Data-Enabled Organizational Transformation of a Manufacturing Company

Toward a Systematic Methodology to Facilitate Digital Servitization

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Publication date:
2020

Document Version
Publisher's PDF, also known as Version of record

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TO FACILITATE DIGITAL SERVITIZATION

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Dissertation submitted: September 2020

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ISSN (online): 2446-1636
ISBN (online): 978-87-7210-812-4

Published by:
Aalborg University Press
Kroghstræde 3
DK – 9220 Aalborg Ø
Phone: +45 99407140
aauf@forlag.aau.dk
forlag.aau.dk

Printed in Denmark by Rosendahls, 2020

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PERSONAL SUMMARY

Kuan-Lin Chen is an innovative and highly energetic researcher, having a proven ability to analyze and to integrate information on business development and shaping organizational tactic strategies. Her “can do” attitude is the default principle in taking on challenges.

She had a Bachelor of Management Information System from Taiwan. This was followed by an MBA degree (in double options – Supply Chain Management and e-Business) from California State University, USA. Afterward, she was working in Taiwan at the global ODM laptop manufacturing firm in the project management domain to coordinate the development of new design projects among the R&D teams, global business customers, and the factories. She earned another master's degree in Global Innovation Management from the Erasmus Mundus Joint Master program (the first year in the University of Strathclyde, UK, and the second year at Aalborg University, DK). Since then, she has found a balanced way to work with the knowledge and contribute herself.

ENGLISH SUMMARY

Data and digital transformation are becoming ubiquitous in the era of the fourth industrial revolution. This development also brings a significant further influence on those manufacturing firms that are offering smart products to the markets. It opens up a new opportunity for these manufacturing firms to seek a second revenue stream (an extension of their business potential) from the digital service and even the smart, connected product. In this vision, the smart, connected product transforms the competition and companies toward significantly leveraging the power of information technology. This creates not only business potential toward downstream markets (Porter & Heppelmann, 2014) but also the necessity for organizational changes within the firms (Porter & Heppelmann, 2015). Digital servitization is one of the transformations that feature in this industrial revolution.

Business-to-business (B2B) manufacturing firms are eagerly developing new product capabilities as digital services to engage with their end-users, and further extend their business focus, in which they are working on leveraging the advantages of a combination of smart products, the implementation of IoT (the Internet of Things) technology, and environmental benefits. The goal here is clear; however, how to transform firms with a product-centric mindset toward a blending with service-thinking is a challenge.

In this thesis, design science research (DSR) is applied consistently as the principle to engage with practitioners and to evaluate the rigor and relevance of this research project. In other words, it serves to ensure that the research contributions are generalizable to firms that are in the midst of a similar development condition and could possibly be experiencing a similar transformation journey. More specifically, three key research methods – case study, action design research (ADR), and intervention, are used in the three stages of research development. Each method, with its individual idiosyncratic techniques, is applied to craft the defined goals in different stages. Applied together, they create a unique methodology to experiment within this research project.

The research project begins by analyzing the problematic context of the theoretical development in the digital servitization context, and the practitioners' struggles at the initial stage of transformation development. The results of the investigation indicate that digital-enabled servitization is an ill-structured problem. There is less scientific attention to the role of the influence of IoT on the operations perspective of servitization. So, the objective of this thesis is to establish a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management.

Within this thesis's objective, there are two layers of research concerns. First, it aims to work on the concrete level - to examine how (IoT) Internet-of-Thing's data could strengthen the existing business system (which is realized together with the ERP (Enterprise Resource Plan) data set) for supporting managers in decision-making. In

addition, it also intends to probe the benefits of IoT for the organization's development toward digital servitization. Three hands-on experiments are set up to decouple the complexity of this research setup. The altered (IT) artifacts are developed as a part of the interventions to explore the above two layers of research concerns. They are also seen as the empirical deliverables to change a part of this pragmatic issue.

As a result of the hands-on development in the second phase, a four-step model of the data-driven approach is proposed to facilitate digital servitization. The intention is to balance the internal conflicts within the transforming organization between the top-down strategic changes and the bottom-up process changes. In theory, this is developed by the use of two building blocks to decompose this ill-structured problem. First, the operational issue is the degree to which the back-office supporting system needs to reform in order to support the new vision – to expand the business focus toward a digital service (advanced service) business. Second, the managerial issue is how to adopt the explorative data to conduct evidence-based management toward the digital servitization paradigm. In principle, these changes in the two development stages of the mechanism represent the two stages of organizational changes toward digital servitization. The explorative data (here referring to the explorative business insights, explored from the consolidated database between the ERP and IoT data sets) is seen as the enabler to pinpoint the organizational changes in state and in strategy (direction) (Mintzberg & Westley, 1992). In addition, the exploitable data can be used as the leading indicators (Kaplan & Norton, 1996) to stimulate cross-functional communication and collaboration.

To sum up, the research presented in this thesis primarily covers the initial phase of organizational transformation toward digital servitization. The major contributions of this thesis are in three perspectives – the research method, theoretical contributions, and deliverables to the practitioner. First, this thesis emphasizes the importance of prescriptive research, which is a better way to cope with the practitioners' problems and to close the knowledge gap between scientific research and the empirical domain. Second, this thesis argues that the emerging data, such as the IoT dataset, can be used not only in the business development but also to facilitate the internal organizational change. As a result, a four-step model of the data-driven approach is proposed to support this line of reasoning. It further contributes to developing state-of-the-art research regarding the managerial concerns of digital transformation in manufacturing firms (Björkdahl, 2020; Guenzi & Habel, 2020; McGrath, Rita & McManus, 2020) and the challenge of implementing digital servitization (Kamal et al., 2020). Lastly, three managerial propositions are proposed to the practitioners who consider embedding the data-enabled organizational development of digital servitization: 1) to value the power of digitalization and build up the organizational capabilities around it, 2) to recognize the value of data as well as to develop and explore its value from continuously utilizing its potential, and 3) to establish a learning platform in order to escalate the pace of transformation.

DANSK RESUME

Data og digital transformation bliver allestedsnærværende i den fjerde industrielle revolution. Denne udvikling medfører en betydelig forstærket indflydelse på de produktionsvirksomheder, der tilbyder smarte produkter til markederne. Det åbner for en ny mulighed for disse produktionsvirksomheder for at søge en yderligere indtægtskilde (en udvidelse af deres forretningspotentiale) igennem digitale tjenester og endda de smarte, tilsluttede produkter. I denne vision transformerer det smarte, tilsluttede produkt konkurrencen og virksomhederne mod en væsentlig udnyttelse af informationsteknologiens styrke. Dette skaber ikke kun forretningspotentiale mod downstream-markeder (Porter & Heppelmann, 2014), men også nødvendigheden af organisatoriske ændringer inden for virksomhederne (Porter & Heppelmann, 2015). Digital servitisering er en af de transformationer, der findes i denne industrielle revolution.

Business-to-business (B2B) produktionsvirksomheder udvikler ivrigt nye produktfunktioner som digitale tjenester til at engagere sig med deres slutbrugere og yderligere udvide deres forretningsfokus, hvor de arbejder på at udnytte fordelene ved en kombination af smarte produkter, implementering af IoT (Internet of Things)teknologi og miljøfordele. Målet er klart, men udfordringen er at transformere virksomheder med en produktorienteret tankegang mod en blanding med servicetænkning.

I denne afhandling anvendes design science research (DSR) som princippet for at engagere sig med praktiserende virksomheder og evaluere relevansen af dette forskningsprojekt. Med andre ord tjener det til at sikre, at forskningsbidragene er generaliserbare til virksomheder, der er midt i en lignende udviklingstilstand og muligvis kan opleve en lignende transformationsrejse. Mere specifikt anvendes tre nøgleforskningsmetoder - case study, action design research (ADR) og intervention - i de tre faser af forskningen. Hver metode, med sine individuelle idiosynkratiske teknikker, anvendes til at opnå de definerede mål i forskellige faser. Anvendt sammen, skaber de en unik metode til at eksperimentere med, i dette forskningsprojekt.

Forskningsprojektet begynder med at analysere den problematiske kontekst af den teoretiske udvikling i den digitaliserede servitiseringskontekst, og derigennem udøvernes kamp i de indledende faser af transformationens udvikling. Resultaterne af undersøgelsen viser, at digital aktiveret servitisering er et 'dårligt struktureret problem'. Der er i mindre grad videnskabelig opmærksomhed på den rolle, som IoTs indflydelse har på produktionen ved servitisering. Så målet med denne afhandling er at etablere en systematisk metode, der anvender data som en muliggørelse for at lette digital servitisering og understøtte evidensbaseret styring.

I dette speciale er der to forskningsanliggender. Det første sigter det mod at undersøge, hvordan (IoT) Internet-of-Things data kan styrke forretningssystemet (som realiseres sammen med ERP (Enterprise Resource Plan) datasættet) til at støtte ledere i beslutningstagnings processen. Det andet har til hensigt at undersøge fordelene ved

IoT for organisationens udvikling mod digital-aktiveret servitisering. Tre praktiske eksperimenter er oprettet for at afkoble kompleksiteten af denne forskningsopsætning. De ændrede (IT) artefakter er udviklet som en del af interventionerne for at udforske de ovennævnte to forskningsanliggender. De ses også som de empiriske resultater, der ændre en del af dette pragmatiske spørgsmål.

Som et resultat af den praktiske udvikling i den anden fase, foreslås en firetrinsmodel af den datadrevne tilgang for at lette digital servitisering. Hensigten er at balancere de interne konflikter i den transformerende organisation mellem top-down strategiske ændringer og bottom-up procesændringer. I teorien er dette udviklet ved hjælp af to byggesten for at nedbryde det 'dårligt strukturerede problem'. Det første er det operationelle spørgsmål, i hvilket omfang understøttelsessystemet skal reformeres for at understøtte den nye vision - at udvide forretningsfokuset mod en digital servicevirksomhed (avanceret service). Det andet er det ledelsesmæssige spørgsmål, hvordan man adopterer de udforskende data til at udføre evidensbaseret styring mod det digitale servitiseringsparadigme. I princippet repræsenterer disse ændringer de to faser af organisatoriske ændring mod digital servitisering. De eksplorative data (her henvises til den eksplorative forretningsindsigt, udforsket fra den konsoliderede database mellem ERP- og IoT-datasættene) ses som en muliggørelse af at identificere de organisatoriske ændringer i tilstand og i strategi (retning) (Mintzberg & Westley, 1992). Derudover kan de udnyttelige data bruges som ledende indikatorer (Kaplan & Norton, 1996) til at stimulere tværfunktionel kommunikation og samarbejde.

For at opsummere, dækker forskningen i denne afhandling primært den indledende fase af den organisatoriske transformation mod digital servitisering. De vigtigste bidrag fra denne afhandling er i tre perspektiver - forskningsmetoden, teoretiske bidrag og leverancer til den virksomheden. For det første understreger denne afhandling vigtigheden af vejledende forskning, som er en bedre måde at håndtere de praktiserendes problemer og lukke vidensgabet mellem videnskabelig forskning og det empiriske domæne. For det andet argumenterer denne afhandling for, at de nye data, såsom IoT-datasættet, ikke kun kan bruges i forretningsudviklingen, men også til at lette den interne organisationsændring. Som et resultat foreslås en fire-trins model af den datadrevne tilgang til at understøtte denne argumentation. Det bidrager yderligere til at udvikle avanceret forskning vedrørende ledelsesmæssige bekymringer ved digital transformation i produktionsvirksomheder (Björkdahl, 2020; Guenzi & Habel, 2020; McGrath, Rita & McManus, 2020) og udfordringen med at implementere digital servitisering (Kamal et al., 2020). Endelig foreslås der tre ledelsesmæssige forslag til virksomhederne, der overvejer at integrere den dataaktiverede organisatoriske udvikling af digital servitisering: 1) at værdsætte kraften i digitalisering og opbygge de organisatoriske muligheder omkring den, 2) at genkende værdien af data såvel som at udvikle og udforske dens værdi ved kontinuerligt at udnytte dets potentiale og 3) at etablere en læringsplatform for at eskalere tempoet i transformation.

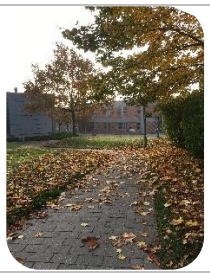
PREFACE

This Ph.D. dissertation builds on an industrially based research project conducted with a global full-line manufacturer from 2017–2020 in Denmark. Through the MADE (Manufacturing Academy Denmark) platform, this research project aims to explore the specific industrial challenges and to develop the state-of-the-art knowledge within the field of the service-related revolution of Industry 4.0, namely digital servitization. I am sincerely grateful for the opportunity to work with the industrial partner – SKOV A/S to conduct such challenging and rewarding research on the topic of the data-enabled organizational transformation of a manufacturing company – toward a systematic methodology to facilitate digital servitization.

Acknowledgments

A lot of people have walked along with me on this journey. They all gave me important supporters in accomplishing this thesis. To express my sincere appreciation to many of you, I use nine photos (taken by me, no plagiarism!), which encapsulate the time and stories we have had together. If you recognize those photos, you have definitely been on part of this journey with me and are on my thank-you list. ☺





Firstly, I would like to express my gratitude to my supervisors, Professor Charles Møller and Associate Professor Astrid Heidemann Lassen. Your trust, guidance, and encouragement have made this thesis complete. Your constant challenges of my views and argumentations have benefited my research tremendously. I have learned from you always to use an extra pair of eyes to examine the situation from the sky and also from the ground. In addition, I thank Professor Jan Björnson Holmström for accepting my short stay abroad studying at the Department of Industrial Engineering and Management at Aalto University. I am truly thankful for the chance to be part of that friendly researcher environment and for your patience in listening, as well as the inspiring discussion on the topics of conducting design science research. Besides, special thanks go to another two people. First, the CTO, Jesper Mogensen, at SKOV A/S. Thank you for being open-minded and supportive of taking on several innovative projects in the firm. In addition, I appreciate my co-author, Assistant Professor Chen Li, at Aalborg University, for supporting the technical development in a part of this project.

I would also like to thank the colleagues who supported during all of the projects, in both groups, the Center for Industrial Production (CIP) research group, and SKOV A/S, where I spent a huge amount of time over the last few years. I am grateful for many of you (CIP - Marco, Jesper, Chen, Rikke, Cheng, Claus, Emre, Michele, Markus, Dan, etc.; SKOV A/S - CSO - Leo Østergaard, Palle, Jes, Nicklas, Esper, Stig, etc.) being around to have many intellectual discussions. Especially thank you to Marco, Jesper, Claus, Emre, and Michele for many energetic conversations in our dinners and have a fun time together.

Finally, I owe my family and close friends a big hug for understanding my physical absence on many occasions; thank you for always including me in some way. There are six photos, chosen, especially for all of you. Thank you for being there to share the laughs, the craziness, and even the tears. Besides my beloved family, two friends I have to mention are Jette & Stefan. You are a couple with great hearts, sharing your kindness and love with the people around you. Thank you for trusting and supporting me at the time. ☺

陳冠伶 Kuan-Lin Chen
Aalborg, Summer 2020.

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LIST OF ABBREVIATIONS AND SYMBOLS

ADR	Action Design Research
B2B	Business-to-Business
B2C	Business-to-Customer
BS	Business System
DS	Design Science
DSR	Design Science Research
ERP	Enterprise Resource Plan
ICT	Information and communication technology
IoS	The Internet of Services
IoT	The Internet of Things
IT	Information Technology
MADE	Manufacturing Academy Denmark
MVP	Minimal Viable Product
PSP	Product-Service Platform
PSP BI	Product-Service Platform Business Intelligence
PSS	Product-Service System
SC	Supply Chain

LIST OF ARTICLES

This doctoral dissertation consists of a summary and of the following articles, which are referred to in the text by their numerals.

Article 1 – Chen, K. L., & Møller, C. (2019). A thousand-miles journey begins with the very first step: The case of a product-centric manufacturing firm transformation towards servitization. *CIRP Journal of Manufacturing Science and Technology*, *27*, 102–113. https://doi.org/https://doi.org/10.1016/j.cirpj.2019.06.002

Article 2 – Chen, K-L., Lassen, A. H. & Møller, C. (2018). Embarking Advanced Services on Servitization Transformation, Making Sense Using System Thinking. In *Joint International Conference of Service Science and Innovation and Serviceology*, 2, 243–247. Taichung, Taiwan.

Article 3 – Chen, K., Li, C., & Møller, C. (2019). Bootstrapping product-service business: An experimental data-driven approach. Manchester: *In Manchester: The International Society for Professional Innovation Management (ISPIM)*, 1-18. Florence, Italy. https://search.proquest.com/docview/2297092414?accountid=8144

Article 4 – Chen, K. L., Lassen, A. H., Li, C., & Møller, C. (2020). Exploring the value of IoT data as an enabler of the transformation toward servitization – An action design research approach. *European Journal of Information Systems (Submitted)*, 1–42.

CHAPTER 1. INTRODUCTION

This chapter introduces the general context of this dissertation, including the industrial motivation and scientific context. It follows an overall introduction and structure of this thesis to guide the reader through the remainder of this thesis.

Data and digital transformation are becoming ubiquitous in the era of the fourth industrial revolution. This phenomenon is also found in manufacturing firms, which are expanding their business focus toward becoming product–service oriented businesses. This means that they not only sell smart products to the markets but also provide the associated (digital) services to the end-users wanting to operate these products. For example, Rolls-Royce is a successful manufacturing firm that sells aircraft engines to aircraft producers (business customers) and also supports a power-by-the-hour service to the airline companies (end-users). The smart, connected products (a combined concept of smart products and digital services) are unleashing this new form of competition (Iansiti & Lakhani, 2014; Porter & Heppelmann, 2014, 2015), in which practitioners and researchers endeavor to servitize their (products) offers and serve customers with value-adding products/services. But now, digital technology is a vital means. However, how to transform a product-centric manufacturing firm to take advantage of digitalization and its output - a new data asset - is challenging today's manufacturing firms. This thesis takes this problematic situation as the departure point. To help manufacturing firms to master the organizational transformation toward the digital servitization vision, the author intends to look for a systematic methodology that leverages the digital power of the fourth industrial revolution to expedite organizational transformation.

1.1. INDUSTRIAL MOTIVATION

The inventions of the steam engines, electricity, and personal computers and automation played major roles in driving the first three industrial revolutions. Those movements build up the foundation of today's world economy, welfare, and advanced society. The fourth technological revolution is now looking for opportunities to enhance such advanced developments. The concept of Industry 4.0 was initiated at the Hannover Fair, Germany. Since then, both industry and researchers have been endeavoring to extract the benefits of this transformation. An earlier industrial investigation evaluated the potential of such transformation as leading to arise of 70% in the manufacturing share of global trade. In addition, every dollar of manufacturing output will add a further 19 cents of service input (McKinsey Global Institute, 2012). The impact of the manufacturing industry on the global economy is substantial. A recent study also shows that this revolution is expected to create up to $3.7 trillion in value by 2025 (WEF and McKinsey & Company, 2018). Amidst this expectation of

growth, the most significant impact is on the change toward becoming more "human-centric." This means that the intention to use technology to drive value for enterprise to achieve 1) customer-centered design, 2) seamless connectivity across functions, and 3) continuous connectivity beyond organizations (WEF and McKinsey & Company, 2019). Besides greater productivity and efficiency, an end-to-end value chain connection is the primary anticipated outcome of this transformation, resulting in forms of (digital) services to connect mechanisms, people, and data assets. As such, the World Trade Organization supports the evidence of this evolution; it particualarly reports that the trade in information and communication technology (ICT) services was valued at US$ 1,756 billion in 2017, which is more than double that in 2005. There is no doubt that value-adding service is becoming an essential element attached to the trading products (World Trade Organization, 2019).

To achieve such transformation, however, practitioners face massive challenges. A follow-up investigation on the manufacturing industry indicates that many companies are experiencing "pilot purgatory." This means that firms have invested extensively in activities related to transforming their operations but are not yet seeing meaningful bottom-line paybacks from this, mainly due to ineffective decision-making in these emerging situations (WEF and McKinsey & Company, 2018). This statement seemingly also applies to the forefront of the Danish manufacturing industry. Through the MADE (Manufacturing Academy Denmark) platform, this research project aims to explore such practical challenges and specifically to look into the service-related revolution of Industry 4.0, namely servitization and its paradox. This means that managers are uncertain about how to evaluate the ambiguous return on investment in developing their (digital) services business (Gebauer et al., 2005). Also, there is no clear information that managers can refer to in adjusting the organization and to help make the right decisions to fight for tomorrow's business.

In this dissertation, the principle of design science research was adopted to investigate this challenge to practitioners. An intervention research strategy was applied to study one Danish manufacturing firm that first embarked on its servitization journey in 2017. The research action began with a systematic literature review and interviews with the selected stakeholders to identify the practitioners' challenges in the context of digital-enabled servitization. The intention is to determine whether the practical challenges, discovered in the case of the selected firm, are the same general obstacles as in similar companies that are undertaking the transformation journey toward digital servitization. Thus, the knowledge obtained complies with the generality of the research principle, and multi-methods were used to nail down the defined research questions derived from the overall thesis objective. In particular, the action design research method was applied to build up the body of this research. The aim of taking such an approach is twofold. On the one hand, it is an interactive method of engaging with stakeholders and finding an appropriate solution with a theoretical foundation to apply in practice. On the other hand, through developing a problem-specific intervention, researchers are able to observe the problematic surroundings, the applied methods of solving the defined problems, and to evaluate the theoretical argumentation. A collection of four articles are delivered to portray this practical issue

and its possible solution. The detailed structure of the thesis is explained in the next section.

