or Positioning and Design School of Minzberg et al. (1998) in the strategy formation, have had such a central role. Cognitive School is seldom used, as trained professionals are assumed to make rational decisions. In those industries where the digital disruption has already taken place, the disruptors seemed to be visionary leaders with entrepreneurial ways of operating, like Steve Jobs, Mark Zuckerberg, and Elon Musk have demonstrated. This leads to a second practical conclusion:

2. *If the actor wishes to adapt to digital disruption or be a disruptor, it is beneficial to use learning as a core element in the strategy formation.*

Prerequisite for the importance of learning in strategy formation is understanding that ongoing systemic change is complex and that the current capabilities are not adequate for winning. It is also builds on a notion that the chances to design or plan are less effective than experimenting and adjusting. The literature offers multiple choices to organize disruptive activities related to digitalization, such as stand-alone business units, centers of excellence, or cross-business-unit steering as suggested by Porter and Heppelman (2015). The objective of the learning is not only strategy formation, but also building unique capabilities, which can be translated to the third practical conclusion:

3. *Competence in digital technologies with strong machine-building and industry knowledge can be combined as a core competitive capability.*

The essence of the conclusions is grasped by two quotes: "*Unlike physical assets, competencies do not deteriorate as they applied or shared"* (Prahalad & Hamel, 1990) and "*The only way to win is to learn faster than anyone else"* (Ries, 2011). Based on the empirical results, orchestration of the network is one of the needed capabilities as well the leadership skills to lead the transformation; both skills are needed by the incumbents.

MBSE and Robotization were the two drivers where there was a disagreement in the value chain. Enablers saw both as a business opportunity. Actors saw MBSE as a powerful thinking tool and a tool to change business, whereas users saw it as an opportunity to communicate their needs better to actors. Users saw Robotization as a change of paradigm in how to run a terminal business, but actors saw it as an evolution of smart machines. From an actor's perspective this finding can be translated to action planning that takes into consideration concerns of both sides.

4. *Diagnostics on understanding the differences on views of business environment changes in the value chain can be developed as new kinds of tools for business planning.*

Many of the earlier practical conclusions have the lack of systemic understanding as one of the root causes and therefore the fifth practical conclusion is:

5. *System thinking or CLD as a specific tool has a lot to offer in strategy formation in machine-building, where it normally is only applied in control systems engineering.*

5.3 Validity and reliability

This dissertation has used mixed methods that have been applied conceptually as seen in Figure 12. All three methods have different issues in their validity and reliability, and they will be reviewed separately. The Delphi interviews and case descriptions are grouped under qualitative methods and the survey under quantitative methods. Validity and reliability will be concluded by considering the use of three separate methods as one mixed method at the end.

Qualitative methods

Both validity and reliability are originally concepts of positivistic worldview and have an assumption that a hypothesis can be verified, and the result is not depending on the researcher (Guba & Lincoln, 1994). In the Delphi interviews, there was an interaction between the researcher and experts, which implies that the results may differ if the investigation would have been done by another researcher.

To mitigate this inherent issue between positivism and hermeneutics, several approaches have been developed. Lincoln and Guba (1985) constructed a concept of trustworthiness that included Credibility (Is the right thing investigated?), Transferability (Is right also right in other contexts?), Dependability (In what conditions are findings consistent?), and Confirmability (How neutral are the results from the researcher?). Stenbacka (2001) argued that reliability in the traditional sense does not apply in qualitative research, but the quality can be judged by *validity, generalizability, and carefulness* as a whole. This requires that informants are correctly chosen, they are able to express their knowledge, and there is a systematic and careful description of the process.

The sample strategies have been described previously and the research design and process descriptions have been integral parts of the methodology in Chapter 3. However, there are specific quality issues related to the Delphi technique and case studies. Linstone (2002) summarized the quality issues in eight pitfalls of the Delphi methodology, which framework is used below to judge the quality concerns.

1. *Discounting the Future*

This implies overweighting the short term, an issue also discussed in the management cognition. The main mitigation for the issue was the design of how panelists were chosen (i.e., three different roles of future) (Kuusi, 1999). It is fair to argue that all three groups have to deal with the long term, but at least one can assume that scientists are familiar with the speed at which technology progresses.

2. *The Prediction Urge*

Humans dislike uncertainty, which leads to prediction even when the expert does not possess the knowledge on which the judgment should be based. The design of the dissertation was not trying to achieve a force consensus, thereby easing part of the pressure and urge to predict. The other quality measure was that order ranking the disruptive drivers was not possible without argument of inhibitive or accelerative factors (sub-drivers). That philosophy was derived from the Argumentative Delphi from Kuusi (1999), but it also served as an indication of expertise.

3. *The Simplification Urge*

The trap, according to Linstone (2002), is when a reductionist approach is applied to social/behavioral systems in order to get more simple explanations. This enquiry was about a complex, systemic phenomenon. Therefore, the PEST approach (Aguilar, 1967) was used in order to take both technological and economic factors into consideration. Participants were also using societal and political factors when they judged the development of inhibitive or accelerative sub-drivers. The second way to avoid simplification was the use of free comments in the enquiry. It also served the purpose of acknowledging that the panelists could have views that are not captured by the research design. The third element of avoiding oversimplification was the construction of the CLD model.

It was not, however, tested with a third Delphi round, but in constructing the survey results and the case descriptions it gave some support.

4. Illusory Expertise

The illusory refers the expertise to forecast outside the own domain expertise. The means to obtain the relevant expertise relates in this dissertation to panel structure, and individual members in relation to the research question. One section of the research question relates to the value chain, which implies that there was equal participation from enablers, actors, and users in the panel. The depth of expertise was assessed by using Kuusi's (1999) definition on expertise on future: decision-makers, synthesizers, and scientists. The majority of panelist were senior professionals and possessed true expertise in more than one role, even when they were asked to approach the questions based on the designated role. This was further utilized in some of the analysis when the perspective was formed by using the expertise of the group of 36 individuals. The panel was underrepresented with Asians, females, and persons younger than 30. The open versus closed society has issues related to cultural differences (Hofstede et al., 2010). The enquiry did not investigate how differences in cultural background impact the view of how digitalization disrupts the machine-building industry. However, in some individual disruption sub-drivers' culture was present, and was not found to be a strong contributor. There were some remarks on national cultures in the free comments.

5. Sloppy Execution

Linstone (2002) refers to sloppy execution, both for the panelist and by the Delphi manager. Panelist sloppiness relates to Stenbacka's (2001) question whether the informants are able to express their knowledge properly. Sloppy execution can also relate to choosing panels based on friendship or such recommendations that lead to group thinking. The issue with the Delphi manager relates to expertise in relation to the panelists, which can impact both what knowledge is shared and the capability to interpret it. The peer relationship most likely is optimal, so that neither one in the interaction takes on the role of lecturing. The process of searching for the panelists was that the Delphi manager created a list of potential companies or universities that fit the study's purpose, and then searched roles and persons. The selection of decision-makers was based on titles (e.g., owner, chairman of the board, CEO, director, executive vice president) relative to the company where they came from. The introduction was done either directly or by someone that the Delphi manager knew who was likely to know the person identified. The end result was that 28 out of 36 of the panelists in the Delphi round two had no prior relationship to the Delphi manager. The logic of the interview was also based on the time being spent on those drivers that the panelist judged relevant as described both in Chapters 3 and 4. There were also a couple of test interviews prior to the Delphi rounds in order to refine the process. The Delphi manager (i.e. the researcher of the dissertation) was assumed -based on his education and industry background- to be qualified to conduct the interview as well to interpret the free comments, but obviously it is a biased judgment. The other interpretation issue was not recording the interviews, which was a tradeoff decision as described in the methodology subchapter 3.1.2.

In the Delphi round two, there was a qualitative self-judgment measure after each interview. In the self-judgment, the session was ranked with four parameters and scale of one to five, where five was an acknowledged international expert and one was someone not adequate for the purpose of the research. The parameters assessed were adequacy of the time, substance knowledge (technology and economic/ strategic management), ability to apply the expertise to the research question, and the average of first three parameters, which was a quality measurement of the interview based on how the researcher judged the interview's success. In order to count in the results, the quality needed to be at least 3 out of 5 points; otherwise, the interview would be continued. Two interviews were continued within a week from interruption, and one was replaced by a new interview with an expert with the same position in 3x3 matrix.

6. Optimism – Pessimism Bias

This trap is related to the earlier comment of over-optimism in the short term and over-pessimism in the long term. The other perspective of Linstone (2002) is that optimism and pessimism are also personal character traits. Availability Heuristics (Kahneman, 2003) also is an issue (e.g., management consulting companies have actively published reports on how digitalization is transforming businesses, which is likely to impact the views). The survey is not mitigating this, apart from being a larger sample than the Delphi interviews. The analysis of the sub-drivers that inhibit or accelerate development reduces some of the concern. Also, the objective of the system model was to illustrate the interrelation of the drivers and sub-drivers, which takes another perspective of the likely development.