1.2. STRUCTURE OF THE THESIS

This section introduces the structure of the dissertation. The thesis consists of three parts (Figure 1). It begins by analyzing the project context, moves to the main body of development, and then closes with the evaluation, discussion, and conclusion.

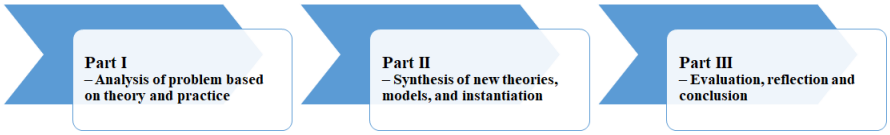


Figure 1. An overview of the thesis structure.

Part I contains the first three chapters, which depict the overall research background. The introductory chapter describes the context of the emerging industrial challenges and the scientific response to these particular practitioners' challenges. The big picture of this thesis is presented at the end of chapter 1. The three research themes (servitization in manufacturing, a system perspective of the servitization – product-service system, and digital-enabled servitization), and the complexity of the research propositions are discussed in chapter 2. Chapter 3 presents a diagnosis of the case studies, and the evolving weltanschauung of the product-centric manufacturing firm's business system is illustrated to elaborate on the implications of this evolution within manufacturing organizations.

Part II is the main body of the research, comprising two chapters. Chapter 4 addresses the research design. It consists of four sub-sections. Section 4.1 presents the research objectives and research framework, which are set based on the knowledge acquired from the previous chapters. Section 4.2 illustrates the research positions, including the research type, methods, data collection, and evaluation methods, to draw the boundary of this research project. In general, design science is employed as the principle to link the problematic environments and the knowledge bases. Furthermore, a longitudinal study as a generalization of the practical issue and its characteristics is presented in section 4.3 to demonstrate the substantial value of this research. The following section 4.4 summarizes the research design and highlights the relevance and rigor of this research. Chapter 5 depicts the research content. First, section 5.1 presents the synthesis of interventions from articles 3 and 4, which aims to respond to the research concerns arising from the research framework (see section 4.1). Section 5.2 analyzes the impact of IoT (the Internet of Things) and its implementation at the organizational level. Section 5.3 then deliberates on the emerging managerial challenges hidden behind the system. It closes with section 5.4, which presents a four-step model of the data-driven approach as a systematic methodology to facilitate digital servitization.

Part III is the reflection and conclusion of this research study. Chapter 6 discusses the implications of the theoretical and empirical findings. Section 6.1 presents the synthesis of the evaluation process in terms of how the design research processes fit for each stage of the defined research objective and its contexts, as well as the whole research. Reflections on the pre-analysis of the ill-structured problem of digital servitization and on the theoretical findings are presented in section 6.2. This leads to a discussion on the implications for practitioners in section 6.3. Chapter 7 summarizes the research contribution, its implications, and the limitations of the studies, as well as potential areas for future research. In addition, it also provides reflections on the emerging situation that manufacturing firms are dealing with (see chapter 1) and managerial propositions. Figure 2 demonstrates the overall structure of this thesis.

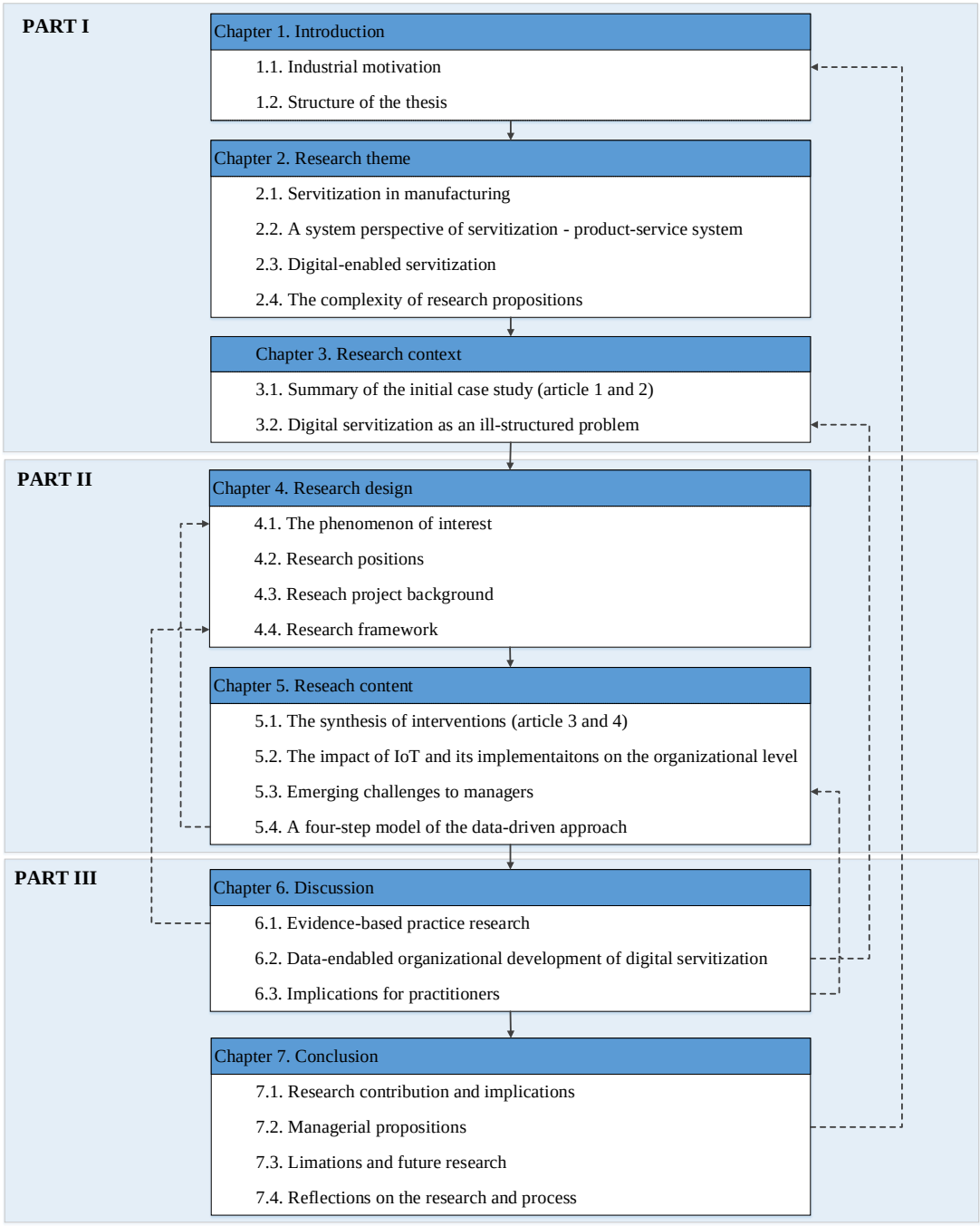


Figure 2. Thesis structure.

CHAPTER 2. RESEARCH THEME

This section will elaborate on the three research themes: 1) servitization in manufacturing, 2) the notion of the product-service business, and 3) digital-enabled servitization. Further, the section illustrates the complexity of the research propositions. The synthesis outlines a comprehensive view of the theoretical background of this Ph.D. project.

2.1. SERVITIZATION IN MANUFACTURING

Servitization, a practical concept, was introduced to the manufacturing industry by Vandermerwe and Rada (1998) long before the Industry 4.0. With the goals of engaging downstream customers (Wise & Baumgartner, 1999) and regaining firms' competitive advantages, they argued that manufacturing firms should consider services as a value-adding stance to their physical products (Vandermerwe & Rada, 1988). This practical thinking also influenced Schmenner's later argumentation on the necessity of innovation in supply chain (SC) activities (Schmenner, 2009). It thus boosts the infusion of service activities within this domain. Servitization has become strategical leverage to enlarge the business focuses to gain competitive advantage, and to avoid the commodity trap (Gebauer et al., 2011). Continuing studies validate the effectiveness of such a strategic move (Eggert & Ulaga, 2002; Reinartz & Ulaga, 2008; Ulaga, 2003) in gaining business benefits (Neely et al., 2011). Although concern with servitization paradoxes (Gebauer et al., 2005) has dogged practitioners, this servitization movement is still going on and moving even further into digital form (Iansiti & Lakhani, 2014; Parida et al., 2015; Rönnberg Sjödin et al., 2016).

Since then, the research topics around servitization have been periodically deliberated upon across disciplines. On the one hand, marketing researchers are dedicated to looking into the variances that manufacturing firms use to gain competitive advantage to win the market. The research topics include the type of product-service system (PSS) (Tukker, 2004; Tukker & Tischner, 2006), business model (Adrodegari et al., 2017; Tukker & Tischner, 2006), development of services strategies, evidence and benefits of the servitization of manufacturing (Baines, Lightfoot, Benedettini, & Kay, 2009; Baines, Lightfoot, Benedettini, Whitney, et al., 2009; Lightfoot et al., 2011; Story et al., 2017; Zhang & Banerji, 2017). On the other hand, the operations researchers seek to gain performance knowledge to promote the servitization journey. They address subjects such as challenges and barriers (Baines et al., 2017; Bigdeli et al., 2015; West et al., 2018), the servitization approach (Baines & Howard, 2013;

Baines & Shi, 2015; Wiesner et al., 2013), and managing the transition from products to services (Oliva & Kallenberg, 2003; Tan et al., 2010, 2006). This research stream has slowly grown twofold over time (Chen & Møller, 2019). On the one hand, the marketing researchers recognize the context and rationale of pursuing servitization. On the other hand, the operations researchers endeavor to persist in their efforts to develop servitization. Figure 3 presents the complexity of this topic.

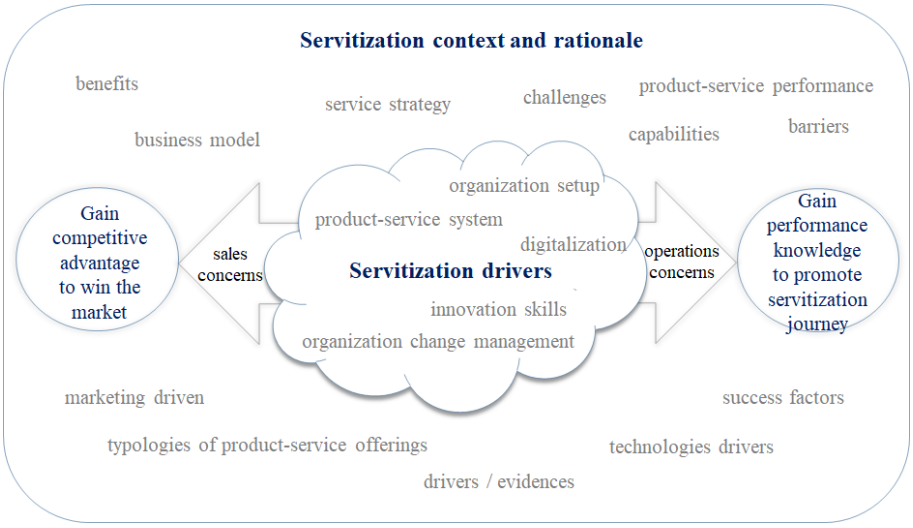


Figure 3. An illustration of servitization context, rationales, and drivers (adapted from Chen & Møller, 2019).

In general, the term "servitization" that scholars have adopted in this decade encompasses and inherits many of those identified perspectives. Bigdeli et al. take into consideration both the business model and organizational change and propose a theoretical framework to study organizational transformation toward servitization (Ziaee Bigdeli et al., 2017).

2.2. A SYSTEM PERSPECTIVE OF SERVITIZATION – PRODUCT-SERVICE SYSTEM

The product-service system (PSS), furthermore, extends manufacturing firms' service capability into a systems perspective. Instead of an explanatory description of servitization, the PSS researchers pay more attention to "an approach to designing integrated products and services with a focus on both customer and product life cycle

activities" (Tan et al., 2010). There are two streams of research, interpreting the product-service system (PSS) with similar intentions but diverse purposes. First, Goedkoop (1999) introduced this concept to achieve the juxtaposition of ecological and economic considerations. He discussed PSS with a practical perspective in mind. Goedkoop et al. (1999) emphasized PSS as "a marketable set of products and services capable of jointly fulfilling a user's need." Since then, it has been discussed in the cleaner production, environmental and sustainability research and practice contexts (Goedkoop et al., 1999; Manzini & Vezzoli, 2003; Mont, 2002). Second, Wise and Baumgartner (1999) argued that manufacturers increased business opportunities and profits by going downstream. Embedding services in products created this kind of vertically integrated cross-organization. Therefore, PSS can also be seen as an integrated product and service offering that delivers value through the use of information technology as a special case of servitization (Baines et al., 2007). It offers the opportunity not only to decouple economic success but also to increase the engagement of firm–customer relationships. In general, PSS is categorized into three subcategories, namely, 1) product-oriented, e.g., extension service, 2) user-oriented, e.g., car rentals 3) result-oriented, e.g., Rolls-Royce (Tukker, 2004) because of the value degree of product-service offerings. In addition, eight types of business models (Tukker & Tischner, 2006) have been generated according to the offerings. Regardless of the benefits of PSS in several respects, the challenges of engaging customers in PSS are also pointed out in several areas (Brax, 2005), as shown in Table 1.

Table 1. Challenges of establishing in PSS (Brax, 2005).

Marketing	1) Lack of customer support, 2) insufficient information technology and users, and 3) inadequate sales propositions and representatives
Production	1) Increases the needs for documentation in installed configurations, operation and maintenance data for each customer
Delivery	1) Cultural problems and 2) incorrect training
Product-design	Unsophisticated usability of a system
Communication	Inadequate feedback loops from customers and within the focal firm
Relationship	Lack of the credibility of expertise

Manufacturing firms with a business development lens are therefore looking for a more comprehensive product-service system to pass on the delivery value to customers in the business environments (Bigdeli et al., 2015). Hence, this PSS could be extensively performed to reach far and deep into the value chain (Porter, 1990). A

particular research stream (Tan et al., 2010; Zaidat et al., 2005) is taking an engineering approach to look into materializing the design value proposition and how to model the business approach to customers. In their studies, however, both case firms had two independent business units (product-oriented, and service-oriented) to avoid conflicts in the existing value chain (Tan et al., 2010). There is little study to demonstrate an integrated solution to complete the value chain without harm.

2.3. DIGITAL-ENABLED SERVITIZATION

Digital servitization, another concept, is associated with servitization. It introduces the specification of the impact of digitalization when manufacturing firms are providing IT-enabled services to their customers (Lerch & Gotsch, 2015; Vendrell-Herrero et al., 2017). It often involves discussion on the topics of information technology (Dinges et al., 2015), digital capability (Iansiti & Lakhani, 2014; Parida et al., 2015; Rönnberg Sjödin et al., 2016), the platform approach (Cenamor et al., 2017; Eloranta & Turunen, 2016; Pekkarinen & Ulkuniemi, 2008), and business models as an ecosystem (Kohtamäki et al., 2019), together with the servitization concept. In general, this stream of research emphasizes not only the importance of adopting information technology but also the significant effects of having information-sharing inside and outside the boundaries of the firms. The benefits identified include the degree of organizational integration and reciprocity among different actors (Eloranta & Turunen, 2016; Kowalkowski et al., 2011), for example, the coordination between back- and front-end units (Cenamor et al., 2017), and the establishment of relationships within networks of firms (Ulaga, 2003). Porter and Heppelmann's studies precisely address how information technology materializes the end-to-end value chain connection when the companies consider adopting the Internet of Things (IoT) and the Internet of Services (IoS) technology to extend their product capability and business opportunities (Porter & Heppelmann, 2014, 2015).

However, scholars also point out how difficult it is for product-centric manufacturing firms to transform their business intension and organization toward being product- and service- providers, especially in digital form. Rönnberg Sjödin et al. (2016) draw attention to several capabilities with which the organization needs to equip itself for (digital) advanced service offerings (Baines & Howard, 2013), and in the extension of the product capability in digital form. They accentuate the essential role of the digital capacity in manufacturing organizations to access and interpret information and to coordinate the work process. Without this, the consequences are a lack of fluent communication across functional teams (Parida et al., 2015) and separation of the organization (Cenamor et al., 2017). Thus, practitioners and researchers both still have to deal with this critical challenge.

2.4. THE COMPLEXITY OF RESEARCH PROPOSITIONS

Servitization itself is not a surprising new topic in either research or practice; however, researchers have been reexamining the diverse objects in the different domains with highly relevant interests and specific focuses. Thus, there also arises the complexity of the outset (Chen & Møller, 2019; Kamal et al., 2020; Kohtamäki et al., 2020; Zou et al., 2018). Three major research streams: 1) servitization in manufacturing, 2) a system perspective of servitization – product-service system, 3) digital-enabled servitization, mentioned in the last three sections, are directly associated with the notion of servitization. However, each research stream is looking at a part of the organizational endeavors and trying to make sense of how well it will engage with the end-users and bring the anticipated return business benefits. To some degree, the explorative knowledge and associated solutions in the three earlier mentioned domains are quite nuanced. Nevertheless, they also recognize in common the role of information technology (IT) to enable this transformation. This phenomenon is especially revealing in manufacturing firms that are offering complex smart, connected products and embedding the IoT/IoS technology and platform in their product/service offers and business models.

The impact is threefold. First is from the design and development perspective. Scholars focus on the enabling role of IT and its implementation in product-service offerings and the associated business model. Second, scholars endeavor to explore emerging information when applying IoT (the Internet of Things) / IoS (Internet of Services) to engage different parties (e.g., B2B manufacturing firms, business customers, and end-users). Last but not least is to establish the operational processes, providing 'value' (Eggert & Ulaga, 2002; Ulaga, 2003) across participants. In such a view, the question, concerning organizational transformation, might not be what and why changes occur from these three earlier mentioned domains, but how to restore the operational response inside the organization. The potential issues might include the understanding of how a manufacturing organization is able to adopt the new development of IT as a mediator. Only if this is understood can the advantages be applied to both sides of managerial concerns, as shown in Figure 3. On the one hand, the firm might be able to gain the benefits of applying valuable information-gathering by means of establishing IT channels to engage with customers further downstream. On the other hand, such digital capability might also help the firm to quickly set the operational responses and processes to articulate the emerging situations along the end-to-end value chain. Figure 4 depicts the complexity of the digital servitization research paradigm in this Industry 4.0 era. The three major domains – business, information system, and operations, are often interconnected in the literature studies (see sections 2.1, 2.2, and 2.3). In this thesis, the author adopts a similar theoretical boundary to others to set out on the journey. To help manufacturing firms to master the organizational transformation toward the digital servitization vision, however, the author, narrows the focus to the intersection among digital technology, information, and operational processes.

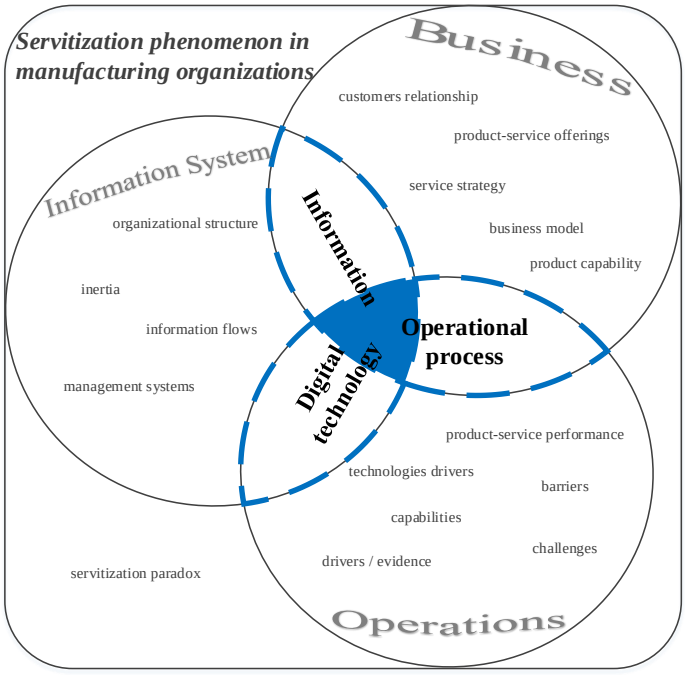


Figure 4. Theoretical framework – the triple views of the digital servitization paradigm.

CHAPTER 3. RESEARCH CONTEXT

This chapter includes two sections. First, it presents the study summary from two articles on a longitudinal case study, including a brief but dense synthesis of the longitudinal case study as a whole. Second, the evolving demands of the product-centric manufacturing firm's business system are illustrated to elaborate on the implications of such evolution. It provides a concrete grounding to emphasize the relevance and the rigor needed to turn practice-based evidence toward evidence-based practice research (van Aken & Romme, 2012) and leads to the groundwork of this Ph.D. project.

3.1. SUMMARY OF THE INITIAL CASE STUDY

To probe the particular theoretical interest, as shown in Figure 4, two case studies were conducted to examine the practitioners' issues within this narrow research circle. This section presents the research objectives of the two case studies, the key findings, and the contributions to understand the complexity of the servitization movement in both empirical and theoretical domains. Table 2 presents the synthesis of the two case studies.

Table 2. Overview of articles covered in Chapter 3.

Article 1: A thousand-miles journey begins with the very first step: The case of a product-centric manufacturing firm transformation towards servitization.

Research method: a literature review and case study

Research Question: Why is a conventional product-centric manufacturing firm struggling to deploy the product-service logic when embarking on a servitization journey?

Summary:
This research uses an embedded case to explore and rationalize why a conventional product-centric manufacturing firm struggles to take the first steps of transformation toward the advanced services scenario of servitization. A case study firm, which is equipped with sophisticated capabilities to produce and sell smart products, is eager to move on to the next level of engaging its end-users by offering a digital form of advanced services (Baines & Howard, 2013). This means that the status of the value proposition of the firm is moving from the concept of "customers who want us to do it with them" toward "customers who want us to do it for them" (Baines & Howard, 2013).

Gioia's inductive research methodology (Gioia et al., 2012) is applied to extract two highlighted aspects of the managerial proposition: (1) managerial challenges,

and (2) operational conflicts for the practitioners in order to resolve the complex situation.

- **Managerial challenges:** a) Change the organization's mindset from an interest in being product-centric to caring about customer needs, b) Change the focus of customer interactions from transaction to relationship-based, c) Difficulty with value services and their profitability, d) Coping with servitization paradoxes.

- **Operational conflicts:** a) Confusion in designing the advanced service**,** b) Hesitation in extending business processes**,** c) Uncertainty about the business orientation**,** d) Inapplicable organization platform.

Through this case study, three research propositions are identified in the operations domain of servitization: 1) Refine the operations environment in terms of adjusting the product-centric business system to accommodate better the relevancy of servitization tasks; 2) Adopt systems thinking to understand the servitization topic in a holistic view to propose a solution that can be adopted for the transformation problems over time; 3) Investigate the newly-added tasks, and the need for data/information and (digital) technology to perform the servitization-relevant tasks. To sum up, this study sheds light on defining the key arguments, connecting the servitization-related literature and the dilemma the practitioner faces in the Industry 4.0 era.

Article 2: Embarking Advanced Services on Servitization Transformation, Making Sense Using System Thinking.

Research method: literature review, semi-structured interview, and case study.

Research Question: What kind of organizational mechanism is fit for tackling this transformation challenge in the servitization context?

Summary:
This case study engages with a conventional Danish manufacturing firm, which is taking a proactive approach to transforming its organization towards the advanced services paradigm and needs normative guidance. The research objective is to identify the complexity of the organizational activities behind the development of the product-service-offering and to appraise the best-fitting mechanism to work around the organization's transformation issues in the servitization context. The McKinsey 7S framework (Waterman et al., 1980) is adopted to develop the semi-structured interview questions. Seven senior functional managers in R&D, sales, marketing, services, HR, business development, and internal sales are interviewed to understand the internal organization stresses and the operationalizing correlation of the servitization-related tasks. The purpose of this study is twofold. First, it is to

evaluate the propositions proposed in Article 1. Second, it aims to understand the internal operational setup of the firm, which is at the initial stage of digital servitization. The concerns include 1) how each function team manager prepares his/her team to perform the ongoing development of the integrated product-service solution, and 2) what challenges they have experienced and might foresee on the road ahead. The aim is to derive an overall understanding of the complex issues that those managers are addressing in the servitization context. Systems thinking (Ackoff et al., 2010) is applied during the investigation to draw up a picture of the emerging synergy inside the organization and also to analyze the aggregated data in order to provide evidence of the complexity and its root cause. A conceptual process model illustrates the reflection on the impacts of servitization in operational processes. The article sheds light on the critical arguments between the servitization-related literature and a pragmatic approach to drive the servitization journey. The article thus aims to provide insights into the transformation issues in the servitization context.

3.2. DIGITAL SERVITIZATION AS AN ILL-STRUCTURED PROBLEM

In a nutshell, the digital servitization that the management team is dealing with is rather a dynamic challenge, in which the internal struggles are continually evolving together with the external business environment. The principle of digital servitization is similar to servitization – to design and to deliver value-adding services to their customers. The resolutions, however, have been evolving to be more sophisticated, to embody environmental factors (e.g., the development of technology, such as IoT/IoS) and to apply them with more digital means. This argumentation is not hard to find in either the pioneering manufacturing firms such as Rolls-Royce or the servitization related works of literature (see Chapter 2). Researchers are widely exploring this pressing business concept, its challenges and benefits. Instead of a simple box-selling business to business customers, smart product manufacturing firms want to be able to expand their business opportunities to end-users under two conditions. First, they must manage to offer the digital service, which enables the extension of the product capability of the smart products (called advanced services (Baines & Howard, 2013)) into digital form. Second, it is also required to establish an attractive business model to engage with their increasing numbers of stakeholders. However, there are few studies that probe this practical issue holistically and examine how a product-centric manufacturing firm handles such issues from the internal operations perspective.

Two empirical cases go some way to explaining the complex situation that practitioners have to deal with when they are actively transforming a firm into a product-service provider. These illustrate the results of pursuing the two abovementioned conditions and give a clear view of why firms struggle to pursue their goals (see section 3.1). The firm lost touch with aspects beyond the logic of the problem (Checkland, 1999). Suddenly, the structured problems (e.g., designing the

digital service offers, and/or establishing an attractive business model) are wrapped up in an ill-structured problem involving social concerns (Checkland, 1999; Simon, 1997). Thus, it is important to involve a scientific perspective (Simon, 1997) to investigate this gap and to reform this ill-structured problem to accommodate it within a design approach (Checkland, 1999).

In the big picture, practitioners/manufacturing firms are growing their business expectations from pure product-centric toward a product-service orientation. Figure 5 illustrates such evolving expectations, with which manufacturing firms are seeking a transformation toward digital servitization (the blue part of Figure 5). It thus leads to three clearly defined challenges: 1) reacting to external market pressure, 2) developing digital technology-enabled services, and 3) calibrating the back-office supporting system, e.g., the business (information) system in responding to the emerging changes in the value chain/network, the operations complex, and organizational capability (Chen et al., 2020).

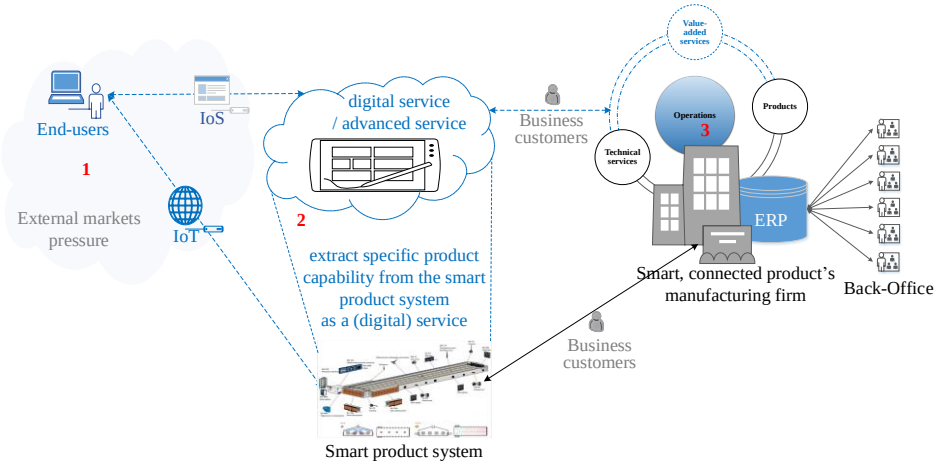


Figure 5. Smart product manufacturing firm's business opportunities, challenges, and operations environment in the servitization context (Chen et al., 2020).

In consequence, this expanding business vision draws attention to the new transformation situation and managerial concerns. At this time, instead of having clear goals and defined assessment criteria, the management team only know what they want to achieve in this new vision: 1) to transfer their business to be more product-service oriented (servitization), 2) to service and engage further downstream with end-users, and 3) to have a second revenue stream to avoid the commodity trap (Gebauer et al., 2011). They do not, however, have any appropriate means to approach these desired goals. There is neither sufficient information nor an adequate mechanism to gain the ground and to assess such complex progress of the development as a whole. Without clear information circulating within the organization, it is hard for top

managers to see the working progress and return on investments in such a big picture. Thus, the servitization paradox (Gebauer et al., 2005) becomes an inevitable long-term result.

In addition to the challenge perspective, a managerial view of handling the operational conflict between the revision and organizational inertia is presented in Figure 6. It adopts the lens of Checkland's soft systems thinking (Checkland & Poulter, 2010) to summarize two empirical case studies (see section 3.1). The servitization journey begins with the revision of the business intention, which further influences the internal operations environment, and vice versa. The B2B strategy to sell the product systems has successfully engaged with dealers and captures the dominant markets. However, it seems to create a barrier that hinders the firms from making contact with their downstream end-users without hurting the partnership with the business customers. Therefore, the manufacturing firms have no clear evidence to define the user experience regarding the usability of either their smart product system or the smart, connected products, and are not able to precisely pinpoint end-users' pains and gains.

A similar dilemma also appears in the operations processes. The product-centric organizational platform, business process, and information are designed and extracted to support managers in making decisions to win more significant markets, to become quicker at delivering their products, and so on. There is no qualified information to nurture the key servitization elements, such as the concept of digital product-service offerings and the associated business model. This therefore raises the following two concerns. First, the managers have no clear idea about what to design a simple but value-adding (digital) service to be associated with the product systems they are offering. Second, there is a strong hesitation about breaking the existing business models and agreements with business customers (e.g., dealers) and reaching out to the end-users (bound on the current business model). In order to overcome this tricky situation, managers are seeking new information to evaluate the potential markets and to establish the appropriate processes to collaborate with their business customers and perhaps reach out to end-users without hurting the existing partnerships. Both theoretical studies and practitioners are sending the strong signal that the IoT/IoS technology is changing the extent of manufacturing firms' operations boundaries (Chen & Møller, 2019). On the one hand, this offers a virtual highway toward the end-users and opens up vast opportunities in the B2C market. On the other hand, it also challenges managers' recognition of conducting a steady operations setup, which supports the physical products business only. In this pre-analysis investigation, the author recognizes this typical challenge of doing evidence-based practice research (Holmström et al., 2009; van Aken & Romme, 2012). In this case, the focus is on the managerial challenges in terms of conducting the organizational transformation in the digital servitization context. This is rarely addressed in the existing servitization research.

In conclusion, this section presented an analysis of the research context based on two empirical case studies conducted in a Danish manufacturing firm. The intention is to observe how digital technology such as IoT/IoS impacts the organizational

transformation at different levels, what the main struggles are for the stakeholders, who is in charge of driving this revision, and how the managers deal with this complex ill-structured problem.

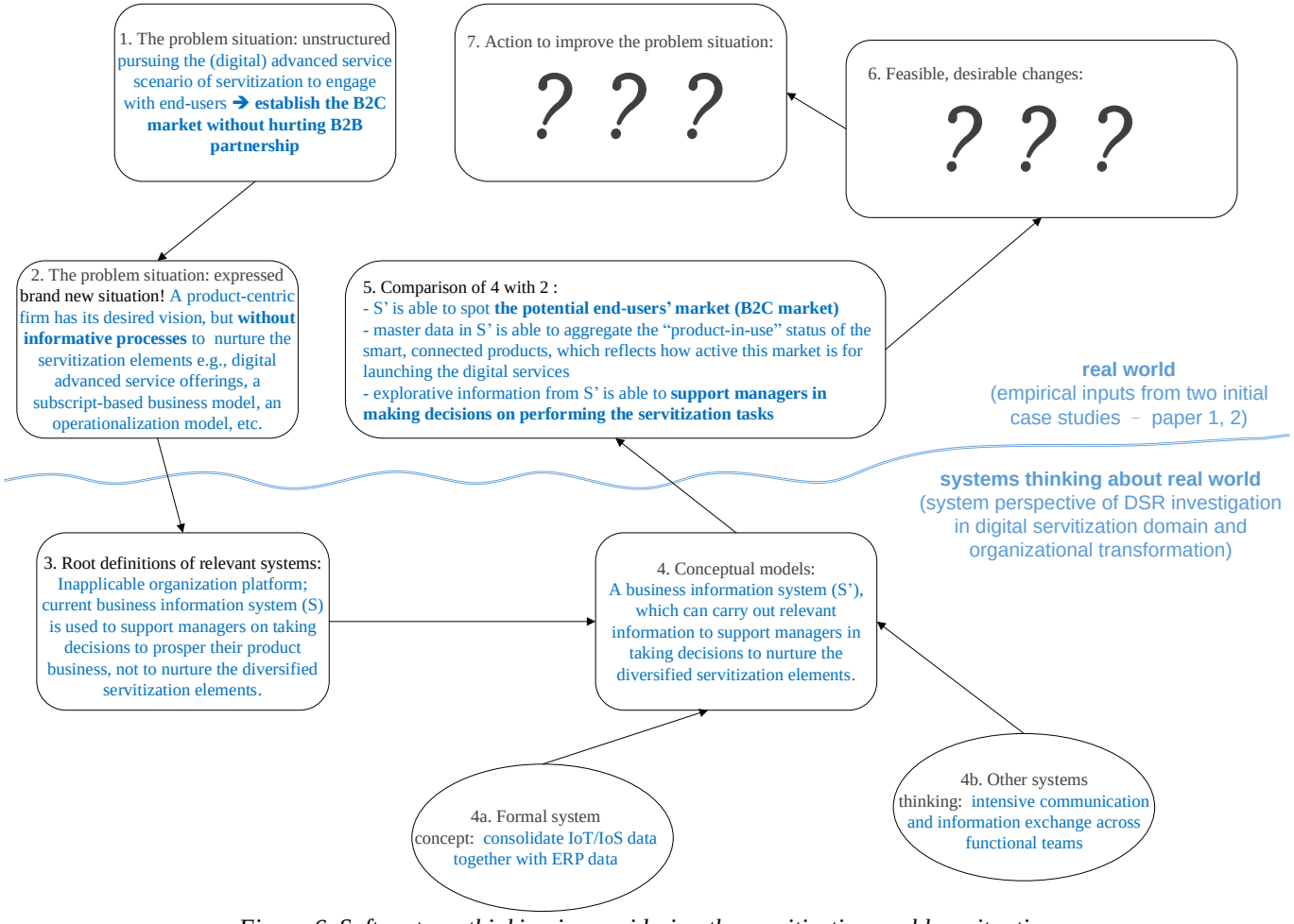


Figure 6. Soft systems thinking in considering the servitization problem situation (adapted from Checkland, 1999).

CHAPTER 4. RESEARCH DESIGN

This chapter presents the research process (McGrath, Joseph E. & Brinberg, 1983), *including the phenomenon of interest (the research gap and the objective of this thesis), the research position (research strategy, methods, and design), industrial case, and research framework. The purpose is to draw the boundaries of why, how, and on what to conduct this research to ensure it is rigorous and of high relevance to practitioners (Holmström et al., 2009) to the servitization research community.*

The chapter describes the process of researching organizational transformation in the digital servitization context. Four sections are presented to delimit the boundaries of this research. First, the background of the phenomenon of interest is defined based on the pre-case studies and analysis in the previous three chapters. Thus, the research gap and the thesis objective are presented accordingly in section 4.1. Section 4.2 illustrates the research positions, including the defined research strategy, research methods, data collection, and evaluation methods, to draw the boundary of this research project. In general, design science is employed as the principle to connect the problematic environments, the knowledge bases, and the solution space (Hevner et al., 2004). Section 4.3 presents the background knowledge of this longitudinal study and demonstrates the practical concerns with the theoretical development. Lastly, section 4.4 presents the research framework, which summarizes the overall structure of this research design and process.

4.1. THE PHENOMENON OF INTEREST

In order to reap the full benefits of the fourth industrial revolution, servitization is an inevitable path upon which manufacturing firms are slowly setting out (WEF and McKinsey & Company, 2019). The aim is to get close to both business customers and end-users with value-adding smart, connected products (the combination of smart products and digital services). Only in this way will they be able to interact with end-users further downstream and expand their business horizons. That is the initial motivation for this Ph.D. project, which has been part of the MADE[1] initiative to help Danish manufacturing industry to evolve toward the state-of-the-art. However, this revision toward product-service oriented business is not a simple task, as the investigations showed in the pre-analysis in Chapter 3 on the research context.

The servitization concept, in general, is not a new topic for researchers or practitioners. However, it has periodically attracted the attention of cross-disciplinary research

[1] MADE - Manufacturing Academy of Denmark is the Danish national initiative for collaboration, innovation and research in manufacturing. https://en.made.dk/

(Baines, Lightfoot, Benedettini, & Kay, 2009; Baines, Lightfoot, Benedettini, Whitney, et al., 2009; Neely et al., 2011; Zhang & Banerji, 2017) to examine aspects of its evolving scenarios and applied means, for instance. The theoretical argument began from the repositioning of manufacturing firms' value proposition to be closer to customers by providing services to warrant the quality of products (Vandermerwe & Rada, 1988). Over decades of development, the scope of the services is slowly becoming more sophisticated in the relationship with customers (Baines & Howard, 2013) but is complex for firms' internal operations (Chen & Møller, 2019). This situation is no less apparent when B2B manufacturing firms are trying to expand their business focus toward the end-users' markets through the direct selling of digital services that are able to enhance the capabilities of the smart products they have purchased.

Dealing with the challenge of digital servitization for those who first encounter is like facing an ill-structured problem (see section 3.2). Neither sufficient information nor an adequate mechanism is available to gain the ground and to assess the complex progress of transforming the organization as a whole. Thus, the research objective of this thesis is to resolve this ill-structured situation by:

Establishing a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management.

Systems thinking (Ackoff et al., 2010; Checkland & Poulter, 2010) is adopted as a lens to examine the existing organization setup and the business (information) system. The intention is to restore the organization's back-office supporting system, namely the business (information) system, to support problem-solvers like managers in their decision-making (Simon, 1973, 1996) toward evidence-based management. Figure 7 illustrates the complex concept of this relation in the digital servitization context from the discussion of chapter 2 – research theme and chapter 3 – research context.

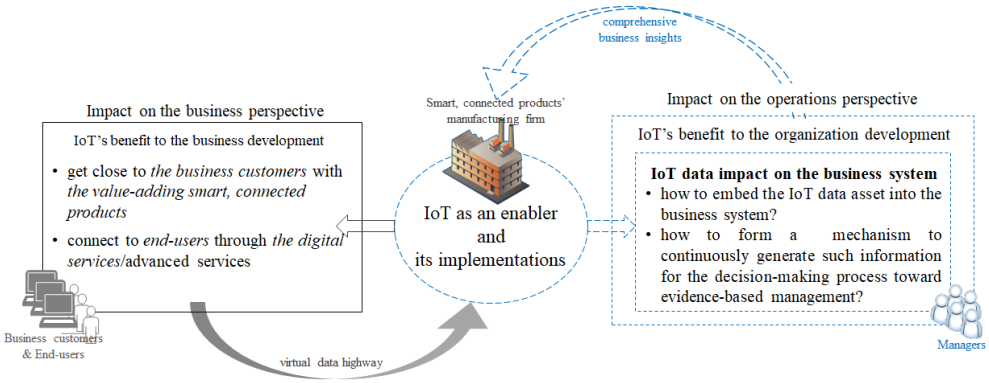


Figure 7. The related research subjects and the research gap.

The majority of (digital) servitization-relevant concepts have been proposed to explain and explore the connection of the left part of Figure 7 – considering the IoT as an enabler to gain business benefits (Cenamor et al., 2017; Eloranta & Turunen, 2016; Iansiti & Lakhani, 2014; Parida et al., 2015; Pekkarinen & Ulkuniemi, 2008; Porter & Heppelmann, 2014, 2015; Rönnberg Sjödin et al., 2016). There are few studies that focus on the concern of the right part of Figure 7 – to investigate the role of the influence of IoT on the operations perspective of servitization. Clearly, the implementations of IoT generate large quantities of data around the smart products at the end-users' side and their context of use. This becomes the first of the direct touchpoints for B2B manufacturing firms connecting to their end-users. The question is what to filter the collected IoT data so that it can be used to improve the understanding of the end-user markets, and also how to consolidate this set of filtered IoT data with the business (information) system, e.g., the Enterprise Resource Plan (ERP) system, so that managers can refer to this information in order to decide on the tactics and actions needed to move toward digital servitization. Therefore, this raises further the questions, namely, what changes will be required in the system? How to form a mechanism to continuously generate such information to support managers in the decision-making toward evidence-based management? These questions need to be explored to support the objective of this thesis.

Thus, this research project aims to explore the existing business system and to examine what might be changed in order to generate sufficient information to support managers in the decision-making to transform the organization toward the vision of being a smart, connected product provider; and in addition, whether there is any workable and suitable mechanism that can continue to generate such supporting information for those stakeholders who need to perform the transformation-relevant tasks.