7. Overselling

There are a few traps included in the overselling, over-usage of the method for the same question (the same panelists), anonymity, forced consensus, or hidden agendas. The researcher was not aware that any of the panelists had previously participated in a Delphi panel that was investigating the same research problem. Also, as referenced earlier, there was no forced consensus in the process. Anonymity was maintained during the interviews, but the participants were aware of what type of companies or universities were in the panel and what types of experts the other panelists were. The hidden agenda suggests that there would be a vested interest either by the panelist or the Delphi manager to get a certain type of result. This issue most probably was most problematic with enablers, as they were also suppliers to actors and enablers. However, their coverage in digital technologies was not based on a single technology such as 3D printing, and therefore it is fair to assume that they did not push any particular conclusion to be formed. For the researcher, the intent was the right answer, as false but pleasant results would logically not lead to a useful strategy for the background organization of the researcher.

8. Deception

Deception is related both to manipulation and integrity. Manipulation can be regarded as the more severe form of hidden agenda that was reviewed in the previous paragraph. A researcher cannot objectively judge his or her own honesty apart from the logic that there is no motive to promote a specific picture of future development other than being as truthful as possible.

As described in the motivation (sub-chapter 1.1) the Delphi manager is himself a machine-builder and consequently has a dual role as a researcher and stakeholder. From validity perspective this poses an objectivity issue for Information Policy (Kuusi 1999) of the interviewees and for interpreting the results by the Delphi manager. The magnitude of drivers, sub-drivers, their abstraction level, industry level perspective and time horizon that is beyond ordinary business transactions most likely has mitigated partly the issue of objectivity.

Case descriptions

The case descriptions were brief and not strong enough to form an individual research method. Their application was to describe, from adjacent industries, examples that possess disruptive features of digitalization according to the literature. Cases were taken from public sources, but they were validated by experts who knew the cases, industries, and the uses of digital technologies. Suitability of the cases were related to Outcome Economy (World Economic Forum 2015), the preliminary finding on systemic characteristics of disruption (Figure 14) from the Delphi round one, and the concept of Systems of Systems by Porter and Heppelman (2015). Therefore, it can be argued that the issues of validity and reliability have connection to theory building from the cases. Eisenhardt and Graebner (2007) were discussing part of the problem with the thought: "Better stories versus better theories." They opinioned that particularly with thin stories, like the short descriptions in this dissertation, tables are practical tools to highlight the essence of the constructs. Table 14 where the cases were summarized was an attempt to do that.

Quantitative methods

The use of quantitative methods in triangulation and expansion does not take the ethos of the research away from Hermeneutics. There are, however, different types of validity and reliability issues in quantitative methods. Reliability, according to Olkkonen (1994) is particularly relevant in statistical analysis, as statistical criteria can tell the probability that the results are reliable and indirectly also if the same result can be achieved by repeating the study. The statistical criterion was integrated in the results in sub-chapter 4.3. Repeatability of the results is still most likely hard to obtain for two reasons concerning temporality. First, the publicity of digitalization appears to have grown since the experiment was done, which most likely will have an impact on the judgment of potential participants. The second, more factual reason is that the related technology advances quickly, as well as does the number of cases applying it.

Validity in quantitative research according to Creswell (2013) is *whether one can draw meaningful and useful inferences from scores on the instruments,* which can be further split into:

- Content Validity *(Do the items measure the content they were intended to measure?)*
- Predictive or Concurrent Validity *(Do scores predict a criterion measure? Or do results correlate with other results?)*
- Construct Validity *(Do items measure hypothetical constructs or concepts?)*

The basic questions in the survey were simple in their nature. How strong is an impact, to an object, and how strong are drivers? Logically, the main Content Validity concern was whether the respondents understood the meaning of the objects and drivers, and if they understood them in the same way.

The format of the process, which included introduction of the concepts, was chosen to mitigate the issue of respondents' understanding of the variables. The formatted introduction created a burden to the researcher, who had to conduct the introduction every time in the same way. To accomplish this, the researcher created a script specifying how the concepts were introduced orally apart from the text that the audience saw, in order to improve the consistency.

Predictive Validity appeared to have some issues beyond triangulation. The sample population using the 3x3 matrix should have been quite a bit larger than 305, in order to increase the potential to generalize the results (e.g., to other industries). High variance in the raw data might also have originated from the fact that it is truly difficult to judge the systemic impact of digitalization, and there is confusion on the issue. Concurrent validity was not possible to check, as the research was not using a method that would have applied in comparable research questions including the same criterion.

Was the construct valid (i.e., were the drivers in the survey the right ones for measuring digital disruption)? The process of picking the original drivers was based on recent research reports of commercial research institutes that either specialized in digital technologies (e.g., Gartner, Cisco, Accenture and IBM) or more generic institutions that were also researching digitalization from a perspective of strategic management (e.g., McKinsey & Co). Delphi round one interviews also served the purpose of validating this.

Mixed methods

The use of mixed design was based on an assumption that disruption enabled by digital technologies or economic concepts is a systemic phenomenon, and it is difficult to form full understanding of the research question. The use of several methods expanded the coverage as illustrated in Figure 12. In the same figure, one can see that the Delphi one interview validated also the survey (drivers) design, validated Delphi round two drivers, and suggested sub-drivers as well. Delphi round one results were also used in the case design.

Results were presented as stand-alone as well as the judgment on validity. In the discussion and conclusion phases, the second strength of mixed methods came through triangulation. Both the survey results and case description were used to validate findings from the Delphi round two interviews.

5.4 Future research avenues

The components in this dissertation related to industry evolution, strategy formation, and digitalization as a systemic phenomenon that could have disruptive impact on the machine-building industry serving global container terminals. The research design utilized mixed methods. It also appears that development of digital technologies and their applications in business is moving quickly. These premises open the first two natural research avenues: (1) First, to repeat the study with the methodology in an adjacent industry that meets the same criterion as described in the sub-chapter 1.2. This avenue would create comparison data to draw conclusion whether the disruption and its mechanisms have similarities between industries. (2) Second, another plausible way is using exactly the same design; and repeating the study in the global container handling industry. The purpose of that alternative would be justified with the assumption that the topic is moving quickly, and that some of the conclusions of this study could be temporal.

Different perspectives of future research could be derived from the main conclusions: Big Data/AI and Networks, Crowds, Platforms. The logical direction would be to delve deeper into the mechanisms. It could be done either by continuing the study in global container handling or by constructing a multi-industry design. One attractive method could be a case study with an objective to construct a more detailed framework of the disruption mechanisms. The other alternative of building from the conclusions would be an extensive literature review of how the conclusion would be able to contribute generically to the gap that industry dynamics by Five Forces or various innovation based trajectories have when platforms and ecosystems emerge into capital intensive industries. Deeper or wider approaches based on the conclusion would work also in the strategy formation. A theoretical approach there could be an analysis of the impact of platforms and open systems on existing strategy schools.

The third set of further research avenues relate to the methodology. This dissertation did find Kuusi’s Argumentative Delphi useful when it was applied with rank ordering together with inhibitive and accelerative sub-drivers that impacted future development. This was triangulated with a survey. An interesting alternative would be developing the methodology into online Delphi, where those two methods would be merged. That would require special attention to user interface in order to motivate the panelists. That could also incorporate use of visual illustrations (Adelson & Aroni, 2002) to decrease the variance in understanding the arguments. Pre-programmed analytics could further enable instant feedback to the panel, maybe even shown as a system dynamic model. The use of scenarios based on the Delphi findings as suggested by Mannermaa (1999) or applying the futures Map (Kuusi et al. 2015) could be methodologically also an interesting direction to continue the research. One of the most suitable technologies as a research object is Additive Manufacturing / 3D printing as it got quite polarized responses, and also got several suggestions of being a wild card or Black Swan.

The last set of research possibilities centers around management. If the conclusions are correct, what does it imply in day-to-day strategic management? Does the firm truly have a chance to disrupt the industry, or is the development such that it is beyond the incumbents of traditional industries? Even so, based on the findings of this research, business model innovation and experimental culture are advantageous in achieving quantum leaps in competiveness. Also, a practical checklist of choices, like the one Porter and Heppelman (2014) suggest, are useful, and one could study the conditions that impact how to make those choices.

If the assumption in the beginning of this dissertation is true -that the ability to transform any kind of data, observations, events and so on to a digital form, by processing it, storing it, and sharing it, economically, globally, and in real time -has the same kind of systemic characteristics as the invention of writing or printing, the theme will stay a rich source of further research for years to come.