To conclude, the research presented in the thesis is delimited to primarily covering the organization level, where IoT/IoS is defined as a primary enabler of this transformation. The ubiquitous data (Iansiti & Lakhani, 2014) platform approach (Cenamor et al., 2017; Eloranta & Turunen, 2016; Pekkarinen & Ulkuniemi, 2008) will be taken into consideration in the setting up of this research. Furthermore, the desired vision of transforming manufacturing firms toward being powerful providers of smart, connected products (=smart product + digital service) will be reflected in the formulation of the managerial proposition as the practice outcomes.

4.2. RESEARCH POSITIONS

As presented in the previous sections, this Ph.D. project is undertaking evidence-based practice research (van Aken & Romme, 2012) to address a managerial issue, the research outcomes of which can be of mutual benefit to both the practice and research communities. This means taking practical action on a theory-laden basis (Checkland, 1985) and creating a positive loop including reflective actions. Design science is applied as the principle in this project to evaluate the importance of the form

of intervention research (Oliva, 2019; Van de Ven, 2007) and to extract the managerial propositions to deal with the observed changes in the problem situation. Thus, this section begins with an explanation of intervention research as the research strategy selected to engage scholarship with practitioners' concerns. Also, the research methodologies will be presented, delineating how they set the boundaries and criteria to ensure the relevance and rigor of the research in the research design and evaluation.

4.2.1. INTERVENTION RESEARCH

A fundamental notion in intervention research is *"to explore the role that interventions (the ultimate manifestation of design science) can play in testing and developing theory (the ultimate goal of an academic endeavor)"* (Oliva, 2019). In this framework (Figure 8), researchers are asking what methods (M) to apply to a basket of theories (T) to bring a problem situation (S) to S' (Chandrasekaran et al., 2020). This is rooted in the principles of action research and the explanatory framework of process theories. The formal principle renders the purpose of research actions and makes sense of the problematic situation (S) by trying to change it, which Oliva calls Model 1 – interventions as a test of theory. The latter creates causal explanations for how and why things happened and how the intervention interworks dynamically with environmental events and further elucidates the observed transformation path (from S to S') as a result of implementing the intervention, which is named Mode 2 – interventions as a source of theory.

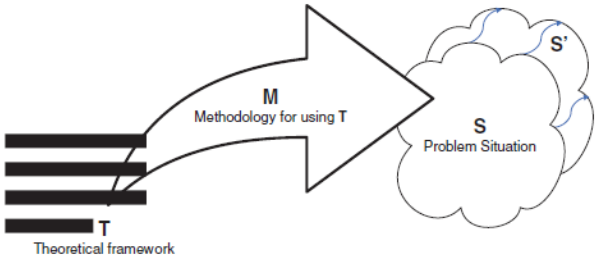


Figure 8. The framework of the intervention research (Checkland, 1985; Oliva, 2019).

This intervention research strategy is normally applied in three particular scenarios to derive useful evidence from the developing theory and the proposed intervention as a mechanism (Oliva, 2019). These are 1) when problem situations are ill-structured, 2) when empirical evidence from the problem situation contradicts predictions emerging from existing theory, or 3) when the intervention strategy is developed with new theories on the context S. In general, scholars apply this research strategy to take trial-and-error iterative actions to test the problematic field until a fit solution is revealed. During the research process, questions such as: what are the problematic situation and the desired goals? how to achieve the desired goals? and why to achieve such desired goals? are consistently asked, and answers sought by the researchers. By combining

different research methods in the iterative processes, an adequate representation of the research can be presented as the result of this thesis.

4.2.2. MULTI-METHODS RESEARCH

In order to create a useful but theoretically-based intervention to bridge the practice and theory and to develop and test theories (Holmström et al., 2009; Oliva, 2019), three key research methods are used in this research design. Each method, with its idiosyncratic techniques, is applied to craft the defined goals in different stages. These, when all applied together, create a unique methodology to experiment on the objective of this thesis. Figure 9, adapted from McGrath and Brinberg's research process principle (Lynch & Brinberg, 1986; McGrath, Joseph E. & Brinberg, 1983), illustrates the purpose of the three research stages and the multi-methods in this thesis.

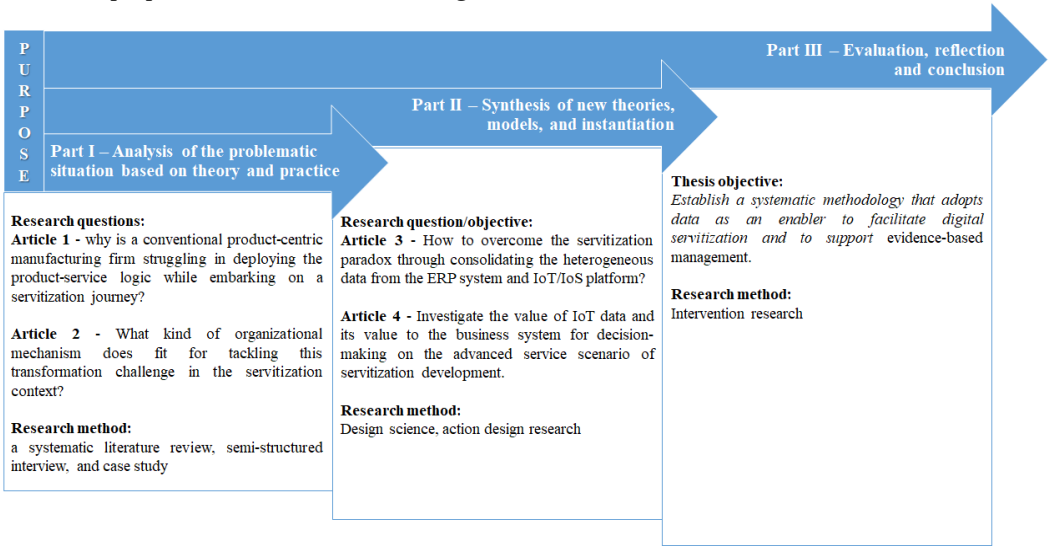


Figure 9. The summary of this multi-methods research and placement.

As seen in Figure 9, each main research phase has its own purpose and achievements, which serve as the theoretical foundations that contribute toward the thesis objective. In each phase, the sub-research questions are addressed to express the knowledge gap between practice concerns and theoretical divergence. Based on the sub-research questions asked, the specific research methods are selected to carry out the research procedures, to collect the research data, and to evaluate the validity and reliability of this particular stage.

The aim of part I is to explore the research (problem) context and to understand the practitioners' struggle in transforming the organization toward digital servitization and how the existing literature supports conducting this transformation (Chen &

Møller, 2019). The case study method is used to investigate in-depth and in the problem's natural setting (Eisenhardt, 1989; Siggelkow, 2007). By applying induction logic (Karlsson, 2009) and the qualitative rigor of Gioia's model (Gioia et al., 2012), the knowledge gap between practice concerns and theoretical divergence can be examined. This is a method that is particularly useful for the earlier phase of the research project, where the problematic context being researched is inconsistent with the observation of the observation of the reality. Thus, the premise of applying a case study is to understand the misperception of relations such that a new theoretical perspective can be developed through empirical analysis (Eisenhardt, 1991; Gioia et al., 2012).

In the second part of the research, design science methods are applied to engineer the problematic context, where the IoT is seen as one of the enablers causing this particular complex situation at the organization level (see Figure 7 in section 4.1). In this dynamic hypothesis, IoT as an enabler and its influence on the organization are the two phenomena to be explored. Here design science research (DSR) comes in handy. The principle of this type of method is to undertake iterative experiments to work on the design, relevance, and rigor (Drechsler & Hevner, 2016; Hevner, 2007) within the environment, design, and knowledge spaces. The aim of understanding the relations between those two phenomena is to extract "*further knowledge that aids in the productive application of information technology to human organizations and their management"* (Hevner et al., 2004). In this case, Hevner et al.'s framework (Hevner et al., 2018) is applied to draw the blueprint on how to create the benefits of applying IoT technology, and to evaluate the value of this design artifact in the servitization context (Chen et al., 2019). By working on developing an applicable instantiation, the knowledge of how things can be constructed and how to achieve the desired set of goals in both improving the reality and theorizing the concept is revealed (Gregor & Hevner, 2013).

In addition, action design research (ADR) (Sein et al., 2011; Sein & Rossi, 2019) is applied to extract its impact at the organization level, the second phenomenon. ADR has roots in both action research (AR) and design science research (DSR) methods. The inherited characteristic of the former method aims to solve the real-world problems in the social science domain, and often only applies in the naturalistic evaluation associated with socio-technical problems (Järvinen, 2007). The latter, however, has a broader objective, where the design artifact is an innovative concept to be worked around technical and/or socio-technical issues. In this sense, it is also able to test the artifact in the artificial (imaginary) environment (Iivari & Venable, 2009), which in this thesis refers to the organizational impact in the servitization context. Thus, the ADR method is able to evaluate the ensemble value of this dynamic hypothesis - IoT as an enabler and its influence on the organization.

Finally, the purpose of the last part of the research process is to respond to how the management team evaluates this transformation path, of which IoT technology and its data value are seen as the primary enabler that causes this emerging complexity at the organization level. However, the same enabler creates an applicable solution to

support managers in unraveling such complex situations. The ensemble of the engineering solutions, which are designed in phase II, is used here as interventions to extract the lessons learned and insights from the management team. Instead of enquiring about the knowledge of the static status of the intervention – Oliva's model 1 (Oliva, 2019), which is broadly carried out in part II, the exploration of mode 2 provides explicit explanations of this particular transformation issue.

Figure 10 delineates the summary of these two (phenomena) layers of research concerns and their associated research processes, in which the prescribed solution(s) are developed under the normative research. The interventions are dynamic forms and continuously evolve through the progress of understanding the problematic environments, the knowledge bases, and the solution space (Hevner et al., 2004). The blue interventions are used to engage with the managers and evaluate the value of the design (IT) artifacts in the servitization context. The green interventions are the technical engagements on how to create the benefits of applying IoT technology to enhance the business system. The green stars are the concrete prescription solution(s) as (IT) artifact(s), which are co-developed with the servitization team and evaluated with the stakeholders (comprising both the servitization team and managers). They are also used as parts of the interventions to engage with stakeholders and to evaluate what, how, and why changes are made and how the design (IT) artifacts create value in the servitization context (pink stars). All these engagements serve as inputs to prescribe the systematic methodology – the thesis objective in part III.

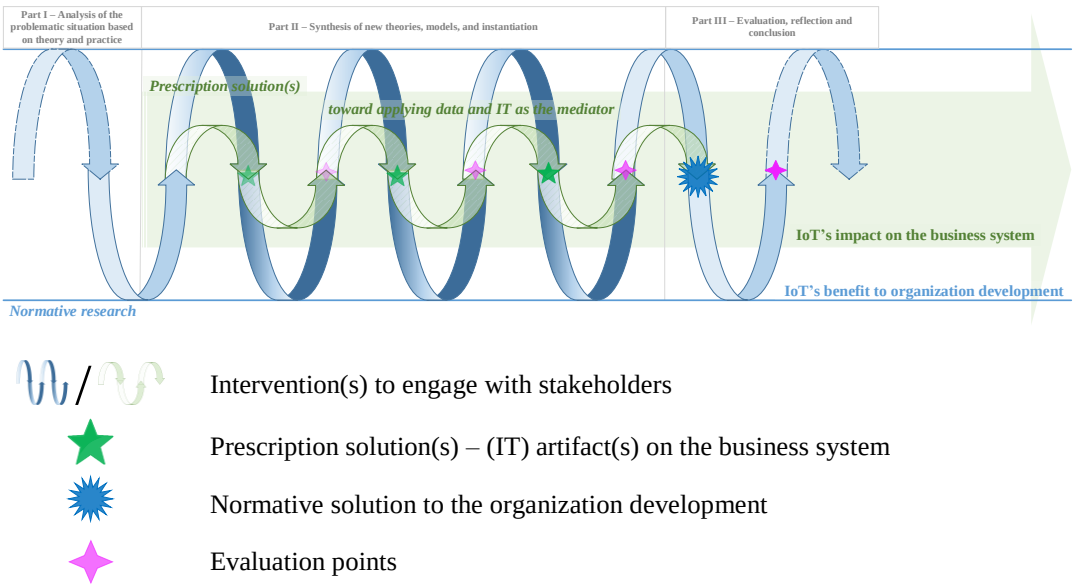


Figure 10. Two layers of research concerns and its associated research processes.

In summary, the research methods – the literature review, case study, semi-structured interviews, design science, and intervention research method - are chosen to respond to the particular defined research concerns and objectives of each stage (see section 4.1).

4.2.3. DATA COLLECTION

The multi-methods approach is applied throughout this thesis, which brings about two types of research data. The primary data sources were gained from direct participation in the innovation workshop, operations meetings, observations, and designing/developing the artifacts. In addition, complementary data, through face-to-face interviews and the archival records about the specification of the IT systems and working procedures, were also acquired during the project development and evaluation phases.

The McKinsey 7S framework (Waterman et al., 1980) was applied in two primary interviews with the top management team and stakeholders in the servitization team with the purpose of understanding the synergy created from each union inside the organization. The aim was twofold. First, it was used to understand the internal organization stresses in operationalizing the servitization-related tasks (in the latter stage of part I). Second, it was also used to reflect on the managers' attitudes and actions, working on initiating changes to capitalize on the artifact data asset created from the consolidation project (part II). Table 3 summarizes the data types which were collected during the three phases of the project time.

Table 3. Overview of collaborative activities and the received data types.

	Part I - Analysis	Part II - Development	Part III - Evaluation
Direct participation in project-related activities, e.g., innovation workshop, operation meetings, etc.	Investigate the knowledge gap between practice concerns and theoretical divergence in the servitization context 02/2017 – 04/2018		
Research project team lead to engineer the defined problematic context	Investigate the specific data resource, system setups, working processes, etc. to take a lead in consolidating the two heterogeneous data from ERP and IoT platforms. The different forms of the artifacts have been designed and delivered between 08/2017 – 01/2020		
Acquire the complementary data through archival records and interviews	7 hours of orientation meetings 08/2017 – 10/2017 20 hours of managerial interviews 08/2017 – 04/2018		
		11 hours of investigation interviews (applied McKinsey 7S framework) 06/2018 – 08/2018	
			17 hours of evaluation interviews (applied McKinsey 7S framework) 10/2019 – 02/2020
Observation the empirical concerns, response to changes in stakeholders and organization level	Observe the phenomena of IoT as the enabler and its impact on the organizational transformation 08/2017 – 02/2020		

4.2.4. RESEARCH RELEVANCE AND RIGOR

This section continues the discussion of the research design by explaining the ensemble logic of this research design. It focuses on the relationship between the objectives of the thesis and the articles presented in each phase, and the actions taking in the empirical context. Venable et al.'s strategies for design science research evaluation (2008) are followed to evaluate the outputs of this research, including theory and artifacts. Even though the broader context of this research is about servitization, its core enabler is IoT technology and the data collected through this implementation. Therefore, the focus of the subject being evaluated is still concerned with the (IT) artifacts and their influence on the environmental settings.

In this case, the broader servitization context is seen as an artificial setting, while the design and usage of the (IT) artifacts are part of the naturalistic evaluation. The aim is to demonstrate the utility, quality, and efficacy of the design artifacts in the experimental settings (Hevner et al., 2004). Figure 11 presents a framework for strategically evaluating the research contributions of this thesis. Together with the applied research methods (see section 4.2.2.), there are five steps to evaluate the relevance and rigor of this research's outcomes at each stage and as a whole. The narrative causality problem - having insufficient information, leading to a lack of quality decisions and the servitization paradox in the long term - is defined through the empirical case study together with the intensive literature review (step 1). To overcome such concerns in practice and research, a conceptual method, which considers IoT and its implementations as an enabler, is proposed as the first step to initiate this research journey. Through applying the intervention research strategy, several iterations of experiments (building and implementing the artifacts) and interviews (evaluations) take place with the stakeholders to materialize the proposed conceptual method as the interventions (steps 2 and 3) to observe the impact in the experimental environment (step 4). A systematic methodology, which embeds the idiosyncratic characteristics of the IoT data, is proposed for conducting the organizational transformation toward digital servitization (step 5). The overview of the specific content is further elaborated in Table 4.

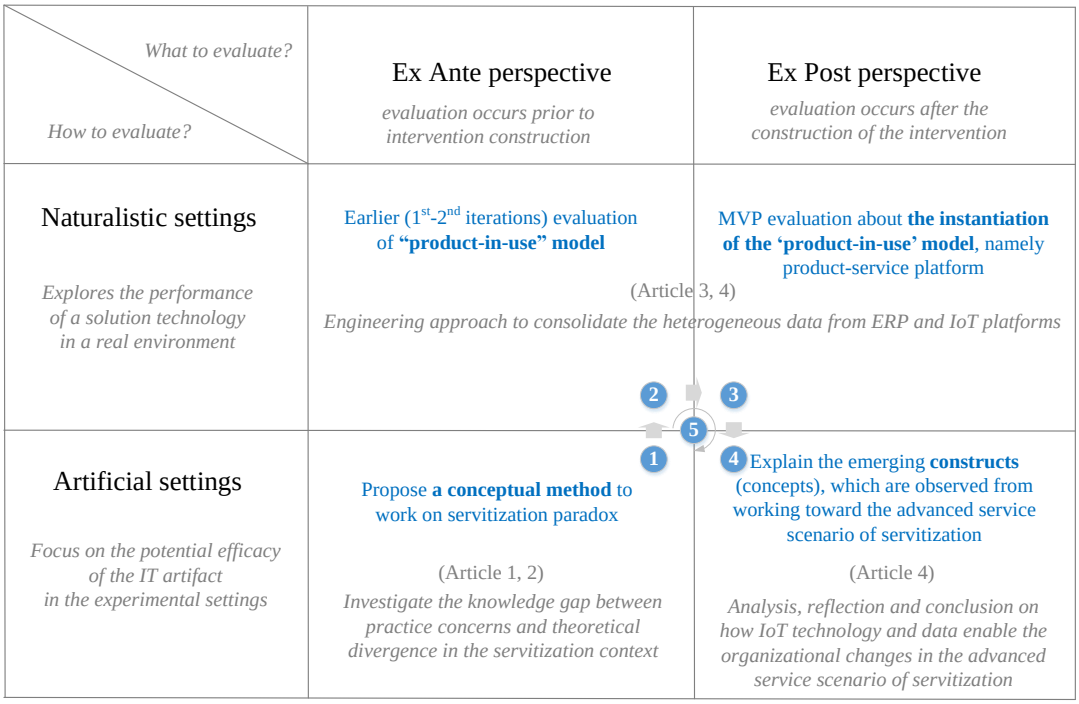


Figure 11. A strategic DSR evaluation framework

(adapted from (Pries-Heje et al., 2008; Venable et al., 2012).

Table 4. A summary of the evaluated objectives, the applied methods, and research projects.

Steps / Criteria	1	2	3	4	5
What is actually evaluated	A **conceptual method** to work on servitization paradox / design process	A **"product-in-use" model** to consolidate the heterogeneous data, retrieved from ERP and IoT platforms / design product	An **instantiation of the "product-in-use" model** to carry the explorative information regarding the potential markets of product-service business / design product	Emerging **constructs**, observing from working toward the advanced service scenario of servitization / design process	A **systematic methodology** that adopts data as an enabler to facilitate digital servitization and to support evidence-based management / design process
When evaluation takes place	Ex Ante	Ex Ante	Ex Post	Ex Post	Ex Ante
How it is evaluated	Artificial / real problem	Naturalistic / real users and stakeholders	Naturalistic / real users and stakeholders	Artificial / real organization system	Artificial / field experiment
Methods	Case study	Design science research	Action design research		Intervention research
Research projects	Article 1 and 2	Article 3	Article 4		Thesis

4.3. RESEARCH PROJECT BACKGROUND

This Ph.D. project is based on a longitudinal study, in which the cooperation is established through the MADE platform. Intending to aid the Danish manufacturing industry to stand at the state-of-the-art, this particular practice-research cooperation setup assures the outcome of this project, which is more than a simple consultancy or theoretical research project. Therefore, the outcome of this project not only supports immediate benefits to the industry but also generates substantial knowledge for the research circle who are interested in this topic.

The case firm has decades of experience in selling its own brand of high-quality farm equipment and systems to the global market and its alliance business partners. Its physical product systems have reached over 88 countries across continents. From years of success in its domain, the firm can offer smart products, which have product systems, adopting sensor technology, and software products. Of these, the software products are used as the interface to visualize the production condition of the end-users' facilities. Gradually the firm is realizing the implementation of IoT/IoS concepts as an extension of its product systems. Overall, this smart product identifies the firm as an intermediate service provider maturing toward being a digital service/advanced service (Baines & Howard, 2013) supplier (Chen & Møller, 2019). In 2017 the top management team decided to expand its business focus from selling smart products toward smart, connected products, including developing intangible (digital) services/advanced services. The intention is to use the digital services of the smart, connected products to boost sales of the physical product components, including through the installed base business and the smart products. Figure 12 summarizes the business setup of the selected case firm.