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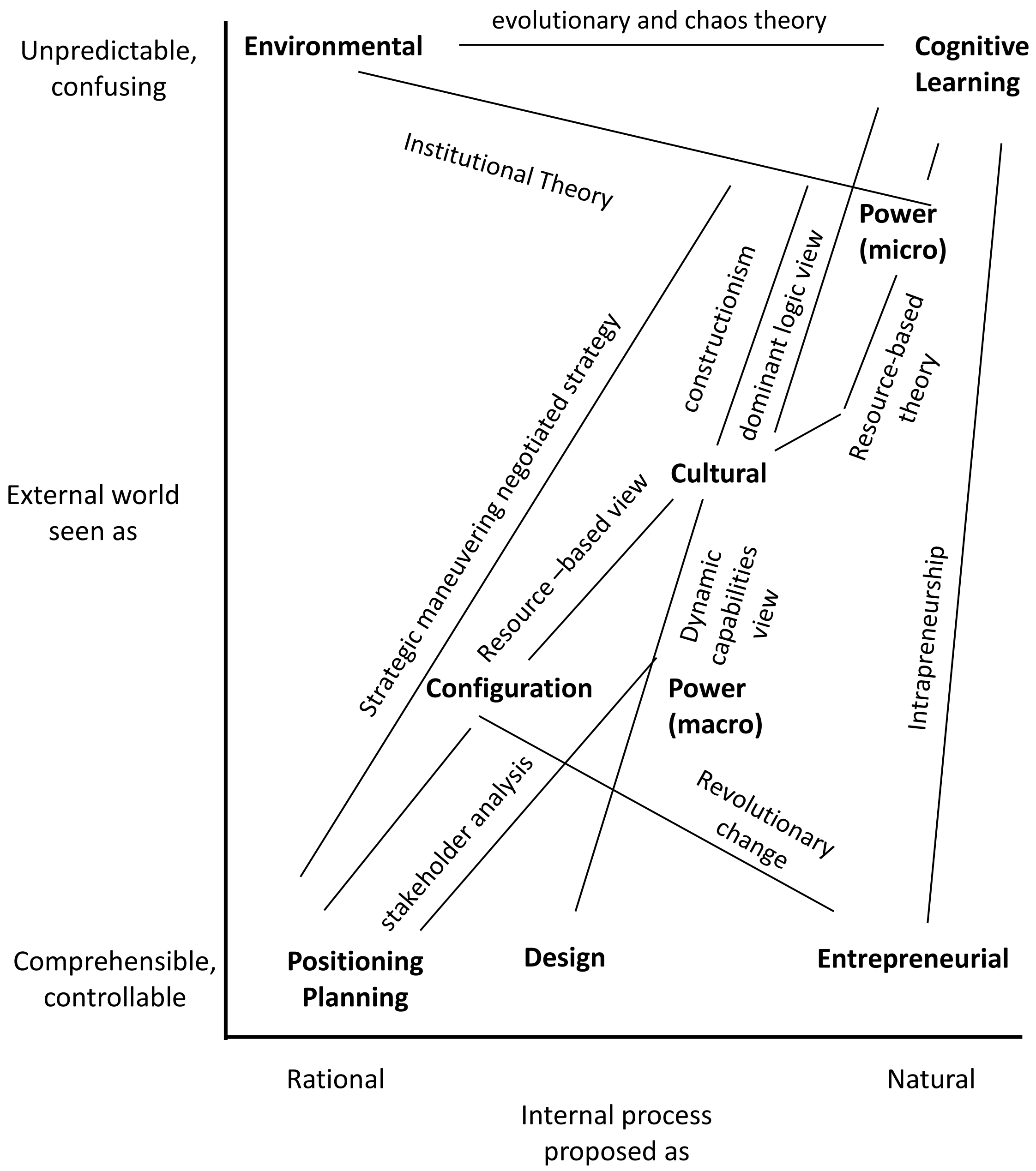
Appendix 1. Mapping strategic schools related to strategy formation (Minzberg et al. 1998)



Research question

It is likely that digitalization is a major systemic enabler for future competitive advantages of the machine-building industry, and in some phase of the value creation, it is or will be disruptive within the next 10 years.

Which drivers enabled by digitalization accelerate or inhibit disruption in a machine-building industry that serves global container handling?

Do the enablers, actors and users have different views on the drivers or sub-drivers that either accelerate or inhibit the disruptive development?

How are disruptive drivers related to each other in a machine-building industry that serves global container handling?

Object of a potential impact

Products

Services

Operations

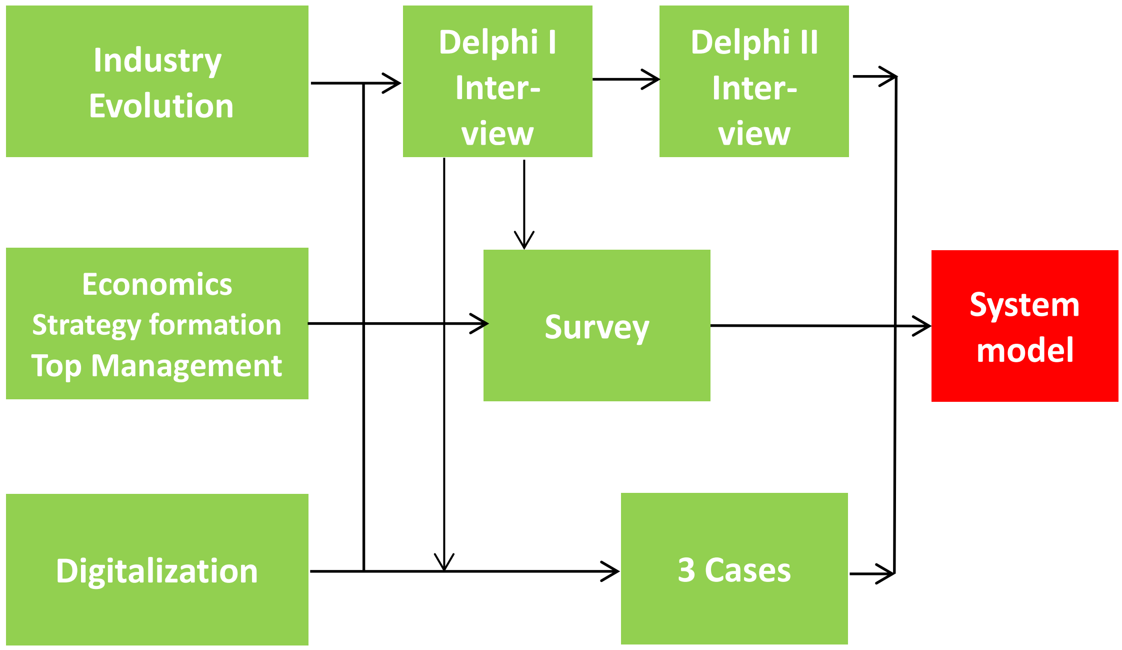
Business models

Business model change can also be integrated into products, services or operations and there is ongoing diffusion of all of the elements like service of everything

Nature of the potential impact

Continuous improve-ment	Staying where you are - This is housekeeping
Quantum leap	Change of positions - Innovation gets you here
Disruption	Change of rules - Transformation gets you here

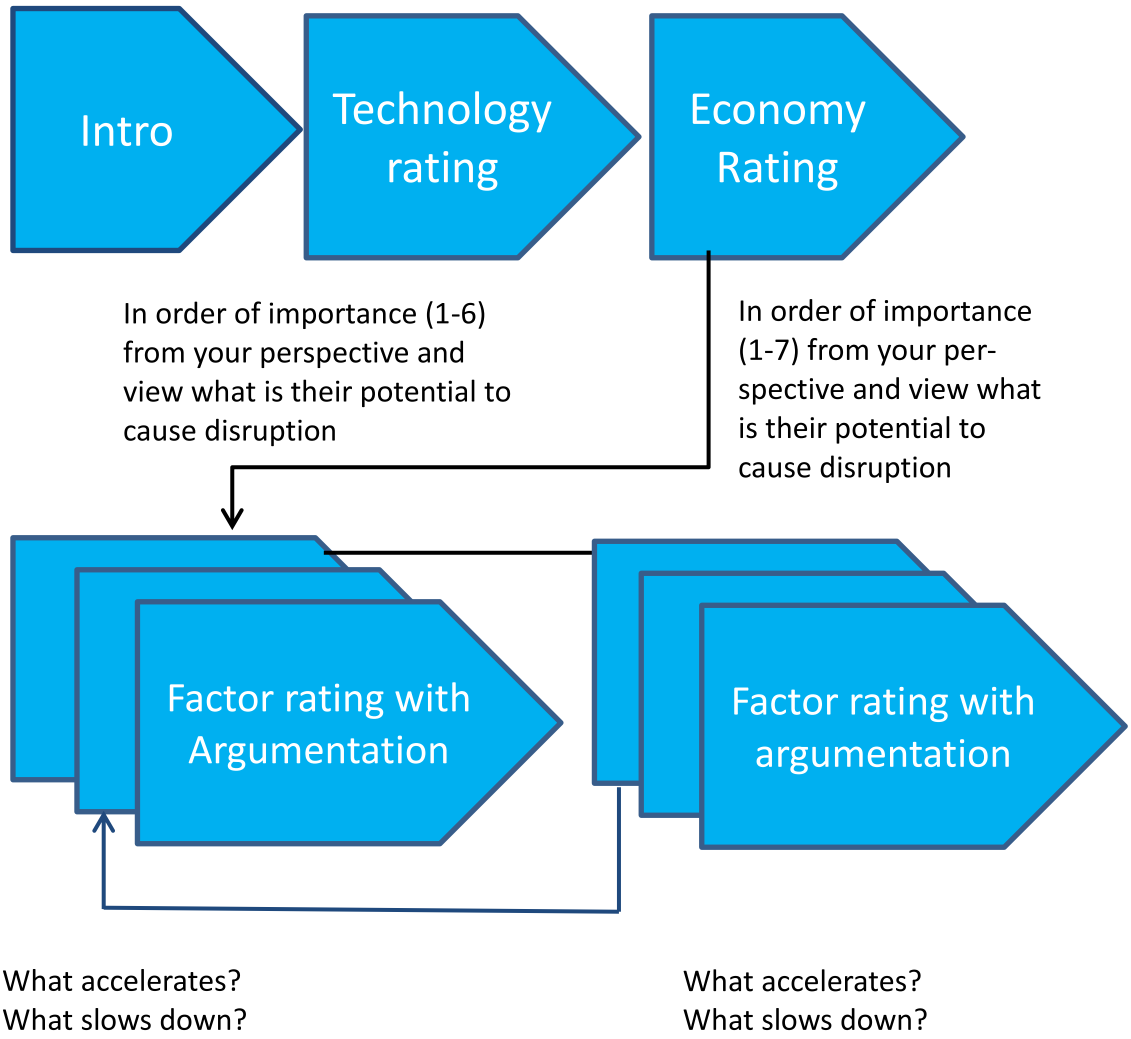
Research design



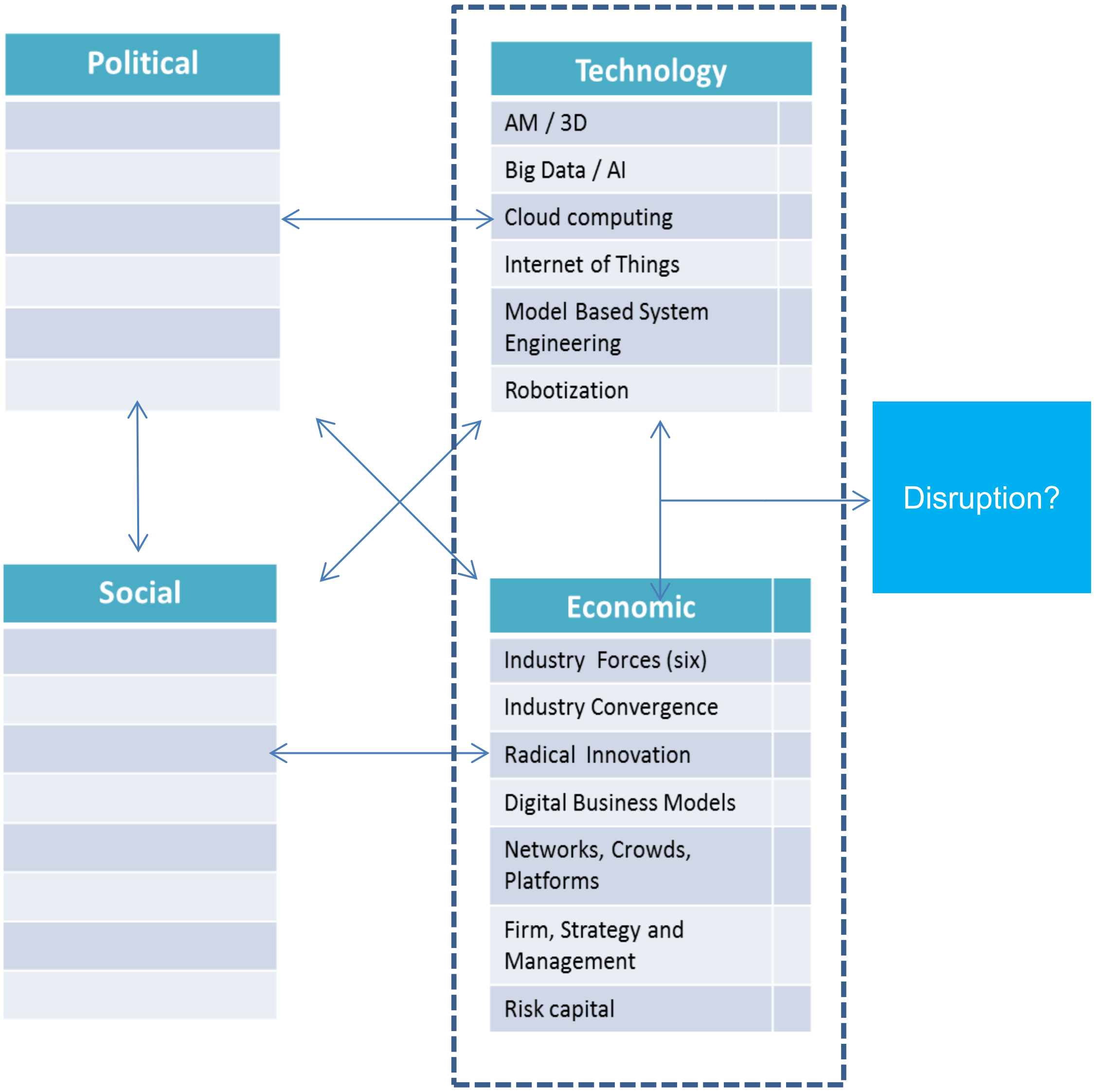
Panel composition

	Enabler	Actor	User
Scientist	4	4	4
Synthesizer	4	4	4
Decision maker	4	4	4

Interview process



PEST

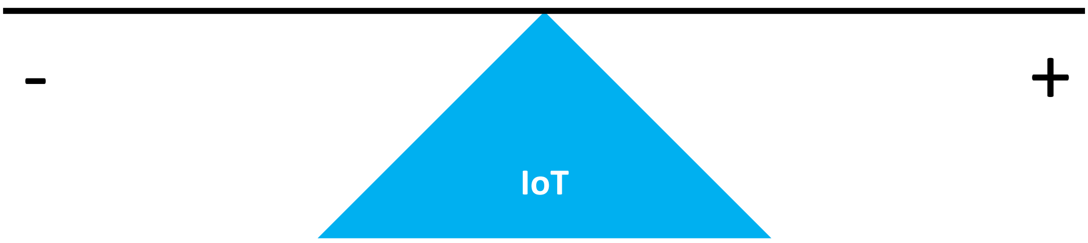


Political
Technology
AM / 3D
Big Data / AI
Cloud computing
Internet of Things
Model Based System Engineering
Robotization
Disruption?
Social
Economic
Industry Forces (six)
Industry Convergence
Radical Innovation
Digital Business Models
Networks, Crowds, Platforms
Firm, Strategy and Management
Risk capital

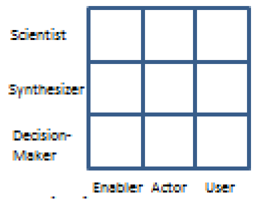
Sub-driver analysis

Sub-driver	Top 3 Relevance
Other	

Sub-driver	Top 3 Relevance
Other	



Appendix 3. Survey form



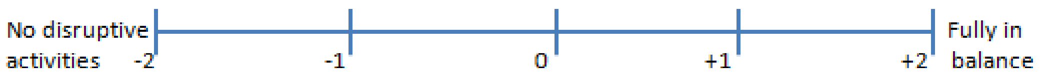
The impact of digitalization for your most important business

	Continuous improvement	Step change	Disruption -5,5-10,+10 y.
Future products			
Timing if disruption			
Future services			
Timing if disruption			
Future operations			
Timing if disruption			
Future business models			
Timing if disruption			

The relative importance of drivers for your most important business

	Continuous improvement	Step change	Disruption
AM (3D printing)			
Big Data			
Cloud			
Internet of Things			
Industrial Internet			
Model Based System Engineering			
Open Innovation			
Robotics			
Other			

How is your current investment (infrastructure, R&D, process and IT development) in balance in relation to growth opportunities or impact to competitiveness which is enabled by digitalization?