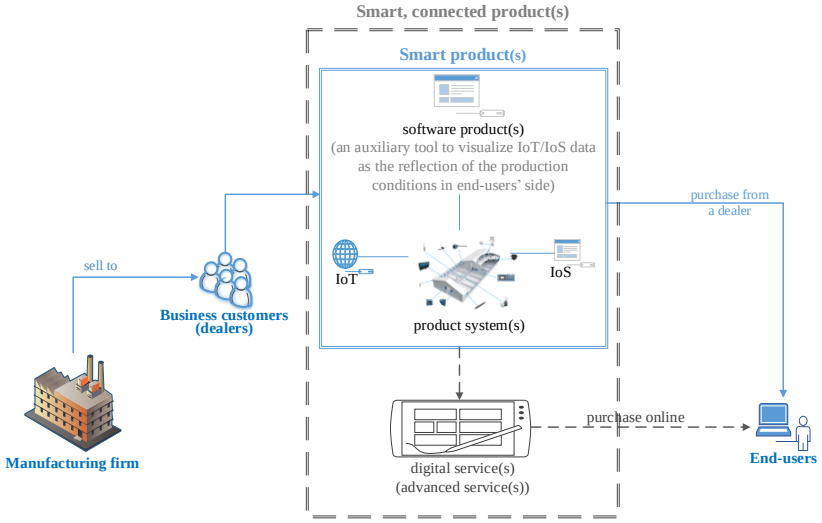


Figure 12. The business setup of the selected case firm (Chen et al., 2020).

Although this firm is already providing smart products, it is also seen as offering intermediate services (Baines & Howard, 2013) to its end-users, and its deeper organizational thinking and organization structure continue to reflect a product-centric mindset. The two pre-analysis case studies, addressed in section 3.1, made this clear and revealed the ongoing struggles to transform the organization toward a smart, connected product provider (Chen et al., 2018; Chen & Møller, 2019). The existing organizational platform and business system, which thoroughly adopt lean manufacturing principles, perform well enough to carry through the logistic mission (e.g., the box-selling). However, it demonstrates limitations in supporting the management team in decision-making needed to facilitate organizational changes toward digital servitization (Chen et al., 2020).

So, in this academic-industry project, the objective is to develop a means and a systematic methodology to mitigate this particular transformation challenge in the digital servitization context. To do so, several experiments are conducted to develop a trial solution(s) to change some of the real-world problems, to observe what might need to change in the business system and at the organizational level, and to analyze why those changes need to take place.

4.4. RESEARCH FRAMEWORK

This section summarizes Chapter 4 - research design in the big picture and highlights the key take-away for later discussion in Chapters 5. The aim of Chapter 4 – research design – is mainly to set up the boundaries of why and how to carry out this project, what is required in order to be highly relevant to the practitioners, and also rigorous for the digital servitization research community. The research objective was drawn out from the two case studies (Chapter 3.1), which pre-analyzed the practical concerns and theoretical interests (Chapter 3.2). The findings indicate that most of the works in the literature on digital servitization tend to describe the rational and causality of servitizing manufacturing firms from the business perspective (see Figure 7, section 4.1). Only a small number of works pay attention to prescribing systematic solutions for the practitioners and to drawing the theoretical lessons to bridge the gap between academia and industry. Consequently, these initial trends have slowly reached a ceiling in terms of discovering the theoretical knowledge in practice, leading to a difference between practitioners' concerns and the theoretical interests. Thus, the research framework (Figure 7 in section 4.1) proposes to take IoT as an enabler and to investigate how it and its implementations can influence the organizational perspective of developing digital servitization. In this case, the author adopts an interventions research strategy (Chandrasekaran et al., 2020; Oliva, 2019) to work with the practitioner and aims to *establish a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management* (see section 4.1- research objective). Specific research methods, such as a case study (Gioia et al., 2012) and action design research (Sein et al., 2011), are applied to probe the problematic context and to engage with the stakeholders involved

in this research project. Through several iterations of building, implementing, and evaluating, interventions are created together with the stakeholders at the different stages to change the special problem situations for the targeted users. The goals here are to figure out what to filter the IoT data and how to create a fitting mechanism to continuously generate useful business insights to support managers in the decision-making process toward a product-service oriented business.

In this research design, the iterations of building and implementing tasks are mainly in the business information system domain. However, the impact of the (IT) artifacts as interventions is evaluated iteratively in both the business information system domain and the operations perspective of the digital servitization context (see Figure 10, section 4.2.2). This is to ensure that the interventions are useful to the domain-specific users and also fulfill their higher purpose in the business context. Only in this way can the lessons learned be applicable to other firms that are on a similar transformation journey. Figure 13 summarizes the contents presented in sections 4.1 and 4.2 and clearly illustrates the overall structure of chapter 4.

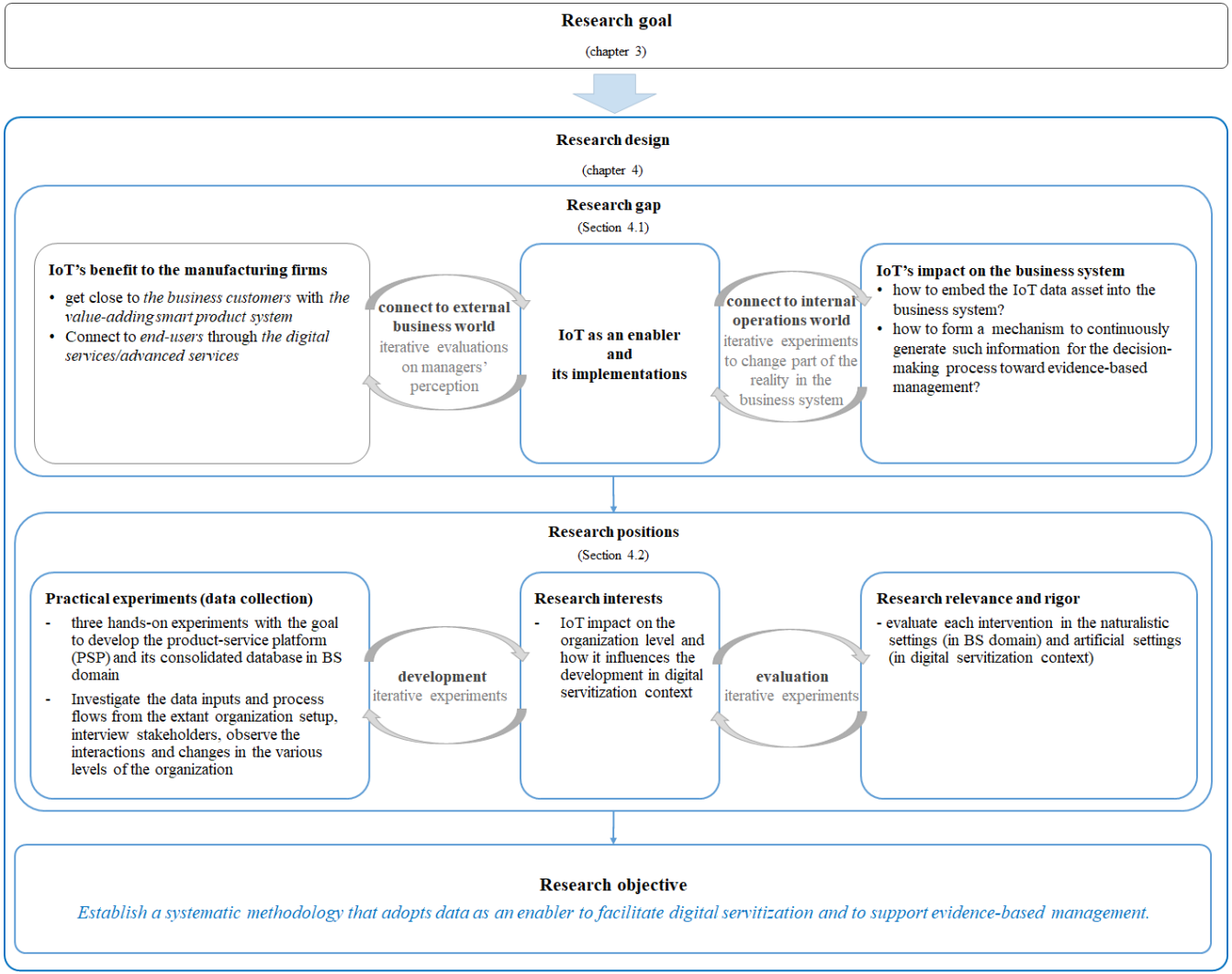


Figure 13. The structure of the research design.

CHAPTER 5. RESEARCH CONTENT

This chapter presents the content of this exploratory research (Holmström et al., 2009), including the summary of two DSR articles (from three engaged experiments), the analysis of the impact of IoT and its implementation on the organization level, the observation of the emerging challenges to managers, and the normative solution to this ill-structured problem and the implications of this systematic methodology – a four-step model of the data-driven approach.

Chapter 5 presents the research outcomes. The goal is to respond to the research concerns and the research objective from Chapter 4. There are four sections. Section 5.1 presents the synthesis of the interventions (summarized from articles 3 and 4). Section 5.2 responds to the research concerns arising from the research framework. Three facets of theoretical contributions are extracted from the lessons learned from articles 3 and 4. Section 5.3 indicates the managerial challenges, which are to balance the intrusive strategic changes from top-down, and the infusive process changes from bottom-up (Mintzberg & Westley, 1992). Section 5.4 responds to the research objective and presents the four-step model of a data-driven approach to bring together the diverse voices of transforming the organization toward digital servitization. In addition, the implications of this model are discussed. Figure 14 illustrates the structure of Chapter 5.

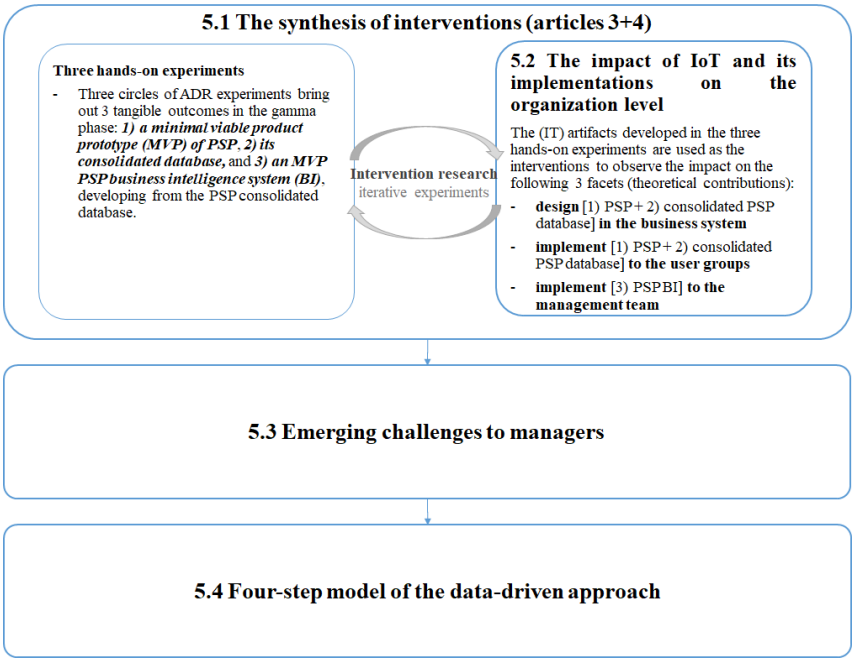


Figure 14. The structure of the research content.

In this research, there are three hands-on experiments to engage with participants in two layers of research concerns and their associated research processes (see Figure 10, section 4.2.2). Figure 15 presents the detailed design of these two layers of research processes. The first is to develop the (IT) artifacts to probe into how IoT and its data implementation might change the business system (the green rectangle of Figure 15). Three circles of ADR experiments take place to deliver the different maturity of (IT) artifacts to the practitioner. In the Gamma phase, a fitted IT artifact composed of three elements: 1) a minimal viable product prototype (MVP) of PSP, 2) its consolidated database, and 3) an MVP PSP business intelligence system (BI), are developed from the PSP consolidated database, which is developed to explore the consolidated data between the ERP and IoT datasets. The second is to observe how IoT benefits the organization's development in the digital servitization context (the blue rectangle of Figure 14). The intention here is to observe and analyze the organizational changes and their impact during the development processes.

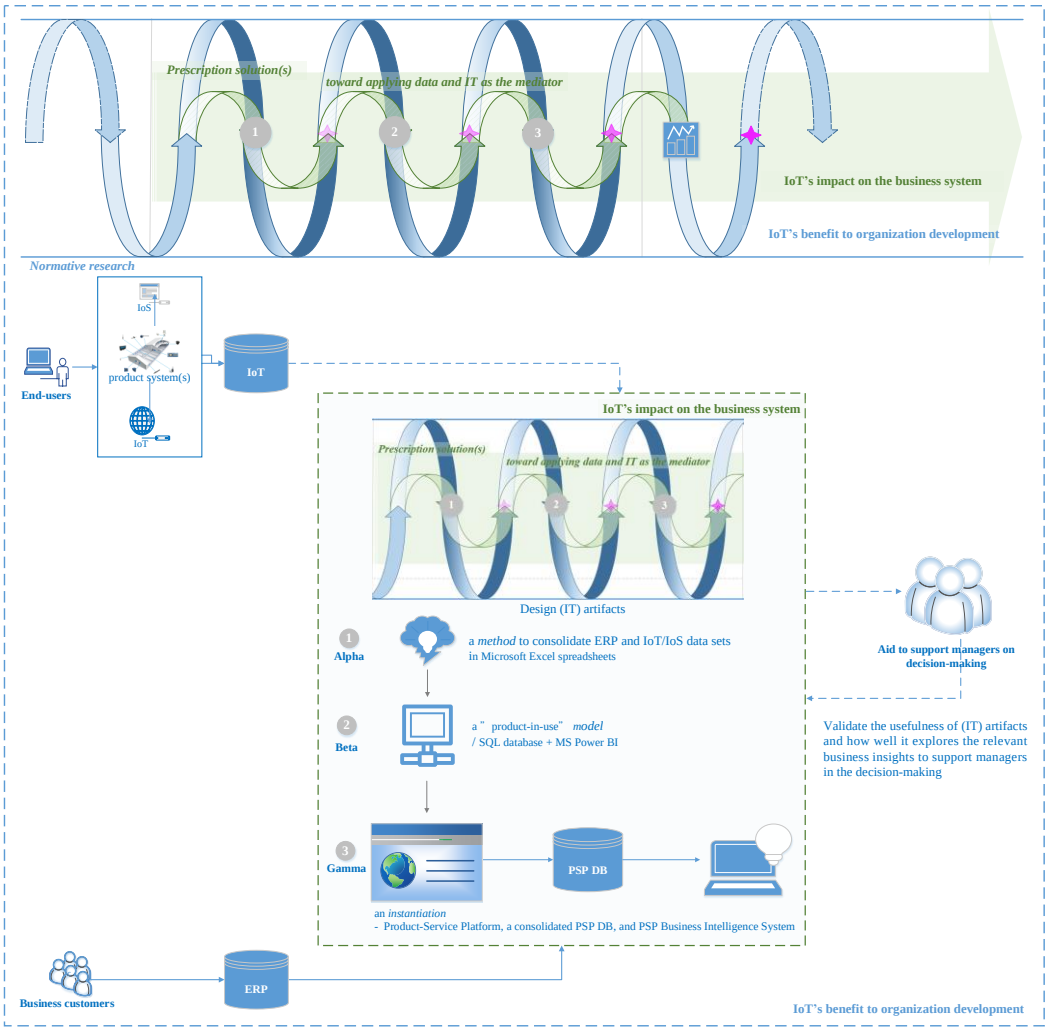


Figure 15. The detailed view of two layers of research processes and deliverables.

5.1. THE SYNTHESIS OF INTERVENTIONS

This section presents the synthesis of interventions, as summarized from articles 3 and 4, to illustrate the empirical findings and to examine the defined research concern (see section 4.1). The original design concept of the instantiation – the product-service platform (PSP) – is presented in article 3. The comprehensive work on the iterative building, implementing, and evaluation of the evolving interventions is presented in article 4, which engages stakeholders in the different stages to alter the special problem situations for the targeted users and management team. The goals are to examine if each evolving intervention is suitable for moving the specific problem from S to S' (see Figure 8, section 4.2.1) in the business information system domain and also for meeting the higher business purpose in the operations perspective of the digital servitization context. This is to ensure that the interventions are useful to the domain-specific users and also fulfill their higher purpose in the business context. Table 5 presents an overview of articles 3 and 4.

Table 5. Overview of articles covered in Chapter 5.

Article 3: Bootstrapping Product-Service Business: An Experimental Data-Driven Approach

Research method: an experimental study to develop an instantiation, and semi-structured interviews to evaluate its usefulness, and research relevance and rigor.

Research question: How to overcome the servitization paradox through consolidating the heterogeneous data from the ERP system and IoT/IoS platform?

Summary:
The objective of this experimental study is to demonstrate how to overcome the servitization paradox through consolidating heterogeneous data from the ERP system and IoT/IoS platform. The intention is to explore an engineering solution that can process the informative data evidence to support managers' decision-making in transforming organizations toward the product-service business paradigm. However, challenges are revealed in the cross-disciplinary studies (Blaschke et al., 2018) and the exteant of the organizational setup and business information system (Chen et al., 2019).

The two heterogeneous datasets – ERP data and IoT data – are created for different purposes and are also developed and maintained under different function teams. In general, the enterprise resource system (ERP), adopted in the goods-dominant (G-D) logic, is often used as the organization platform for carrying out the business processes. Its purpose is to conduct the business transactions of "exchange" value creation between the focal firms and customers. The system has worked perfectly to drive product-centric firms to achieve production excellence. Typically, it is developed and maintained in a support-oriented department, such as the IT department. On the contrary, the implementations of the Internet of Things (IoT) / Internet of Services (IoS) are set out in the service-dominant (S-D) logic to create

the new business relationship of "use" value creation. It is often initiated in a development-oriented department, e.g., the R&D department, as it is seen as a part of the new product development, but in a digital form and with the idea of helping customers to enhance their productivity. This purpose-driven setup in the product-centric organization results in very little collaboration while developing and maintaining both parts of the system. Also, it seems to be limited in accommodating the contrast of the business process, which is concerned with the products sold once "in-use".

In order to create data value within the service-dominant logic perspective, Blaschke et al. (2018) argue that a black-box model has to be created to accommodate intangible resources, actions, and values, for example. Hevner et al.'s framework – the roles of digital innovation in DSR – is adopted to examine this defined problem (Hevner et al., 2018). Figure 16 illustrates the six specific steps to facilitate the knowledge exchange between domain expert knowledge bases and project design knowledge in this project.

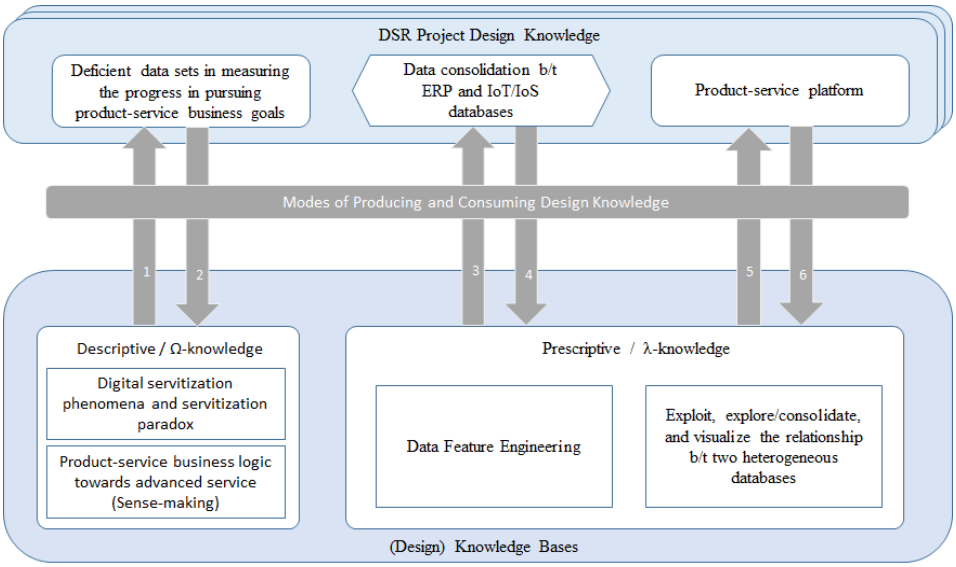


Figure 16. A DSR project model of setting up a data-driven platform to explore the product-service business insights to support decision-making (adapted from Hevner et al., 2018).

- A **descriptive approach** is applied in steps 1 and 2 to scope the problem context, including why, how, and what is the problem that has emerged.

- A **prescriptive method** is used in steps 3 and 4 to engineer a solution, consolidating the exchanged-goods business data (i.e., data from ERP) and smart, connected products data (i.e., real-time data from IoT/IoS). In this stage, the intention is to exploit and explore this set of consolidated data in order to extract insights to justify the actions for operationalizing product-service related tasks.

- An **instantiation** – a visualized dashboard (e.g., a graphical user interface/GUI) – is built to visualize the explored data sets for the relevant stakeholders in steps 5 and 6. From these data sets, the evidence is derived to support the stakeholders in taking suitable actions to get the product-service business rolling.

Semi-structured interviews to evaluate the usefulness and limitations of the solution are conducted with R&D, the digital service sales manager, and digital service/product manager, and IT. The aim is to promote product-service thinking across the organization through this design platform and to recognize value-adding tasks to pursue the product-service business goals. Our approach was tested with empirical data from a Danish manufacturing firm.

Article 4: Exploring the Value of IoT Data as An Enabler of the Transformation toward Servitization: An Action Design Research Approach

Research method: action design research and semi-structured interview

Research objective: The research objective of this article is to explore the value of IoT and IoS data behind the implementations of digital services and to evaluate the organizational change and impact from this newly developing technology.

Summary:
This article extends research in the previous papers (Chen et al., 2018, 2019; Chen & Møller, 2019) by taking a systems thinking view (Ackoff et al., 2010) to reflect on the longitudinal study to examine the servitization issues. The value of IoT data is explicitly pinpointed as the focus of exploration and the organizational impact in the digital servitization context is evaluated.

An action design research (ADR) (Giessmann & Legner, 2016; Sein et al., 2011; Sein & Rossi, 2019; Tesch, 2016) with three iterations is undertaken to explore this new business information asset, which refers to the "product-in-use" data, emerging from the digital traces of the end-users' interactions with the smart products. In both practice and theoretical study, this set of data has been

underexplored in both the servitization context and in the organizational change domain. Thus, this investigation addresses how and what are the benefits of the data generated by the digitalization initiatives such as the IoT/IoS implementation.

Through three iterative engagements, the product-service platform (PSP), composed of three sub-systems: PSP, the consolidated PSP dataset, the PSP business intelligence system (PSP BI) were co-developed with the case firm. They were also used as interventions to engage with the stakeholders from the process and the strategical perspectives. The intention is to explore the value of IoT and observe what needs to change in the existing business system as well as at the organizational level in order to explore the full benefits of utilizing such a new data asset.

In summary, the article brings three research contributions. First, we propose a set of design principles to improve the existing business system toward supporting digital-enabled servitization. There are three layers in this design principle. The bottom layer – c) technical concerns is to create the digital link to connect the fragmented understanding between two data sets as two business markets (here, referring to the product market (date from ERP) and the "in-use" smart product market (data from IoT)). The middle layer – b) business consideration in terms of supporting the operational purpose is to put the smart product in the centric. By extracting the product-in-use insight from the IoT data set and consolidating with ERP data, we are able to draw the digital picture of how the end-users' production condition and the product in-use status. Furthermore, the business potential of the digital market through the aggregative data points of product-in-use sits can be drawn to support managers in understanding the potential of digital service markets. The goal is to aid managers in decision-making to take the right actions to promote the advanced service to the most potential markets. Figure 17 illustrates how this approach supports the business intention and the defined operational purpose.

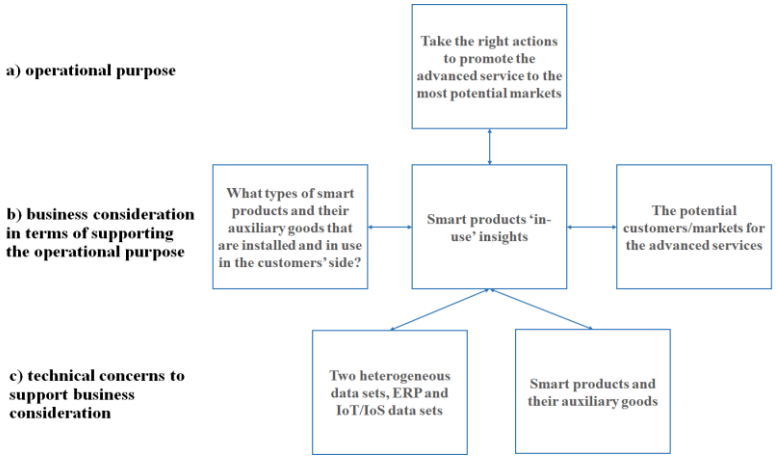


Figure 17. The "product-in-use" model, showing how the data-driven approach supports the business intention and the defined operational purpose.

Second, we bring up theoretical contributions to understand the emerging constructs in the business system to support the digital-enabled servitization. In this case, we observe the potential value of the IoT data to understand the end-users' market, and we further question how to handle this part of the data asset in the business system of a product-centric manufacturing firm. One argument is that the current business system of a manufacturing firm is very much taking the ERP as the foundation of the IT platform to accommodate the enterprise data sets and to establish the operational processes around this surrounding. The emerging data set – IoT data is collecting from a smart product system, which is designed on the R&D team. This separative and isolative development creates a barrier of recognizing the integrated data value as a whole. We, therefore, argue that the internal business system also needs to be expanded in order to explore the IoT data, eg., and to be able to accommodate more and more collaboration processes. So, we argue that the concept of the emerging business system needs to have those three characteristics. The first is able to handle the upcoming (heterogeneous) data assets and explore valuable business insights. The second is to moderate the different opinions among the functional team/silo thinking. It means that explorative business insights should be commonly recognized across departments. The last construct of this emerging business system is to explore the information, recognizing the incentive points that managers can use it to communicate across functional teams effectively.

The last contribution. We discussed our experience in using ADR and argue that the use context of the artifacts should also be co-defined in the building, investigation, and evaluation process. In this case, managers see the additional value of PSP as a reference KPI system, rather than just providing the explorative business insights to understand the potential business markets of the upcoming digital services.

5.2. THE IMPACT OF IOT AND ITS IMPLEMENTATIONS ON THE ORGANIZATIONAL LEVEL

This section aims to respond to the research concerns arising from section 4.1 – research framework. Thus, the research focus moves to the role of IoT and the value of its implementation, such as the collected "product-in-use" data (Chen et al., 2019), to the operational perspective of digital servitization. The questions here are twofold. First is how the organization's back-office supporting system, namely the business (information) system, takes a role in processing this emerging data asset to support the problem-solvers like managers in the decision-making process (Simon, 1973, 1996) and to establish so-called evidence-based management. Second is what might be changed at the organization level when the business (information) system is evolving to respond to the digital servitization trend. Three points of theoretical contributions are extracted from the iterative experiments (see Figure 13, corresponding to the (IT) artifacts as the demonstrators delivered to the practitioner

(see Figure 15)), reported in both articles 3 and 4 (section 5.1). The (IT) artifacts developed in the three experiments together respond to the research concerns about how IoT can be an enabler to enhance the business (information) system. The intention is to consolidate both the ERP data as representative of market insights from the business customers and IoT data as representative of market insights from the end-users, to extract a new layer of business insights to support managers on the decision-making toward digital servitization (Simon, 1973, 1996). They thus influence the long-term managerial perspective on how to conduct evidence-based management on the domain of the operational perspective of the digital servitization.

1. **The conflict behind the two heterogeneous datasets**
   In order to strengthen the back-office supporting system, namely the business information system, to consolidate the emerging IoT data, the author follows Winter's argument to examine the black-box model of the existing business system. The intention is to probe how data can "be used" in the system, from constructional and operational details, and to focus on how the system is used as a whole (Winter, 2019). In other words, it focuses on the functionalities of the system's structure, rather than on how the system is designed technically. In this study, the functional component of the business system, i.e., the ERP system, is the backbone of lean manufacturing. One of its primary functions is to handle the information that supports the logistics mission: to serve its business customers (e.g., business partners, dealers) with the right (soft) products in the right place at the right time. For that, goods-dominant (G-D) logic is adopted to manage the business transaction of the exchange value created between the focal firm and its business customers. However, to cope with the service type of value creation in the notion of economic exchange, the service-dominant (S-D) logic is applied to read the "value-in-use" message from the data. This fundamental element is missing in the case firm, which is strongly attached to the product-centric mindset (Chen et al., 2019). This attitude has been seen as the result of people's behavior, the operational processes (e.g., how and what data is extracted for what purpose and for whom), and the setup of the master data on the ERP system. There is no indication in the data to show how the smart products are used at the end-users' side. The data from the ERP system mainly presents the characteristics of goods and is used to record the business transaction of the exchange value (goods value for the B2B business model). However, the IoT data, in principle, indicates the functionality of the specific installed smart products on the end-user's side (which characterizes the end-user's type and how active the end-user is in using the installed smart product). This inconsistent way of addressing the master data creates an illusion. There is no data link between these two heterogeneous data sets, although in reality the domain specialists can manually recognize the business type of their end-users based on the attributes of the collected IoT data and the (non-written) characteristics of the smart products, which indicates the particular family model of the smart products. Thus, this additional layer of artificial data insights was created at the meta-level to consolidate the two heteregenous data sets between the ERP system and IoT platform.

Figure 18 demonstrates a clear example of how the G-D logic limits the consolidation of IoT data into the existing business system (B1 loop). It also (negatively) reinforces the situation where no available insights are extracted from the end-users' markets (R1 loop) and further (negatively) impacts on the managers' decision on what to change in the organization (R2 loop) toward servitization.

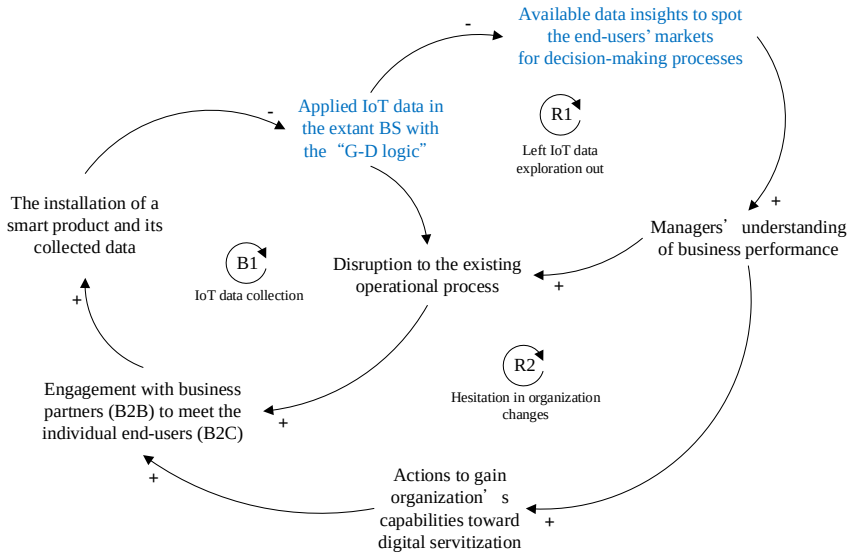


Figure 18. A causal loop diagram – a conflict in consolidating IoT data in the BS with the"G-D" logic and its further impact on the decision-making process.

2. The data-enabled evidence for the organizational changes

IoT is generally seen as one of the vital driving forces to facilitate the marketing perspective of digital servitization (Iansiti & Lakhani, 2014; Kohtamäki et al., 2019). This research, however, see IoT as the enabler also to drive forward the development of organizational changes. The theoretical argument is rooted in Ziaee Bigdeli et al.'s theoretical framework for organizational change toward servitization (Ziaee Bigdeli et al., 2017). They identify 25 levels of change factors from their systematic literature review and categorize them into three perspectives, the context, content, and process, which are significant influences on the development of organizational changes toward servitization. Through three iterative experiments on the ADR project (see article 4, section 5.1), some of the empirical evidence can be drawn out to endorse their theoretical argumentation, especially in the following impact areas shown in Table 6.

Table 6. A list of the impact areas when consolidating the IoT data to strengthen the back-office supporting system (Ziaee Bigdeli et al., 2017).

PERSPECTIVE	CONTENT				CONTEXT																PROCESS				
					Inner Context							*Outer Context*													
Level	Network Level	Corporate Level	Business Level	Functional Level	Structure	Culture	Power	Political Characteristics	Strategic Directions	Level of Trust	Stage of Board Dev. (Age)	Political	Economic	Social	Technological	Environmental	Industry	Regulation	Ownership Structure	Overall Risk	Models of Change	Start-end-Point	Role of Technology	Formulation/Implementation	Business Models
Impact areas				√	√	√									√						√		√		

In the initial stage of servitization, similar to the case firm, the IoT data is the most direct and valuable asset for the management team to use in understanding these untouched end-users' markets. Besides, this change (to consolidate the data set from the IoT platform and the ERP system) is initiated purely within the organization, which eliminates concern about hurting business customers/middle-men. It provides the first step of evidence-based management toward digital servitization. However, through hands-on experience, several impact areas are observed in the conflicts (see Table 6) provoked by changes hidden in the mindset. In order to develop the consolidated dataset, S-D logic/service thinking needs to be adopted to enhance the functionality of the business system (see point 1 above). Thus, extra communication and coordination are required to establish new working processes and patterns among the stakeholders (Chen et al., 2020). In regard to the change process, the PSP BI intervention provides managers with evidence-based business insights. With the data-base business insights, they are able to rethink how to take up a rational tactical plan to approach the most potential business customers and end-users for the digital service business. This learning style is coherent with Mintzberg's and Westley's "mindless change process" of the organizational change model (Mintzberg & Westley, 1992). The procedural planning comes from the iterative learning experience amidst the chaos. In this case, the managers and servitization stakeholders learn what next moves to take from the iterative cooperation and communication when referencing the explorative PSP BI (and its dataset) to perform the servitization-related tasks.

3. An effect of adopting a data-driven approach toward digital servitization

In this case, the potential theoretical knowledge is derived from a series of (building and evaluating stages of) interactions with the stakeholders (see articles 3 and 4, section 5.1), which the altered (IT) artifacts are used as the interventions to induce the causality. The deliverables in the Gamma phase as the interventions

– PSP, the consolidated dataset, PSP BI – are used for two purposes. First, as a practical solution, they are used to demonstrate the feasibility of improving the problematic context. Second, they are as a means to engage with stakeholders (during the building, implementing, and evaluation phases) to investigate how the problematic situation changes, what practical methods applied to apply what might be changed inside the organization, and what managerial benefits there are to having those new interventions as a means to conduct the servitization development. Figure 19 illustrates how a data-driven approach (R1 loop) is constrained from the G-D logic of the business system (B1 loop) and further limits the possibility of having a concrete action plan to engage with both business customers and end-users (R2 loop).

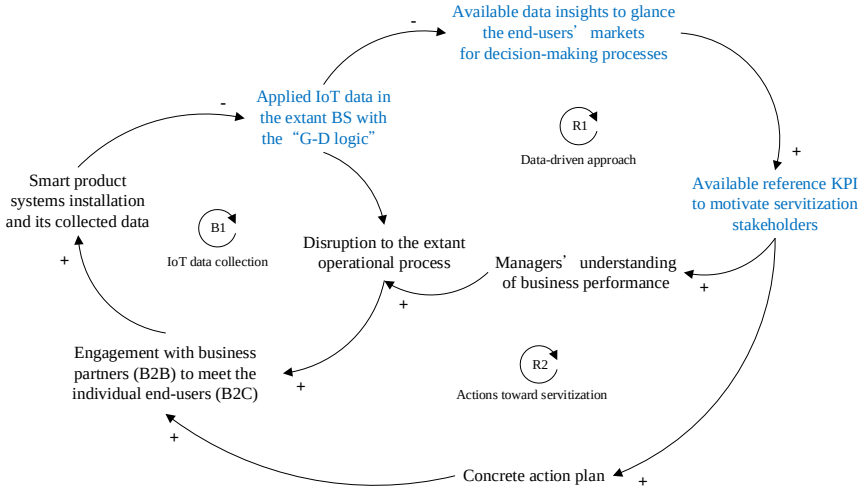


Figure 19. A causal loop diagram, showing how IoT data creates an impact on servitization development.

In summary, this section presents three theoretical contributions to respond to the research concerns, raising from section 4.1 – the phenomenon of interest: 1) the conflict behind the two heterogeneous datasets, 2) the data-enabled evidence for the organizational changes, and 3) the effect of adopting a data-driven approach toward digital servitization. All three together answer the research concerns about how IoT can be an enabler to influence the operational perspective of the digital servitization.

5.3. EMERGING CHALLENGES TO MANAGERS

This section depicts the transformation challenges to managers toward the digital servitization paradigm, especially focused on this particular concern when IoT data is seen as an enabler for the development of the operations in the organization's perspective (see Figure 7, section 4.1.). The challenge here is to balance the intrusive strategic changes from top-down and the infusive process changes from bottom-up (Mintzberg & Westley, 1992). Similar to installed-base servitizing, one of the major challenges in transforming a product-centric manufacturing firm toward becoming a digital service (advanced service) provider is to require it to be cultivated with a service culture (Gebauer et al., 2010; Oliva & Kallenberg, 2003; Story et al., 2017) inside the organization. Without this element placed concretely in the organizational state, people often find contradictions in their actions and, therefore, further reduce their performance in the systems, thus slowing down the transformation. This observation is not hard to find in previous works (Chen et al., 2020, 2018; Chen & Møller, 2019). Six areas are identified that directly impact the operational perspective of digital servitization when the implementation of IoT is seen as an enabler (see Table 6).

Duplicate of Table 6. A list of the impact areas when consolidating the IoT data to strengthen the back-office supporting system (Ziaee Bigdeli et al., 2017).

PERSPECTIVE	CONTENT				CONTEXT																	PROCESS				
Level					*Inner Context*							*Outer Context*														
	Network Level	Corporate Level	Business Level	Functional Level	Structure	Culture	Power	Political Characteristics	Strategic Directions	Level of Trust	Stage of Board Dev. (Age)	Political	Economic	Social	Technological	Environmental	Industry	Regulation	Ownership Structure	Overall Risk	Models of Change	Start-end-Point	Role of Technology	Formulation/Implementation	Business Models
Impact areas				√	√	√									√						√		√		

Initially, the conflicts occurred when the top management has thought of imposing the service-domain logic (Lusch et al., 2007) on the product business and the existing organization. This originates from applying the implementation of IoT to develop a more competitive digital service that can be used to engage with the end-users. However, this rough decision leads to conflicts in communication, in seeking capable employees, in beliefs, and many more (see section 3.1).

Managers, in general, struggle to find an internal balance in three aspects: 1) self-centric (expert-led) vs. diversity (embraced polymath), 2) partnership vs. digital, 3) rigid vs. flexible systems.

The first struggle is revealed when the managers consider going after digital business. They soon realize that designing the digital service is only the first step in committing to this crusade. There are many more obstacles involved in offering an attractive and value-adding digital service to the market. Articles 1 and 2 (see section 3.1) presented a summary of those points of struggle. One of the first setbacks the interviewers mentioned was that their "used-to" working process is somehow not working in this transition status (Chen et al., 2018). Instead of applying their expertise to resolve the tasks on hand and passing it on to the next team, they assume that more comprehensive information could be provided by other teams in order to deal with the tasks. This phenomenon was discovered in R&D, HR, Sales, and Global service. All the managers replied that they needed more precise information to perform the task better. This created tensions within the organization and raised the second thoughts about going after the digital business. The first change happened during the innovation workshop, with the first cross-functional dialogues. The small circle of the servitization team realized the power of sharing their expertise. Embracing the diversities of knowledge from cross-functional teams, they created an innovative concept of digital service. However, this step forward only overcame the first obstacle – to have a sound, value-adding digital service concept to develop for the end-users.

This soon brought out the second concern, coming from the sales section. During the earlier interviews (see Article 1 and 2), the author found a conflict of beliefs – partnership vs. digital. On the one hand, executive officers see the benefit of employing the digital service for the future business, seeing that they are able to create a digital connection with their end-users and have a more steady and independent second revenue stream (Dinges et al., 2015). On the other hand, the middle managers believe that their successful business relies on the partnership with business customers, even though they are doing the box-selling. Some of the interviewees pinpointed their concerns about damaging the relationship with the business customers if there was no carefully throughout tactical plan to handle this change toward downstream end-users. Without a clear tactical plan and evidence of benefits, it was hard to unify the sales team to get on board to move the business in the same direction. In consequence, "*impromptu, for now, is the best approach to deal with servitization tasks", was* one feedback received from the interviews.

In addition to those two internal conflicts, managers face an even greater impediment within the firm. The existing organization platform and processes are not suitable for evaluating the progress of servitization development. The whole business system and its structure work well to support the product business, e.g., product development and logistic tasks. The waterfall (project management) process created a controlled gate to evaluate the quality and cost–benefit of the product design and product delivery. However, this process is not fit for non-material design and unclear market conditions of the newly developing digital services. There is no concrete benefit to evaluate, but there is a cost. So, how rigidly should managers follow the existing processes of the business system? Or should they rethink how to establish a more flexible system in which it is possible to sense the progress of digital servitization development, meaning the collaboration of cross-functional teams?

In summary, the fundamental issue of these three managerial challenges that occurred in the initial stage of the digital servitization is still in the domain of communication and the transparency of the information flow. Top managers go for intrusive strategic changes when there is not enough communication within the organization to prepare employees for doing things differently. Besides, there is no information that shows sound reasoning for going directly to the end-users without hurting the business partners. Thus, all three managerial challenges: 1) self-centric (expert-led) vs. diversity (embraced polymath), 2) partnership vs. digital, 3) rigid vs. flexible systems, slow down the development of the digital servitization even further. The management team, in general, is fighting for an internal balance between top-down strategic changes and bottom-up process changes, while pushing to develop a value-adding digital service offering for the market.