Appendix 4. Participants in the Delphi round one and/or two

Dr. Erkki Ahola, Vice President, VTT Ltd (former Vice President, R&D, Sandvik Mining and Construction); (A)

Mr. Kimmo Alkio, President and CEO, Tieto Corporation; (E)

Mr. Timo Antila, former Managing Director, Packaging Industry of M-real (Metsä-Group); (U)

Mr. Andrew Barrons, Senior Vice President and Chief Marketing Officer, Navis LLC.;(E)

Mr. Philippe Bartissol, Vice President, Industrial Equipment, Dassault Systems SE; (E)

Mr. Alex Duca, Director, Head of Design and Automation, APM Terminals; (U)

Mr. Rob van Eijndhoven, former Managing Director, ECT-DELTA Container Division; (U)

Professor Kalevi Ekman, Aalto University; (A)

Mr. Sauli Eloranta, Senior Vice President, Technology Management & Innovation, Rolls Royce Marine; (A)

Chancellor Emeritus Jarl-Thore Eriksson, Åbo Akademi; (E)

Professor Stuart Evans, Carnegie Mellon University; (E)

Mr. Greg Franklin, Co-founder, Intellect Partners; (E)

Mr. Max Furmanov, Managing Director, Accenture Technology; (E)

Mr. Christer Granskog, Chairman of the Board, Patria Corporation; (A)

Mrs. Jena Holtberg-Benge, Director, John Deere WorkSight™, Deere & Co.; (A)

Mr. Robert Inchausti, CTO, XVELA; (E)

Mr. Juhani Jantunen, Technical Director, Dassault Systems; (E)

Mr. Jouko Jokinen, Editor-In-Chief, Aamulehti; (U)

Mr. Pete Karns, Vice President, Internet of Things, IBM: (E)

Dr. Antti Kaunonen, President, Kalmar; (A)

Professor Martin Kenney, UC Davis; (U)

Mr. Frank Kho, former Head of HNN Container Division, PSA; (U)

Prof. Dr. Jürgen Kluge; (A)

Mr. Glen Koskela, CTO, Fujitsu Nordic; (E)

Mr. Mikko Kuitunen, Founder, Vincit Oy; (E)

Dr. Harri Kulmala, CEO, Fimecc Oy; (A)

Mr. Tommi Lehtonen, Senior Vice President, Crushing and Screening Business Line, Metso Corporation; (A)

Mr. Edmond Leung, CIO & Head of Operations Development and Technology, Hutchison Port Holdings; (U)

Dr. Raymond E. Levitt, Kumagai Professor of Engineering, Stanford University; (U)

Mr. Perttu Louhiluoto, President, Services, Metso Corporation; (A)

Mr. Harri Luuppala, Co-founder, Open Invest (former Senior Vice President, Tieto Corporation); (U)

Mr. Anthony Marshall, Research Director and Strategy Leader, IBM Institute for Business Value; (E)

Professor Jeff Martin, Chung-Ang University; (U)

Mr. Brendan McDonnell, General Manager, Technology & Engineering, Patrick; (U)

Professor Lasse Mitronen, Aalto University; (U)

Professor Martti Mäntylä, Aalto University; (E)

Professor Jorma Mäntynen, Tampere University of Technology; (U)

Mr. Daniel Navarro, Google for Entrepreneurs; (E)

Vuorineuvos Dr. Kari Neilimo, Director of EMBA program of University of Tampere and Tampere University of Technology (former CEO and Chairman of S Group); (U)

Dr. Markus Nordberg, Head of IdeaSquare, CERN; (A)

Mr. Oh Bee Lock, Head of Group Technology (former COO, Singapore Terminals), PSA; (U)

Dr. Tero Ojanperä, Co-founder, Vision+ (former CTO, Nokia); (E)

Mr. Jari Rautjärvi, Managing Director, Valtra Inc.; (A)

Dr. Petri Rouvinen, CEO, Etlatieto Oy; (A)

Mr. Patrick Scaglia, Co-founder CITRIS Foundry accelerator (former CTO, Hewlett-Packard); (E)

Professor Emeritus Reijo Tuokko, Tampere University of Technology; (A)

Mr. Jan Waas, Director, Technology and Engineering, ECT; (U)

Mr. Bill Walsh, President and CEO, Navis; (E)

Professor Matti Vilkko, Tampere University of Technology; (A)

Professor Kim Wikström, Åbo Akademi; (U)

Professor Emeritus John Zysman, UC Berkeley; (E)

Four panelists opted to stay anonymous: 1 Research director from a European research institute (E), 1 Professor from a German university (A), 1 Executive from a German machine builder (A) and 1 Executive from Nordic based process industry (U).

Appendix 5. Results from Shapiro-Wilk test

Whole population

Impact

	Products	Service	Operations	Business models
p-value	< 0,0001	< 0,0001	< 0,0001	< 0,0001
alpha	0,05	0,05	0,05	0,05
Normal	No	No	No	No

Technologies

	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
p-value	< 0,0001	< 0,0001	< 0,0001	< 0,0001	0,000	< 0,0001	< 0,0001	< 0,0001
alpha	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
Normal	No	No	No	No	No	No	No	No

By value chain

Impact

Enabler

	Products	Service	Operations	Business models
p-value	0,000	< 0,0001	< 0,0001	0,000
alpha	0,05	0,05	0,05	0,05
Normal	No	No	No	No

Actor

	Products	Service	Operations	Business models
p-value	< 0,0001	< 0,0001	< 0,0001	< 0,0001
alpha	0,05	0,05	0,05	0,05
Normal	No	No	No	No

User

	Products	Service	Operations	Business models
p-value	0,006	0,006	0,029	0,000
alpha	0,05	0,05	0,05	0,05
Normal	No	No	No	No

Technologies

Enabler

	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
p-value	< 0,0001	< 0,0001	< 0,0001	0,001	0,000	< 0,0001	< 0,0001	0,000
alpha	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
Normal	No	No	No	No	No	No	No	No

Actor

	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
p-value	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001	< 0,0001
alpha	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
Normal	No	No	No	No	No	No	No	No

User

	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
p-value	0,001	0,005	0,001	0,050	0,010	0,010	< 0,0001	0,000
alpha	0,05	0,05	0,05	0,05	0,05	0,05	0,05	0,05
Normal	No	No	No	No	No	No	No	No

Test interpretation:

H0: The variable from which the sample was extracted follows a Normal distribution.
Ha: The variable from which the sample was extracted does not follow a Normal distribution.
As the computed p-value is lower than the significance level alpha=0,05, one should reject the null hypothesis H0, and accept the alternative hypothesis Ha.
The risk to reject the null hypothesis H0 while it is true is lower than 0,01%.

Appendix 6. Interaction effect test

Goodness of fit by adjusted R²

	Products	Services	Operations	Business models	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
Adjusted R²	0,104	0,107	0,069	0,073	0,215	0,095	0,072	0,108	0,134	0,129	0,083	0,076
p-value	0,002	0,023	0,052	0,008	< 0,0001	0,059	0,043	0,001	0,002	0,003	0,142	0,006

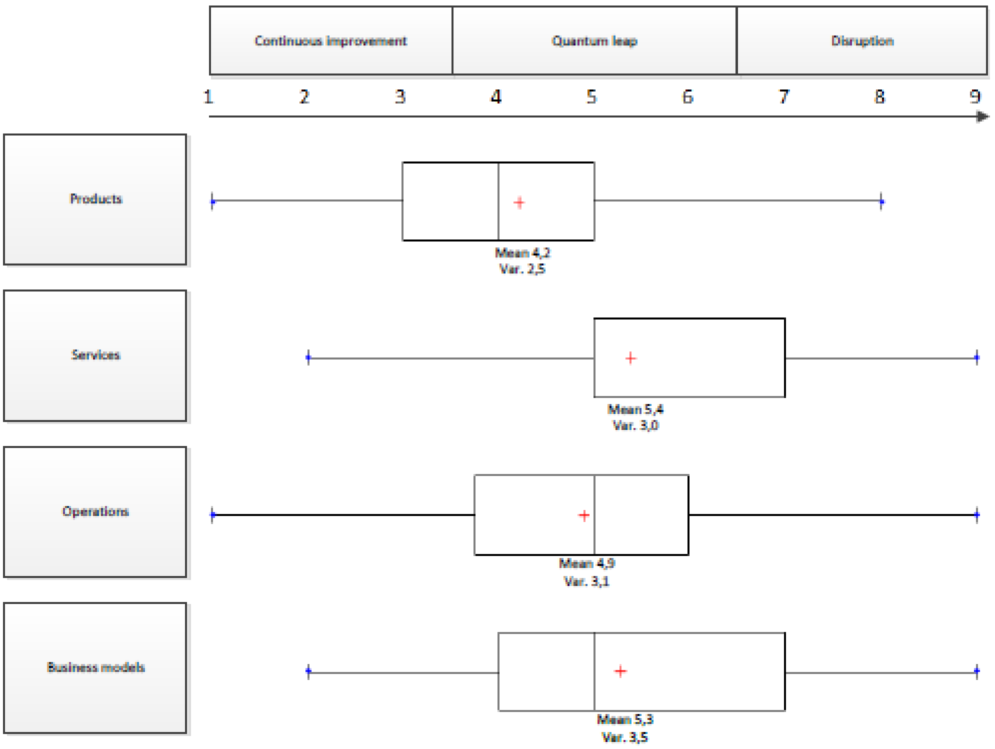
Type III SS

	Products	Services	Operations	Business models	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
VC*Role	0,779	0,931	0,966		0,674	0,993					0,988	
VC*Investment	0,979	0,510	0,245	0,355		0,720	0,669	0,953			0,959	0,749
Role*Investment					0,832		0,790	0,888		0,661	0,900	
VC*Role*Investment		0,065				0,037			0,002	0,023	0,053	