5.4. A FOUR-STEP MODEL OF THE DATA-DRIVEN APPROACH

This section aims to respond to the research objective – *to establish a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management.* This research project is progressing under a dynamic environment, which is associated with the diverse voices of transforming the organization toward digital-enabled servitization. Through the three ADR engagement phases, the author is able to unfold the constraining circumstances (where the operational environment is unknown, and stakeholders also hesitate to take the next moves) bit by bit. The altered versions of the (IT) artifacts are used as the intervention to explore part of the ill-structured problem, its causality, and a possible response mechanism. Thus, the understanding of this complex situation is also improved when the author retrospectively analyzes this research.

There are two building blocks to decompose this ill-structured problem. First, the operational issue is the degree to which the back-office supporting system needs to be reformed in order to support the new vision – to expand the business focus toward a digital service (advanced service) business. The abstraction of this concept is presented in Figure 20. The intention is to restore the back-office supporting system, to be able to sense changes in the external environment, and explore new valuable business information and insights into the long-term memory area. In this case, it is necessary to embody the understanding of the "product-in-use" status from the end-users' markets. IoT data as the harbinger is consolidated with the ERP data to create a panorama of "product-in-use" notions. Here, additional digital data traces were constructed by applying the S-D logic to digitalize the domain-experts' knowledge as the bridge in the data meta-level. Article 3 (see section 5.1) presents the full engineering content of this concept, and a part of Article 4 (see section 5.1) validates this instantiation in practice, together with its impact on the organizational transformation.

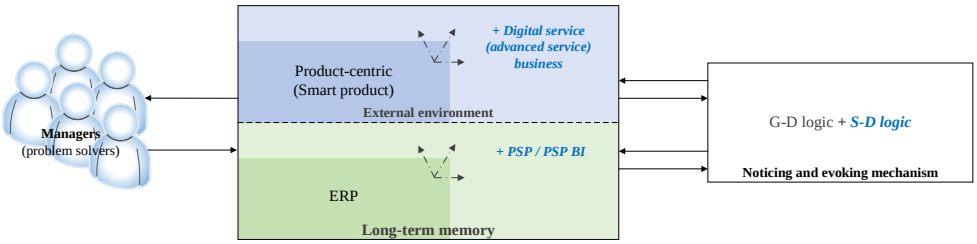


Figure 20. The abstraction of the back-office supporting system toward digital servitization (adapted from the schematic diagram of a system for ill-structured problems (Simon, 1973)).

Second, the managerial issue is how to adopt data as an enabler to conduct evidence-based management toward the digital servitization paradigm. Figure 21 illustrates the abstraction of the managerial mechanism to conduct evidence-based management toward the digital servitization. The restoration of the back-office supporting system (Figure 20) supports managers in the retrieval of product-in-use business information and insights. The continuing practice of this system provides a platform where managers learn how to deal with this dynamic transformation situation together with the servitization stakeholders in the back-office.

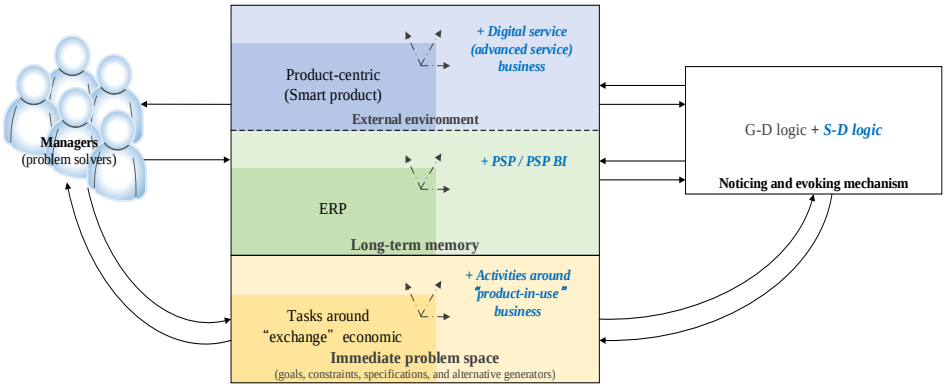


Figure 21. The abstraction of the managerial mechanism to conduct evidence-based management toward the digital servitization (adapted from the schematic diagram of a system for ill-structured problems (Simon, 1973)).

In principle, these changes in the two development stages of the mechanism represent the two stages of organizational changes toward digital servitization. The first stage (Figure 20) is to restructure the back-office supporting system for a particular scenario of the transformation issue, where the data is seen as an enabler to initiate the organizational transformation. In addition, the challenges of digital servitization that managers deal with (Figure 21) are in a general case, in which managers seek supportive information from the back-office supporting system. The repeating processes serve to revise the corresponding operational processes in the problem space.

On the one hand, the former development intends to use the consolidated data to prompt short-term and reversible feedbacks at the organization level. Changes thus have to be carried out to reform this new back-office supporting system on a concrete level—for example, the construction of the meta-data, the product-service platform, and the product-service platform BI. As time goes by, servitization task stakeholders learn from the pattern of coordination and communication and reform the best-fitting operational processes. Eventually, the new patterns revise the conceptual level of organizational structure and culture.

On the other hand, the general case aims to create a more or less permanent learning effect to steer the transformation direction toward digital servitization. The data-enabled notion can be seen as the reference key performance indicator (KPI), according to the empirical evaluation (in Article 4). It serves to reshape the managers' understanding of the end-users' markets. Only in this way can they take corresponding actions to engage with business customers and end-users to gain the business growth from their smart products and digital services. Figure 22 visualizes this data-driven mechanism.

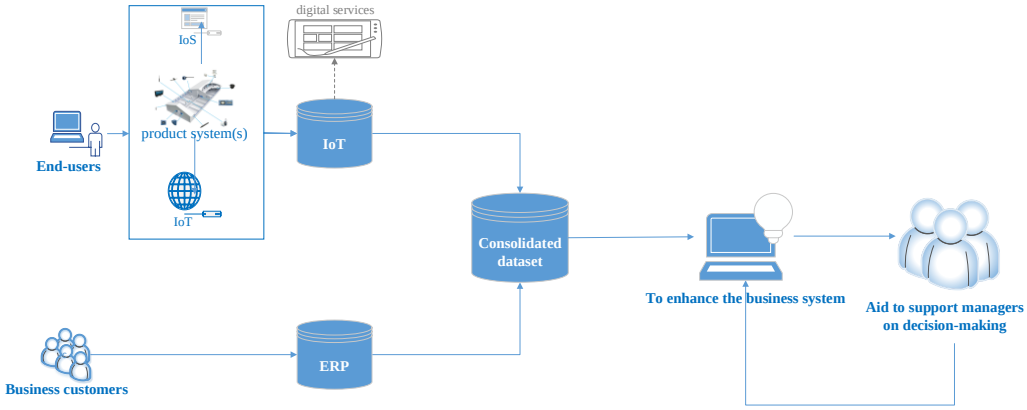


Figure 22. The conceptual view of the data-driven mechanism (adapted from(Chen et al., 2020)).

To extract the lessons learned from this experimental research, the author proposes a four-step model of a data-driven approach to aid managers to overcome the stage of struggling (Mintzberg & Westley, 1992) to transform the organization toward digital servitization. It is specifically applied to the transformation journey, where end-users' data is available to be consolidated with the ERP system. By doing so, managers can probe and combine the understanding of the two fragments of market insights.

According to the experiment feedback from the sub-research project (see article 4, section 5.1), the explorative business insights indicate the potential digital service's market. This can be employed as a reference KPI to establish a short-term position and vision for servitization stakeholders to pursue afterward (step 1). In addition to

the first step, managers are able to set up more actions, such as tactical programs and interactive facilities, to strive for the desired goals (step 2). Through executing the defined programs on the setup facilities, managers can engage more people to work on these goals and gradually realized what to change in the inertial (organizational) system (step 3). This progressively reshapes the culture and organizational structure through iterative executions (step 4). Figure 23 illustrates the four-step model of the data-driven approach. Its goal is to aid managers to overcome the stage of struggle and kick off on a learning journey by setting up the leading indicators (Kaplan & Norton, 1996).

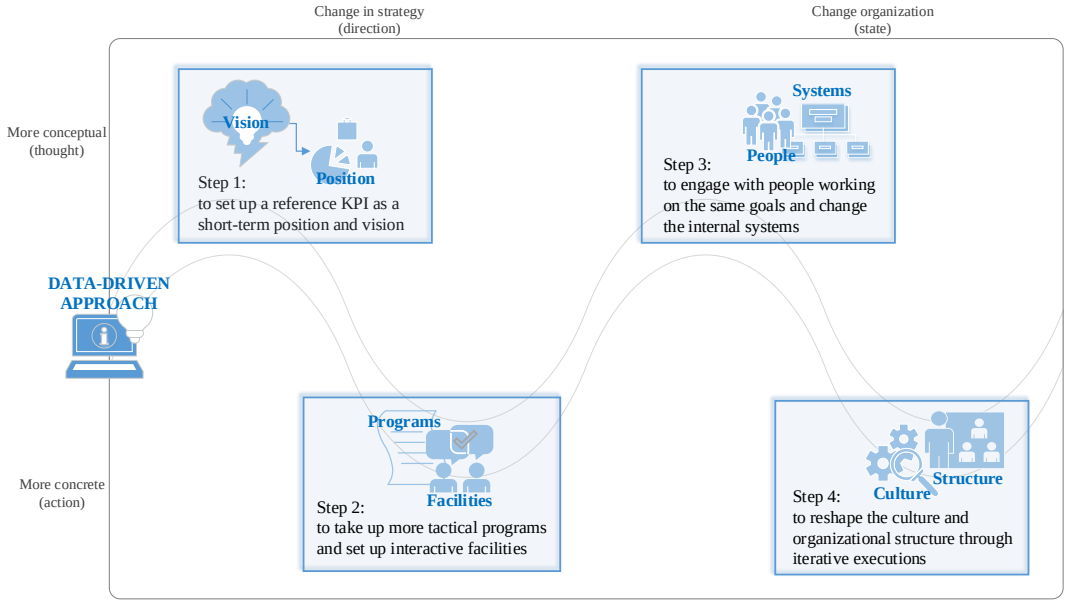


Figure 23. A four-step model of the data-driven approach
(adapted from Mintzberg and Westley's contents of organized change (Mintzberg & Westley, 1992)).

To some extent, the organizational changes in this approach are no longer limited to the technical aspect. There is quite a significant extension to social- considerations as well. The technical- initial aspect can support the shift on the conceptual level, such as the vision and system, but not change the concrete level down to the social level, such as the culture and people. This data-driven approach is built upon the argument of Mintzberg's and Westley's research. They claimed that the complete outlook of the organizational changes is developed under a two (thought, action) by two (state, direction) matrix and composed of eight essential elements (Mintzberg & Westley, 1992). The results of organizational changes will then be reflected in changes in the organization (state) and changes in the strategy (direction).

In a nutshell, this systematic methodology is associated with the changes on two levels. One is more dedicated to provoking long-term effects on the conceptual

perception, such as culture, vision, etc. The other one works on the concrete level of organizational changes in revising the back-office supporting system (see prerequisite 3, Figure 5), which is seen as the particular scenario of the digital servitization. With the available data and explorative business insights to hand, managers are able to set up leading indicators (Kaplan & Norton, 1996) to drive the organizational changes and use these internal forces to pursue the potential markets for digital services as well as to develop digital servitization. The research contributions aim to shed light on the operational aspect of digital servitization as well as the organization's transformation domain.

5.4.1. RESEARCH IMPLICATIONS OF THIS FOUR-STEP MODEL OF THE DATA-DRIVEN APPROACH

In this section, research implications will be drawn to respond to the phenomenon of interest set in section 4.1 of this thesis.

Instead of taking the mainstream of servitization research to investigate the business concern with implementing IoT technology, this research probes into the operational perspective of servitization. Systems thinking (Ackoff et al., 2010; Checkland & Poulter, 2010) is adopted as a lens to examine how the implementation of the IoT technology might impact a product-centric manufacturing firm's back-office supporting system (see Figure 7, section 4.1). The intention is to establish a systematic methodology that can restore the organization's back-office supporting system, namely the business (information) system, to support problem-solvers like managers in the decision-making (Simon, 1973, 1996) toward evidence-based management.

The four-step model of the data-driven approach is extracted from the lessons learned from the three iterative ADR experiments and semi-structured interviews with managers. In these, IT and the exploration of the consolidated data (from, e.g., PSP BI) are seen as the mediator to mitigate two main obstacles – the transparency of the information flow and communication of the managerial challenges that occurred in the initial stage of the digital servitization. The advantage of adopting IT and data in this approach is to virtualize the intangible desired goals, which aid in facilitating the communication across departments and with customers. This brings the two benefits to the domains of servitization and organization.

First, it creates an initial foundation for managers to practice evidence-based management again by continuously applying the traditional performance measurement approach – the principle of the balanced scorecard (Kaplan & Norton, 1996). This time, however, the measurement is based on the leading indicators (e.g., the installed and in-use smart product as an indication of the potential markets for the digital business), and the goal is to shorten the development cost of pursuing the potential markets over time. By doing so, this data-driven approach can mitigate the transformation challenges within the firm, such as cultural inertia (Story et al., 2017),

a lack of information transparency, and a need for more comprehensive project management (West et al., 2018) that scholars identified in the previous case studies.

The second benefit is to develop a long-term perspective regarding the research topics on the efficiency of the growth agenda in the manufacturing firms (Björkdahl, 2020; McGrath, Rita & McManus, 2020). This data-driven approach can serve as a learning platform to support this research stream. Here, it leverages the first benefit above: "*you can not manage what you can not measure"* (Kaplan & Norton, 1992). With this layer of visualizing the goal, managers are able to gradually measure their business excellence by exercising the disciplines of building a shared vision, establishing systems thinking, creating team learning (Senge, 2006), and constructing an innovative learning organization (Senge, 1997).

CHAPTER 6. DISCUSSION

This chapter presents the research reflection of this longitudinal study. Three main learning focuses are on the design research process, the research context, and the research contributions. Thus, the discussion extends from the narrow perspective of developing the (IT) artifacts as interventions embedded in the business (information) system and the organization to the managerial concerns of transforming the organization toward digital servitization.

The purpose of this chapter is to reflect on the theoretical contributions on the research processes (chapter 4), digital servitization as an ill-structured problem (Chapter 3), and the research content (Chapter 5). These will be addressed in section 6.1 – evidence-based practice research, section 6.2 – data-enabled organizational development of digital servitization, and section 6.3 – implications for practitioners.

Design science was employed as the principle for two purposes. First, it serves to connect the problematic situations, the knowledge bases, and the solution space (Checkland & Poulter, 2010; Hevner et al., 2004). Also, it evaluates the importance of using the intervention research form (Oliva, 2019; Van de Ven, 2007) in social science research. The intention in employing intervention research as the research strategy (section 4.2) was to adopt an engaged approach with practitioners and to observe what could be changed and how to advance the existing knowledge bases from the development process in order to reach the desired status S' from S (see Figure 8). In this thesis, S' is a manufacturing firm that is embarking on a digital servitization journey toward being a smart, connected product provider. For this, this research tries to answer questions such as How do we get there? Why do we want to get there? to respond to the problematic space between S and S' (indicated with the green arrows). Figure 24 presents the conceptual overview of the intervention research of this thesis.

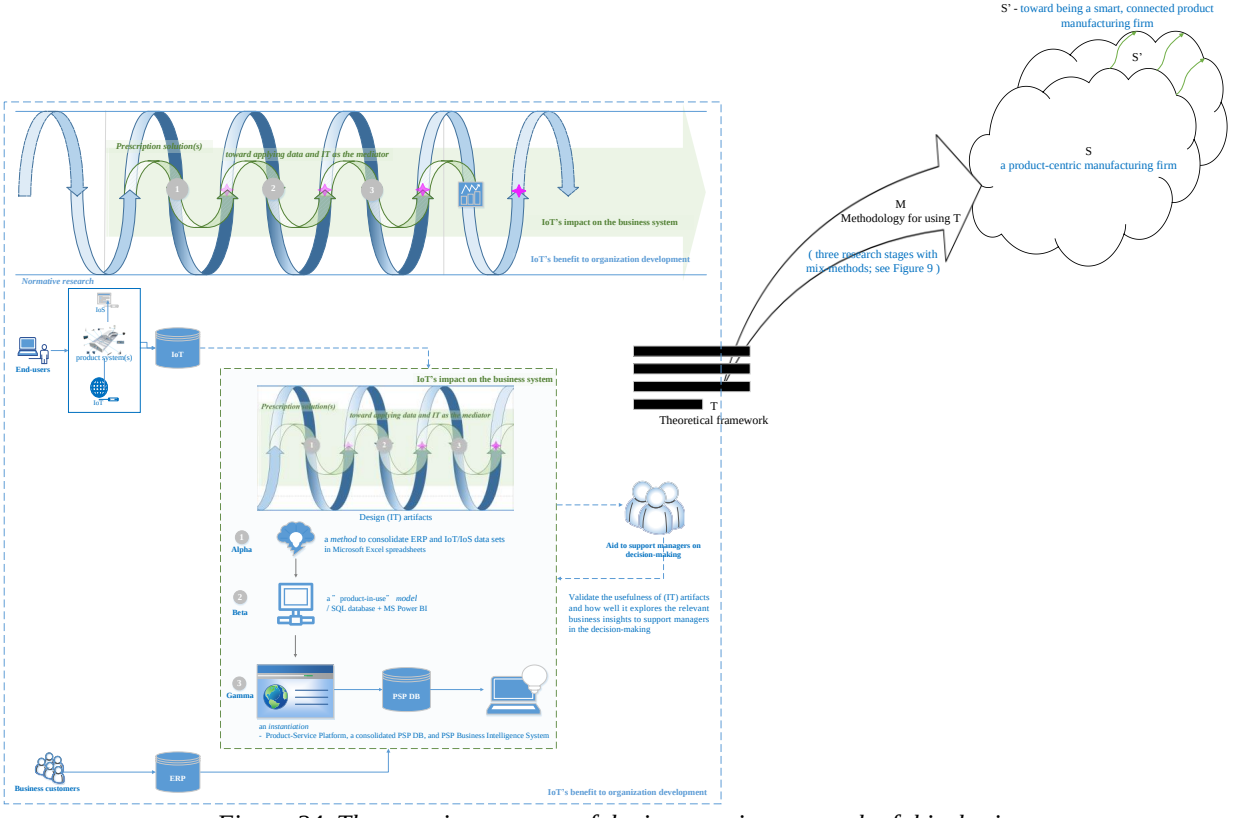
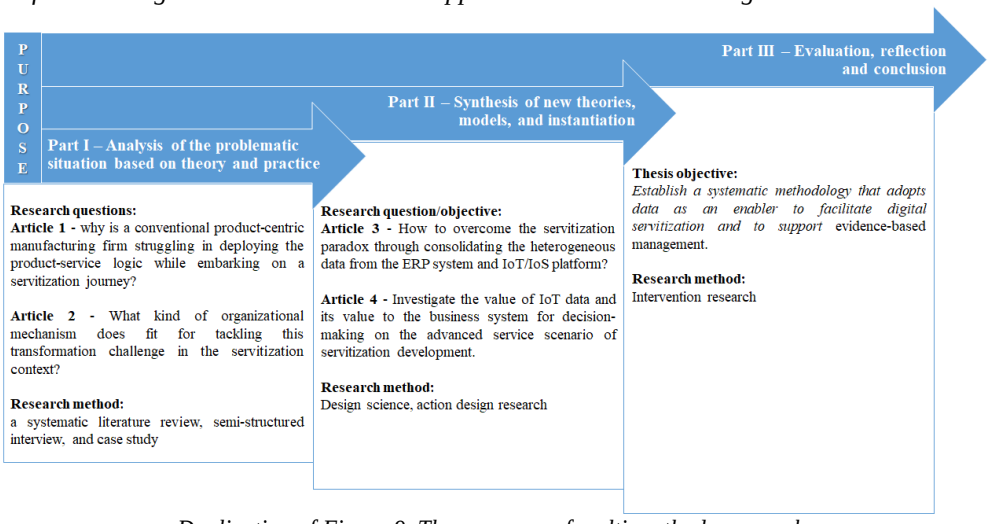


Figure 24. The overview concept of the intervention research of this thesis , adapted from (Oliva, 2019).

Multi-methods (see Figure 9) were designed to carry out the three research stages in the two layers of the research processes (see Figure 10, section 4.2.2). Each stage had specific research questions and contributions, which together respond to the thesis objective to e*stablish a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management.*



Duplication of Figure 9. The summary of multi-methods research.

Besides, a collective engineering approach was taken to deliver the (IT) artifacts to the practitioner (see the green rectangle of Figure 15, Chapter 5). Here, in the Gamma phase, a fitted IT artifact composed of three elements: 1) a minimal viable product prototype (MVP) of the PSP, 2) its consolidated database, and 3) an MVP PSP business intelligence system (BI), developed from the PSP consolidated database, is developed to explore the business insights of the two discrete markets (from the business customers and end-users). From this, these (IT) artifacts are seen as interventions to engage with participants to examine the defined research gap and research objective (section 4.1). Therefore, three perspectives of analysis, namely the impact of IoT and its implementation on the organization (section 5.2), the managerial challenges (section 5.3), and a data-driven approach model (section 5.4), are extracted from the iterations of the experimental engagements with the participants.