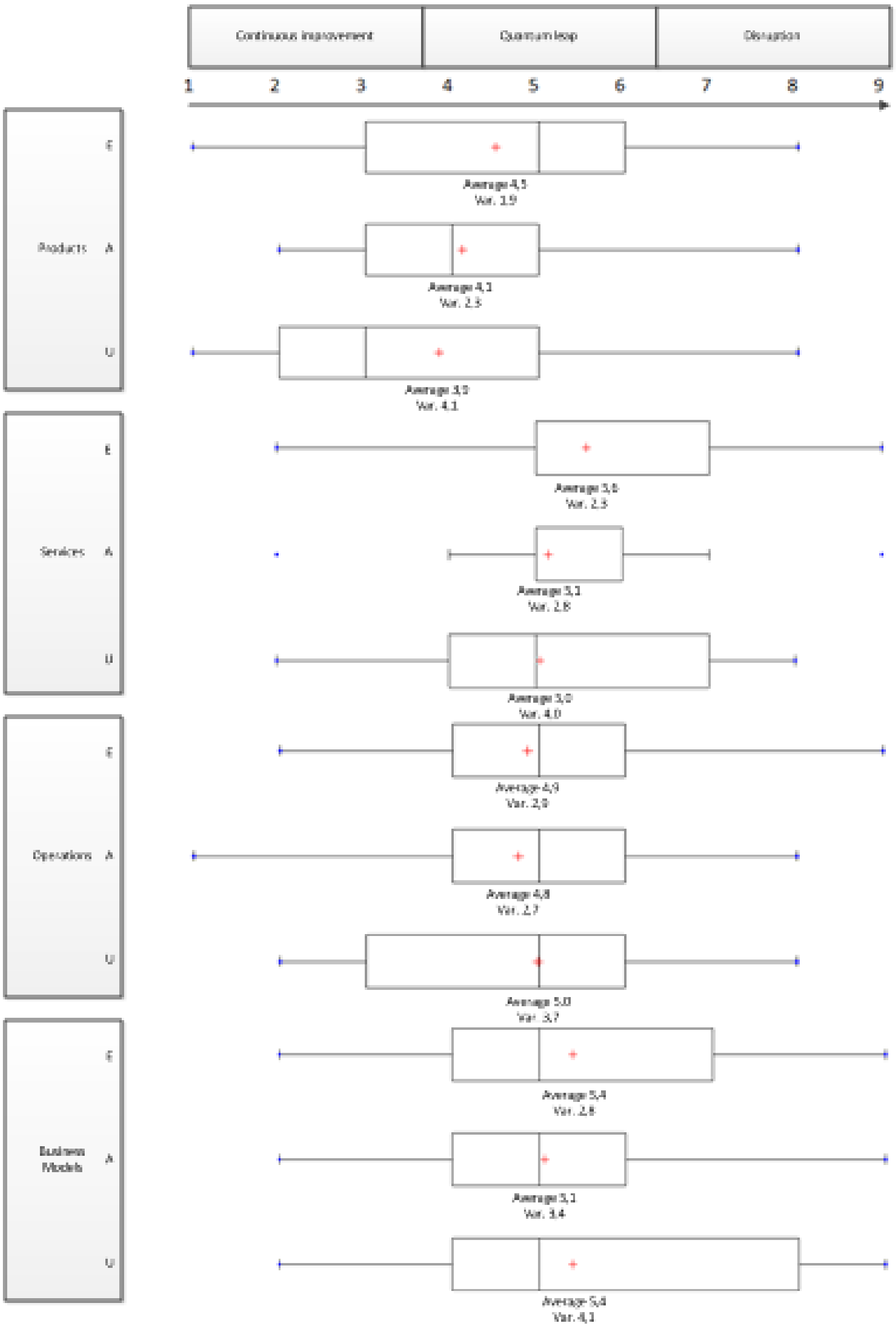
Explanations:

Type III SS values are used to visualize the influence that removing an explanatory variable has on the fitting of the model, all other variables being retained, as regards the sum of the squares of the errors (SSE), the mean squared error (MSE), Fisher's F, or the probability associated with Fisher's F. The lower the probability, the larger the contribution of the variable to the model, all the other variables already being in the model.

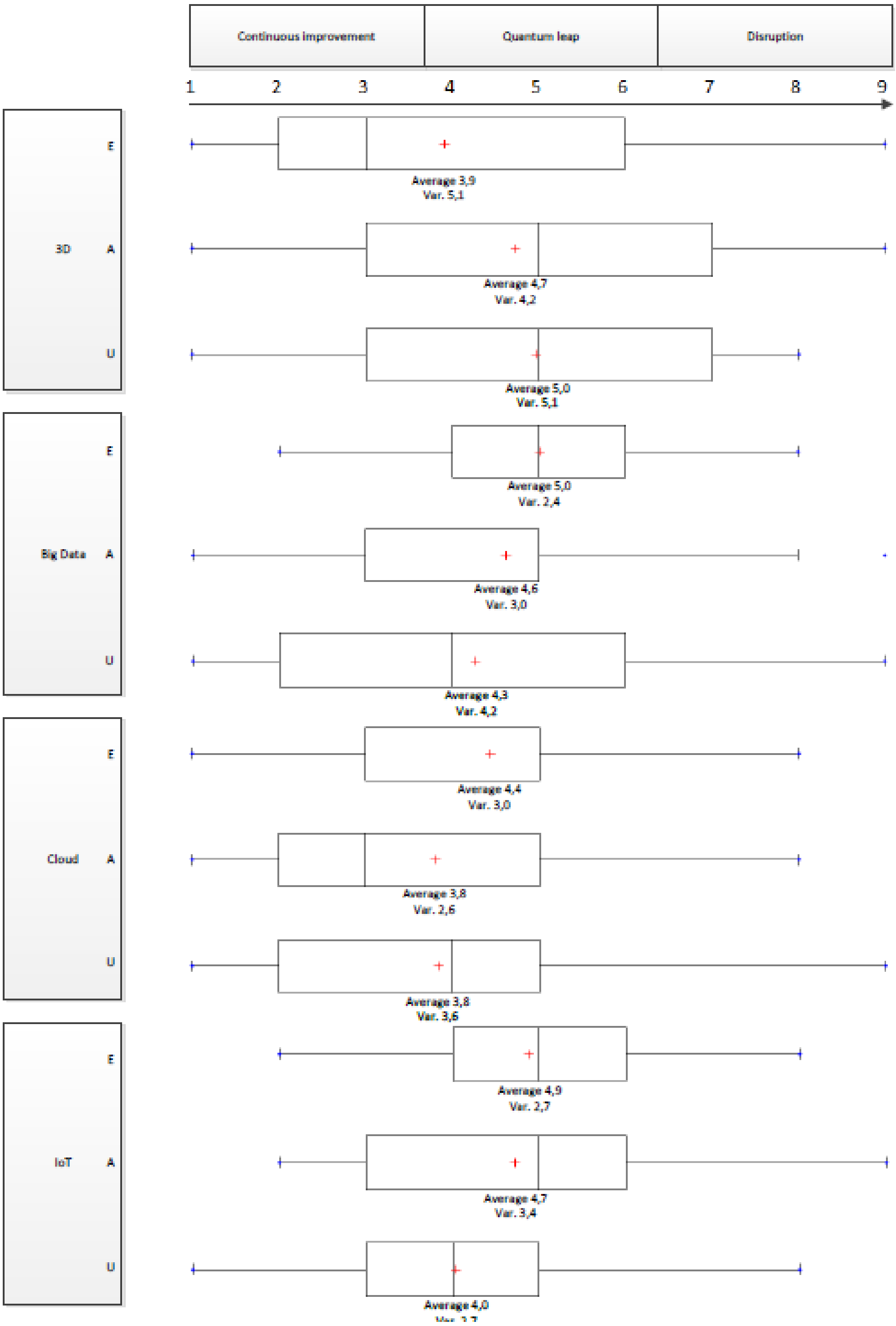
Appendix 7. Disruption impact by whole population, unbalanced data

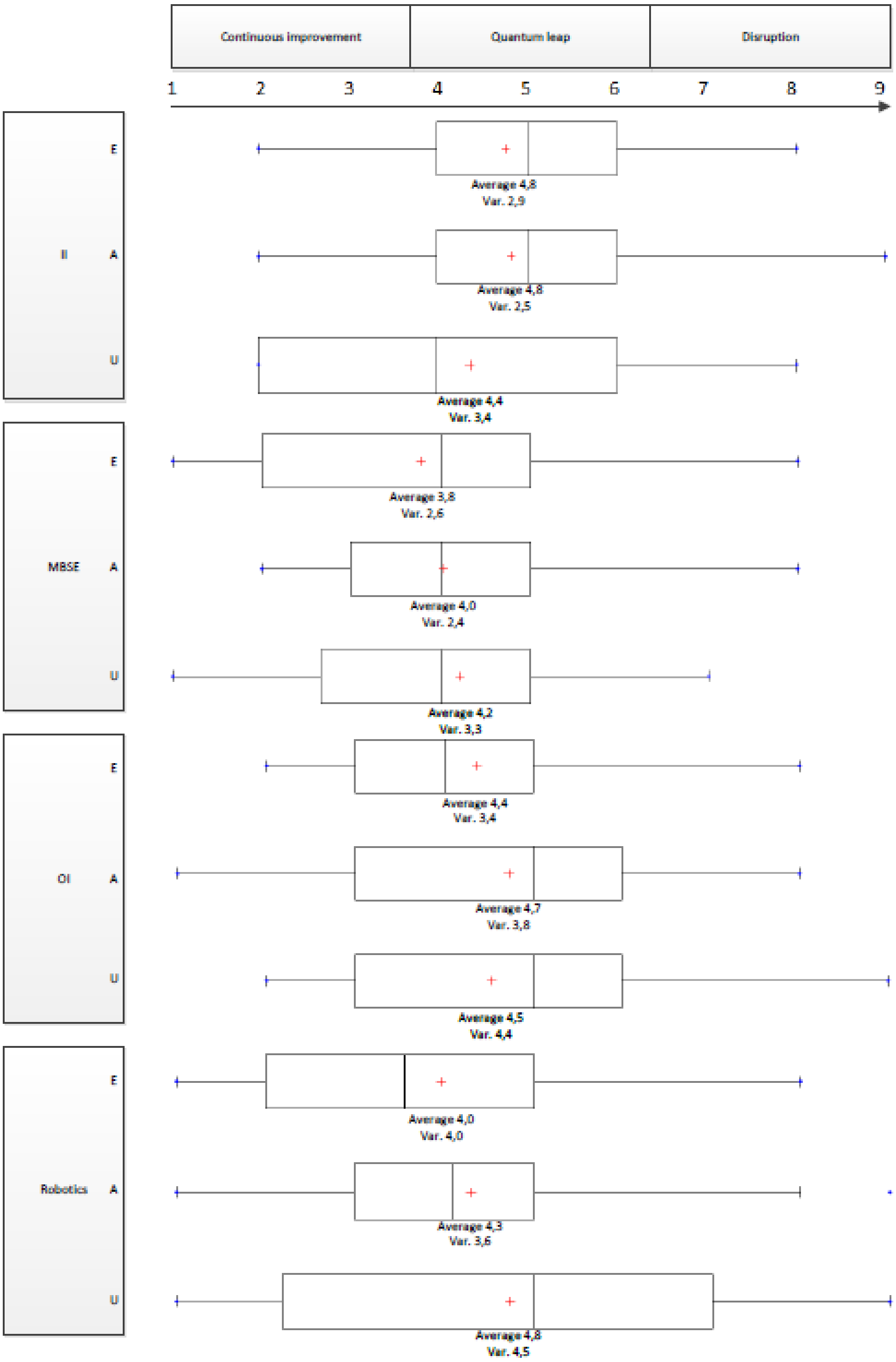


Appendix 8. Disruption impact by value chain, balanced data



Appendix 9.Disruptiveness of individual technologies or concepts by value chain, balanced data





Continuous improvement
Quantum leap
Disruption
1
2
3
4
5
6
7
8
9
II
E
A
U
Average 4,8
Var. 2,9
Average 4,8
Var. 2,5
Average 4,4
Var. 3,4
MBSE
E
A
U
Average 3,8
Var. 2,6
Average 4,0
Var. 2,4
Average 4,2
Var. 3,3
OI
E
A
U
Average 4,4
Var. 3,4
Average 4,7
Var. 3,8
Average 4,5
Var. 4,4
Robotics
E
A
U
Average 4,0
Var. 4,0
Average 4,3
Var. 3,6
Average 4,8
Var. 4,5

Appendix 10. Correlation matrix (Kendall) with whole population

Balanced data

	Variables	Products	Service	Operations	Business models	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
		Impact				Technologies							
Impact	Products	x	-	-	-	-	-	-	-	-	-	-	-
	Service	**0,39**	x	-	-	-	-	-	-	-	-	-	-
	Operations	0,13	**0,19**	x	-	-	-	-	-	-	-	-	-
	Business models	**0,26**	**0,28**	**0,22**	x	-	-	-	-	-	-	-	-
Technologies	3D	0,11	0,04	0,10	0,04	x	-	-	-	-	-	-	-
	Big Data	**0,23**	**0,33**	**0,26**	**0,27**	-0,04	x	-	-	-	-	-	-
	Cloud	**0,24**	**0,20**	0,16	**0,22**	-0,12	**0,26**	x	-	-	-	-	-
	IoT	**0,22**	**0,25**	**0,18**	**0,21**	-0,08	**0,32**	**0,29**	x	-	-	-	-
	II	**0,18**	**0,23**	0,11	**0,27**	-0,08	**0,26**	**0,21**	**0,44**	x	-	-	-
	MBSE	0,00	0,04	0,07	-0,04	0,14	0,06	-0,10	0,03	0,13	x	-	-
	OI	**0,24**	**0,25**	0,07	0,15	0,11	**0,18**	**0,21**	0,11	0,13	0,03	x	-
	Robotics	0,13	0,05	0,13	0,04	**0,18**	0,09	0,02	0,05	-0,05	0,05	**0,18**	x

Values in bold are different from 0 with a significance level alpha=0,05

Code	Coefficient	
	0,2 - 0.29	Low correlation
	0,3 - 0,39	Medium correlation
	> 0,4	High correlation

Unbalanced data

	Variables	Products	Service	Operations	Business models	3D	Big Data	Cloud	IoT	II	MBSE	OI	Robotics
		Impact				Technologies							
Impact	Products	x	-	-	-	-	-	-	-	-	-	-	-
	Service	**0,28**	x	-	-	-	-	-	-	-	-	-	-
	Operations	**0,13**	**0,25**	x	-	-	-	-	-	-	-	-	-
	Business models	**0,19**	**0,26**	**0,20**	x	-	-	-	-	-	-	-	-
Technologies	3D	**0,11**	0,07	**0,16**	0,04	x	-	-	-	-	-	-	-
	Big Data	**0,20**	**0,30**	**0,15**	**0,17**	-0,06	x	-	-	-	-	-	-
	Cloud	**0,15**	**0,18**	**0,10**	**0,13**	**-0,09**	**0,30**	x	-	-	-	-	-
	IoT	**0,16**	**0,23**	**0,12**	**0,19**	-0,01	**0,25**	**0,27**	x	-	-	-	-
	II	**0,19**	**0,24**	**0,16**	**0,29**	0,02	**0,29**	**0,19**	**0,48**	x	-	-	-
	MBSE	**0,12**	0,08	**0,09**	0,00	**0,11**	0,09	0,04	0,06	**0,10**	x	-	-
	OI	**0,22**	**0,21**	**0,12**	0,19	**0,15**	**0,16**	**0,11**	0,09	0,08	**0,14**	x	-
	Robotics	**0,17**	**0,12**	0,08	0,08	**0,20**	0,05	0,07	**0,10**	0,03	**0,12**	**0,20**	x

Values in bold are different from 0 with a significance level alpha=0,05

Code	Coefficient	
	0,2 - 0.29	Low correlation
	0,3 - 0,39	Medium correlation
	> 0,4	High correlation

Appendix 11. Correlation matrix (Kendall) by value chain with balanced data

Enablers

		Areas				Technologies							
	Variables	**Products**	**Service**	**Operations**	**Business models**	**3D**	**Big Data**	**Cloud**	**IoT**	**II**	**MBSE**	**OI**	**Robotics**
Areas	**Products**	**x**	-	-	-	-	-	-	-	-	-	-	-
	Service	**0,40**	**x**	-	-	-	-	-	-	-	-	-	-
	Operations	0,18	**0,23**	**x**	-	-	-	-	-	-	-	-	-
	Business models	0,23	0,21	0,20	**x**	-	-	-	-	-	-	-	-
Technologies	**3D**	0,03	0,05	0,08	-0,04	**x**	-	-	-	-	-	-	-
	Big Data	**0,36**	**0,32**	0,20	**0,26**	-0,02	**x**	-	-	-	-	-	-
	Cloud	0,12	0,15	**0,24**	0,12	-0,11	0,19	**x**	-	-	-	-	-
	IoT	0,20	0,17	0,20	0,18	-0,02	**0,34**	**0,31**	**x**	-	-	-	-
	II	**0,24**	0,21	0,07	**0,35**	-0,02	**0,35**	**0,27**	**0,50**	**x**	-	-	-
	MBSE	0,09	0,05	-0,03	-0,14	0,15	-0,03	-0,01	0,02	0,02	**x**	-	-
	OI	0,15	0,07	0,03	0,17	0,11	0,15	0,11	0,17	**0,26**	0,07	**x**	-
	Robotics	0,06	-0,02	-0,15	0,09	0,22	0,08	-0,08	0,06	0,14	0,11	0,17	**x**

Values in bold are different from 0 with a significance level alpha=0,05

Actors

		Areas				Technologies							
	Variables	**Products**	**Service**	**Operations**	**Business models**	**3D**	**Big Data**	**Cloud**	**IoT**	**II**	**MBSE**	**OI**	**Robotics**
Areas	**Products**	**x**	-	-	-	-	-	-	-	-	-	-	-
	Service	0,10	**x**	-	-	-	-	-	-	-	-	-	-
	Operations	0,15	0,25	**x**	-	-	-	-	-	-	-	-	-
	Business models	0,03	0,17	0,20	**x**	-	-	-	-	-	-	-	-
Technologies	**3D**	0,18	0,05	0,22	-0,01	**x**	-	-	-	-	-	-	-
	Big Data	0,07	0,26	0,13	0,04	-0,12	**x**	-	-	-	-	-	-
	Cloud	-0,07	0,17	0,05	0,17	-0,07	**0,27**	**x**	-	-	-	-	-
	IoT	0,03	0,16	0,05	0,21	0,09	0,18	0,24	**x**	-	-	-	-
	II	0,16	**0,28**	0,16	0,15	0,06	**0,36**	0,10	**0,52**	**x**	-	-	-
	MBSE	0,21	**0,27**	0,16	0,05	0,08	**0,27**	0,07	-0,03	0,07	**x**	-	-
	OI	0,16	0,24	0,24	**0,25**	0,25	0,10	0,03	0,09	0,01	0,23	**x**	-
	Robotics	0,08	0,15	0,07	-0,06	0,08	0,02	0,14	0,14	-0,04	0,11	**0,26**	**x**

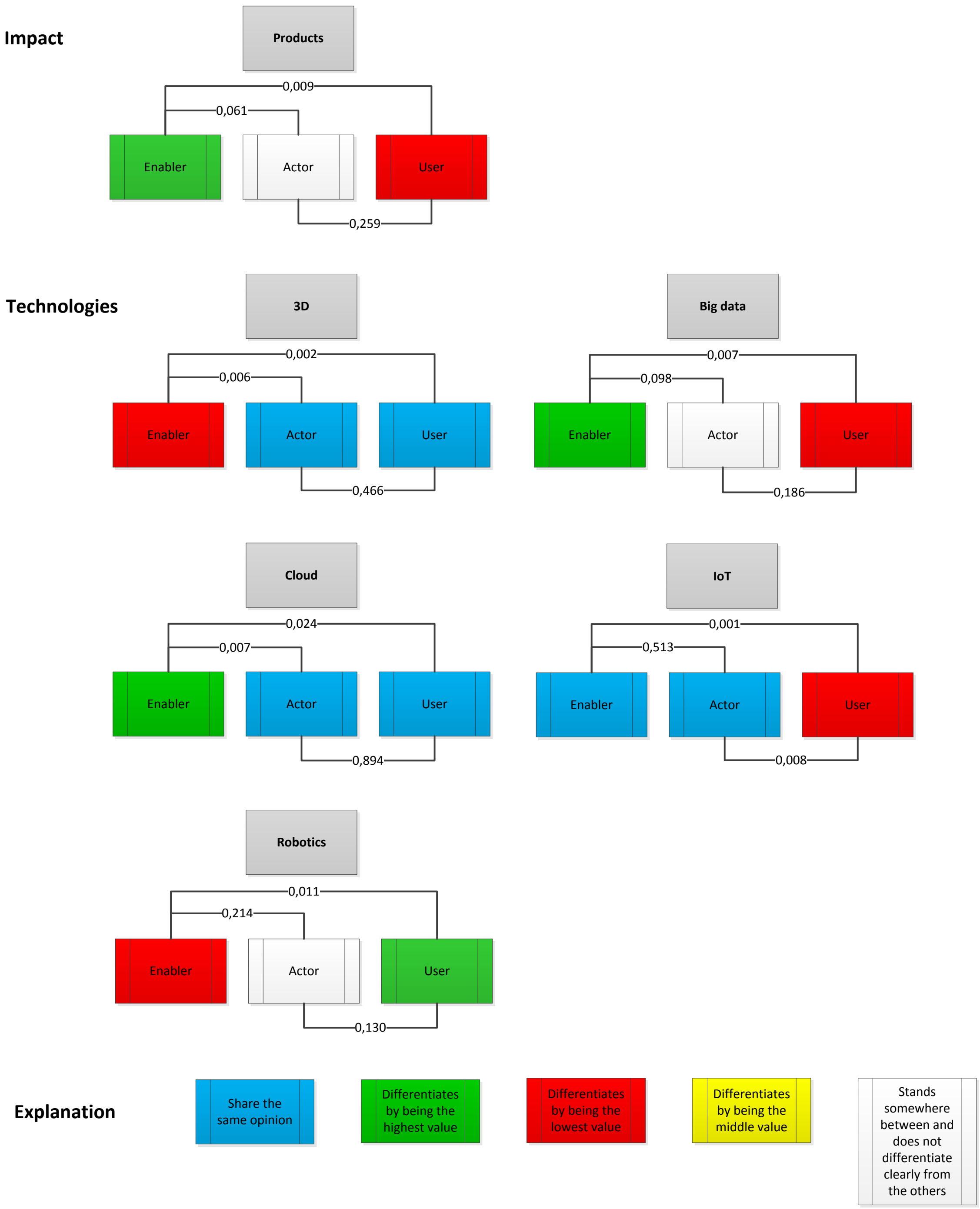
Values in bold are different from 0 with a significance level alpha=0,05

Users

		Areas				Technologies							
	Variables	**Products**	**Service**	**Operations**	**Business models**	**3D**	**Big Data**	**Cloud**	**IoT**	**II**	**MBSE**	**OI**	**Robotics**
Areas	**Products**	**x**	-	-	-	-	-	-	-	-	-	-	-
	Service	**0,39**	**x**	-	-	-	-	-	-	-	-	-	-
	Operations	**0,24**	**0,28**	**x**	-	-	-	-	-	-	-	-	-
	Business models	**0,34**	**0,37**	**0,28**	**x**	-	-	-	-	-	-	-	-
Technologies	**3D**	0,14	0,17	**0,23**	0,11	**x**	-	-	-	-	-	-	-
	Big Data	**0,28**	**0,30**	0,17	**0,23**	0,06	**x**	-	-	-	-	-	-
	Cloud	**0,25**	0,21	0,02	0,16	-0,11	**0,31**	**x**	-	-	-	-	-
	IoT	**0,28**	**0,35**	0,17	**0,39**	0,00	**0,28**	**0,24**	**x**	-	-	-	-
	II	0,18	0,22	0,21	**0,40**	0,13	0,15	0,19	0,54	**x**	-	-	-
	MBSE	0,03	-0,05	0,16	0,00	**0,24**	0,06	-0,13	0,13	0,17	**x**	-	-
	OI	**0,28**	**0,28**	0,22	0,19	0,18	**0,25**	0,12	0,19	0,12	0,19	**x**	-
	Robotics	**0,25**	0,15	**0,23**	0,06	0,12	0,02	0,13	0,06	-0,03	0,17	0,17	**x**

Values in bold are different from 0 with a significance level alpha=0,05

Appendix 12. Variance dependency by ANOVA



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