Venable et al.'s evaluation strategy framework (see Figure 11, section 4.2.4) is applied to evaluate the fit of the defined research methods, research processes, and the theoretical contributions of each stage and this thesis. There are five steps in the evaluation processes (see Table 4) applied in this Ph.D. research.

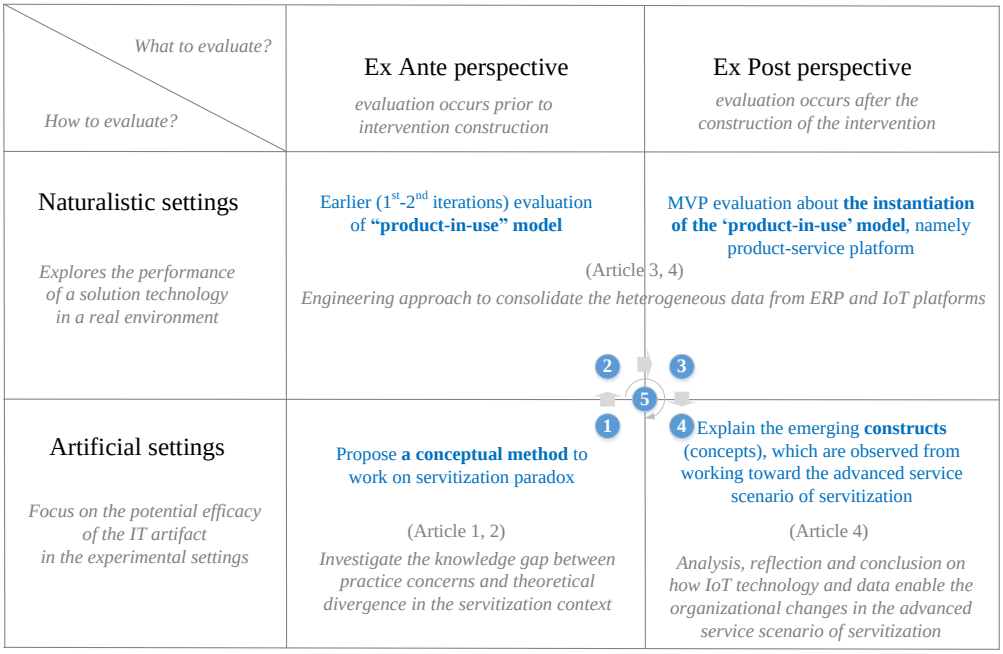
Duplication of Table 4 - A summary of the evaluated objectives, the applied methods, and research projects.

Criteria \ Steps	1	2	3	4	5
What is actually evaluated	A **conceptual method** to work on servitization paradox / design process	A **"product-in-use" model** to consolidate the heterogeneous data, retrieved from ERP and IoT platforms / design product	An **instantiation of the "product-in-use" model** to carry the explorative information regarding the potential markets of product-service business / design product	Emerging **constructs**, observing from working toward the advanced service scenario of servitization / design process	A **systematic methodology** that adopts data as an enabler to facilitate digital servitization and to support evidence-based management / design process
When evaluation takes place	Ex Ante	Ex Ante	Ex Post	Ex Post	Ex Ante
How it is evaluated	Artificial / real problem	Naturalistic / real users and stakeholders	Naturalistic / real users and stakeholders	Artificial / real organization system	Artificial / field experiment
Methods	Case study	Design science research	Action design research		Intervention research
Research projects	Article 1 and 2	Article 3	Article 4		Thesis

The conceptual method used to work on the servitization paradox (step 1) and the design process are proposed and validated through the case studies in articles 1 and 2. The concrete idea of designing and developing the "product-in-use" model (step 2) is illustrated and validated with the design science research method in article 3. In addition, the design product of the instantiation of the "product-in-use" model (step 3), and its developed constructs (step 4), observed through the ADR processes, are presented and validated in article 4. Lastly, the evaluation of the systematic methodology (step 5), which adopts data as an enabler to facilitate digital servitization and to support evidence-based management, will be discussed in section 6.1, which focuses on the ensemble rigor and relevance of this Ph.D. research as a whole. Furthermore, the data-enabled organizational development of digital servitization is presented in section 6.2, and the implications for practitioners are delineated in section 6.3.

6.1. EVIDENCE-BASED PRACTICE RESEARCH

This section presents the synthesis of the evaluation process in terms of how the design research processes fit each stage of the defined research objective and its contexts, as well as the whole research project. Venable et al.'s evaluation strategy framework (see Figure 11) is applied to present a panorama of the evaluation processes of this thesis and its sub-researches. There are five steps to evaluate each stage of the research deliverables in the two-by-two matrix (Pries-Heje et al., 2008; Venable et al., 2012).



Duplication of Figure 11. A strategic DSR evaluation framework

(adapted from (Pries-Heje et al., 2008; Venable et al., 2012).

The primary investigation element of this research is focused on the emerging IoT data and its benefits to the development of digital servitization. It also impacts the goal of the research evaluation. In this case, the goal of each sub-experiment and the deliverable (IT) artifacts is to validate their efficacy (rigor) and effectiveness. The former criterion is to validate "the degree to which the artifact produces its desired effect to consider narrowly the defined problematic situation" (Venable et al., 2012). The narrow aspect here is to provide useful information to support managers in their decision-making toward digital servitization. The latter is to validate "the degree to which the artifact meets its higher-level purpose or goal and achieves its desired benefit in practice" (Venable et al., 2012). In other words, it means producing the benefit of driving the development of digital servitization.

So, the initial investigation began in the artificial setting of the ex ante perspective. In this first quadrant, the knowledge gap between practice concerns and theoretical divergence in the servitization context was investigated in the case study. Article 1 presents the three theoretical propositions and the eight managerial propositions to the practitioners (see section 3.1). One particular concern that both scholars and the interviewed managers discussed often is the phenomenon of the servitization paradox. According to the inputs from the semi-structured interviews with the managers, they understood the importance of working on creating a second revenue stream from the digital services (toward an advanced service business), but they did not have any

reference on how to manage this transformation and what to do the right things to get the internal people on board and to engage with both business customers and end-users. There was no information to support the managers in decision-making toward digital servitization. Thus, the goal at this initial stage was to understand the problematic situations and the available knowledge bases in both the empirical environment and the theoretical domains in order to work on the solution space. In this stage, the design process as a conceptual method was delivered. It was intended to cope with the servitization paradox. Thus, it was further materialized in the Microsoft Excel spreadsheet to engage the servitization stakeholders in the firm. The efficacy (rigor) and effectiveness of the presented information were examined in the practice of setting up the initial business plan, which the business developer used to pitch a high-level servitization tactic plan to executive officers. This earlier engagement created the first trial run to connect the problematic situations, the knowledge bases, and the solution space (Checkland, 2000; Hevner et al., 2004).

In the second and third quadrants, the evaluation setup moves away from the artificial setting to the naturalistic setting. The essence of adopting the data-enabled servitization from the conceptual method was carried out through the second and third iterations of the experiments (see article 4, section 5.1). Two versions of three product artifacts were delivered and tested in these two quadrants. The "product-in-use" model was extracted from the first-hand iterative experiments when building the altered version of the testing model and an instantiation together with the servitization stakeholders within the case firm. The direct servitization stakeholders were involved in examining the two design and implementation perspectives. The design aspect was to refine the efficacy (rigor) and efficiency of the design interventions – PSP, consolidated dataset, and PSP BI. The implementation aspect was to evaluate the feasibility and usefulness in practice.

In addition, the semi-structured interviews were used as the examination points to verify the presented information to support the managers in decision-making to facilitate digital servitization. The interviews are used in the fourth quadrant to examine the efficacy (rigor) and effectiveness of the emerging constructs, which were extracted from the development processes of the three iterations and the managerial inputs from the semi-structured interviews (see article 4, section 5.1). In this fourth quadrant, the emerging constructs addressed what might be changed and how in the organization's content and process levels when this data-driven method is used to aid managers in decision-making toward digital servitization. This was carried out in the fourth quadrant in the artificial setting and examined with the ex post perspective.

All four quadrants of the evaluation processes created a reliable scientific experiment to respond to the defined research concerns, addressed in section 4.1. The iterative development processes refined the rigor and relevance among the concerns of the three DS domains, namely the environment, the knowledge bases, and the solution space (Hevner et al., 2004).

The last step of the evaluation process was to take this research as a whole and examine with the practitioners how this data-driven approach enables managers to facilitate digital servitization and to support evidence-based management. So, the iterative development processes and the empirical deliverables and their impact were summarized and presented to the managers and their responses were received in the last semi-structured interviews (see Table 3, section 4.2.3). The intention was to evaluate both the efficacy (rigor) and effectiveness of the changes in the business (information) system at the organization level and the presented information to support the managers in decision-making to facilitate digital servitization. The four-step model of the data-driven approach (section 5.4) was extracted from the iterative experiments as well as the evaluation interviews to respond to the research objective – to establish a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management. Figure 25 presents an overview of the evaluation steps and the associated empirical deliverables as the interventions. A summary of the evaluation results of the research contributions is presented in Table 7.

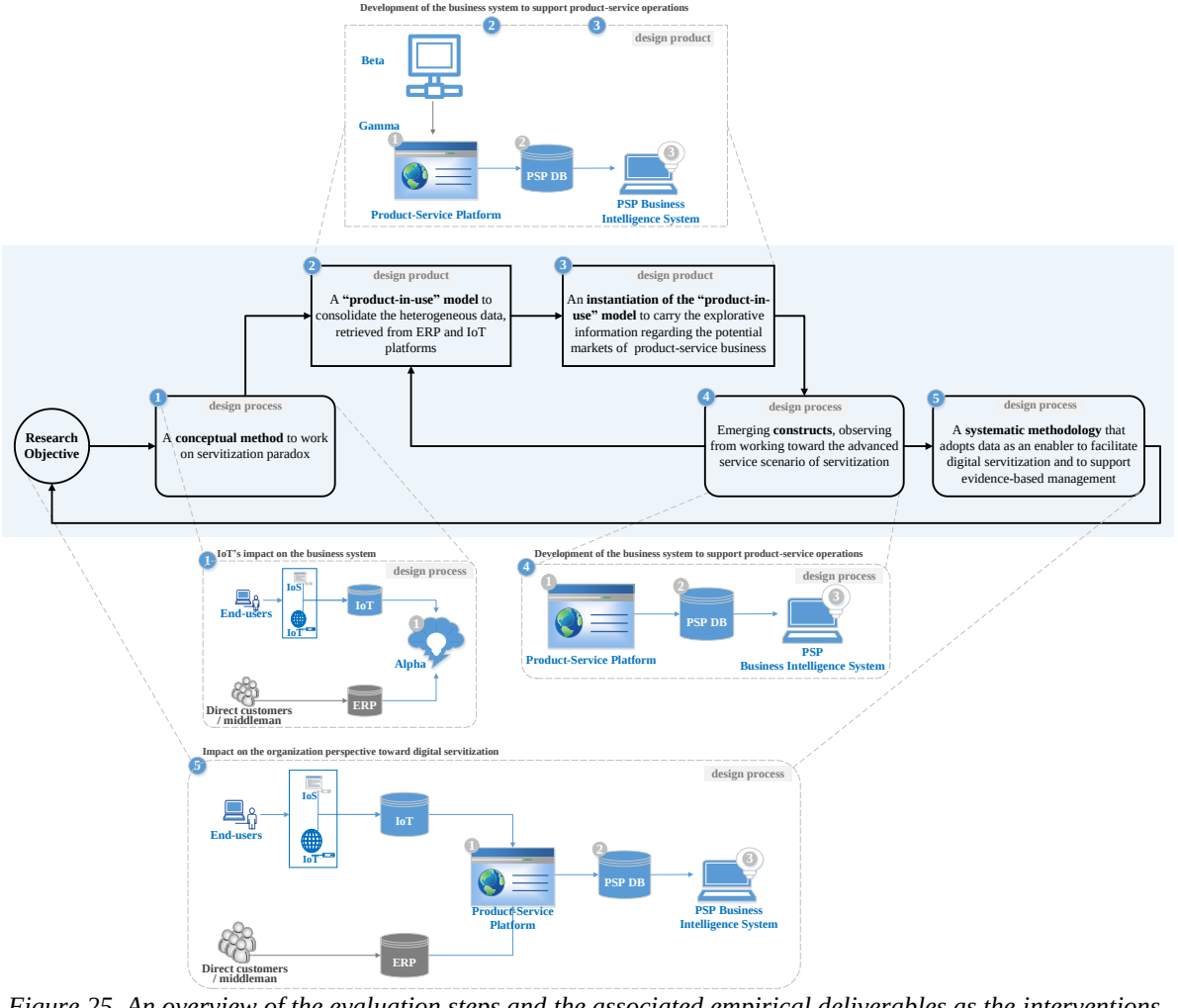


Figure 25. An overview of the evaluation steps and the associated empirical deliverables as the interventions.

Table 7. Summary of the evaluation results of the research contributions.

Evaluation Steps	Design Process or Product	Contribution Types	Knowledge Contribution	Λ – Prescriptive knowledge (how / the set of artifacts)	Criteria	Ω – Descriptive knowledge (what / the empirical evaluation results)
1 (article 1, 2)	Process	Level 2	Exaptation	Method	Efficacy (rigor) and effectiveness	The extraction of the business value-adding information from applying the design method was used to set up the initial business plan, which the business developer used to pitch a high-level servitization tactical plan to executive officers.
2 (article 3, 4)	Product	Level 2		Model	Design - efficacy (rigor), and efficiency Implementation - feasibility, and usefulness	The IoT data was consolidated with the geographic data from the ERP system and benefited the most installed base business.
3 (article 3, 4)		Level 1		Instantiations		IoT data can be consolidated with the family group of the smart product in the meta-level when the service-dominant (S-D) logic is adopted to explore both heterogeneous data sets. Further, the explorative business insight indicated the potential markets for the digital service, and is used to support managers in forming the tactical plan in the sales team.
4 (article 4)	Process	Level 2		Constructs	Efficacy (rigor) and effectiveness	The adoption of the service-dominant (S-D) logic provides a new logic to stimulate the cross-functional teams' communication. It provides a high-level purpose on why and what stakeholders need to do things differently. Furthermore, they take a trial-and-error approach to work on how it might be changed in the organization's content and process levels when this data-driven method is used to evaluate the baseline of the potential performance toward digital service markets.
5 (thesis)	Process	Level 3		A four-step model of the data-driven approach	Efficacy (rigor) and effectiveness	- Emerging challenges - Managerial propositions (extending the knowledge in the problem)

In summary, this research employed the design science principle (Hevner et al., 2004) to demonstrate a case of evidence-based practice research (van Aken & Romme, 2012) in the servitization body of knowledge as well as the organization's transformation domain. The research process was extracted from the first-hand experience of the designed research process (see Figure 13, Chapter 4). The three circles – the problematic situations, the knowledge bases, and the solution space – represents the collective interests between researchers (R) and practitioners (P) (Checkland, 2000; Hevner et al., 2004). The iterative and the theory-laden experiments (Checkland, 1985) creates a positive loop (among the three circles) in having reflective actions (observations from the participant-observer perspective) to leverage for theoretical development (Oliva, 2019) back to the knowledge bases circle. In addition, the research objective (RO) is defined by the researchers from the collective interest, which is used as the goal to drive the theoretical development and move the empirical collaboration forward. An applicable solution emerges to improve the practice situation of concern to the practitioners. The emphasis of this collective process is to engage with practitioners in the three activity stages (Sein et al., 2011). First, both practitioners (P) and researchers (R) co-define the phenomenon of interest in the investigation stage, which gives a concrete grounding to emphasize the relevance and rigor to turn practice-based evidence into evidence-based practice research (van Aken & Romme, 2012). Second, the researchers probe into the knowledge bases and propose a soundly-applicable idea to co-develop an engineering solution with practitioners in the building stage. This creates a learning platform for both to gain first-hand experience of the iterative experiments. According to Mintzberg and Westley, all changes begin with learning (Mintzberg & Westley, 1992). In this case, the learning happened in the development processes of building the (IT) artifacts as interventions – PSP, consolidated dataset, PSP BI – and attempting to change parts of the actual setup. In addition, the learning also came from the validation of the efficacy (rigor) and effectiveness of the presented information to support the managers in decision-making to facilitate digital servitization, the effectiveness of the changes in the business (information) system at the organization level, and the efficacy of the design interventions – PSP, consolidated dataset, PSP BI. All benefit both practitioners (P) and researchers (R).

Lastly, the two parties also co-observe the changes in the organization setup, operational processes, and even the personal mindset for reaching the desired situation (S') in the evaluation stage. This reflection process creates a new understanding of how, why, and what is needed to achieve the defined research objective. Here, the researchers explain this new layer of understandings from their first-hand participation and observations back to the knowledge bases to satisfy the research intention of carrying out the exploratory research (Holmström et al., 2009). Figure 26 summarizes the research process conducted in this Ph.D. project.

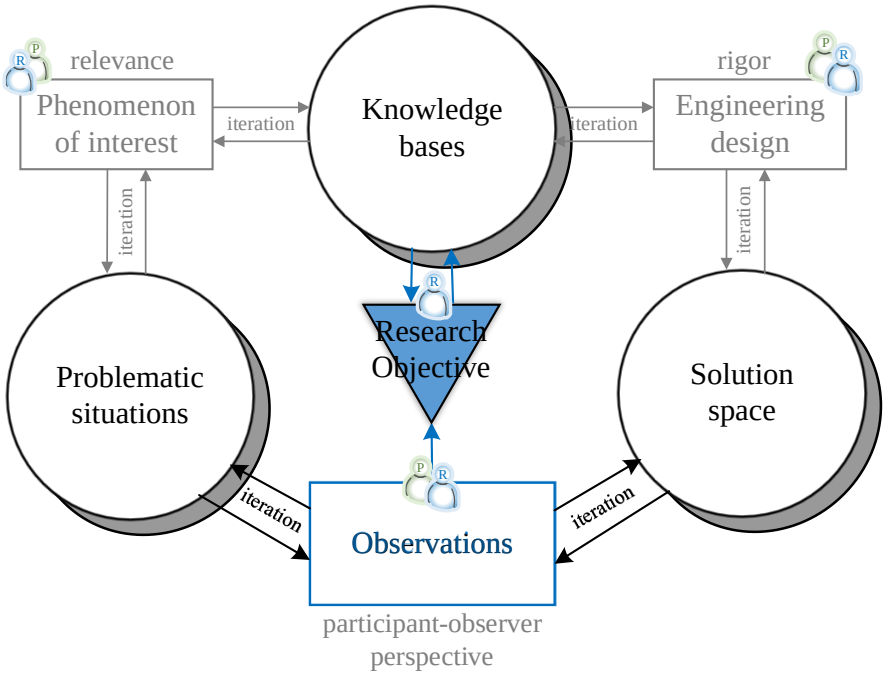


Figure 26. The collective research process.

6.2. DATA-ENABLED ORGANIZATIONAL DEVELOPMENT OF DIGITAL SERVITIZATION

In this thesis, digital servitization is seen as an ill-structured problem because of the pre-study done based on a literature review (see Chapter 2) and the empirical findings from a Danish manufacturing firm (see Chapter 3). The investigation showed that the case firm lost touch with aspects beyond its common logic of handling the operational problem in the initial transformation stage of digital servitization. Managers lose their sense-making in this new situation. On the one hand, the development of the IoT seems to open up opportunities to go to downstream markets. On the other hand, they have little knowledge about the implementation of this technology, the end-users' markets, and how to maintain the relationship with the business customer while engaging with the end-users through the digital service. It is hard to redirect the organization to solve this new perspective of challenges coming from every angle. Suddenly, the structural engineering problems (e.g., designing the digital service offer and/or establishing an attractive business model) are wrapped up in social concerns, e.g., the relationship among the focal firm, business customers, and end-users (Checkland, 1999; Simon, 1997). So, instead of using the case study method to investigate why this problem occurred, design science research is applied to engage with the practitioner and to probe the phenomenon of interest around the IoT (see section 4.1). The intention is to explore how to deal with this ill-structured problem and to gain knowledge through changing a part of this pragmatic issue. Specifically, this research probes into the implementation of IoT in terms of aiding the organization in the desired transformation toward digital servitization. In consequence, hard systems thinking is applied to work on the concrete data level and to improve the existing business system to adopt the IoT data. The findings are positive in such an engineering solution and help to assess the impact from the social-technical perspective. In addition to hard systems thinking, soft systems thinking is adopted to evaluate the potential changes in the operational perspective of digital servitization through the process of developing and applying the artifact, which was developed in the hard systems thinking stage. In other words, the research evaluates how the intervention impacts on the organizational development in the digital servitization context. Also, it serves to think about how to use the intervention results as evidence for the development of new theories (Oliva, 2019).

So, what do we gain from this intervention research? Can the IoT data benefit a manufacturing firm in ways other than developing a value-added digital service and business model? What might be changed if the implementation of IoT data is considered in the development of digital servitization? This thesis provides quite positive answers to the above questions. Certainly, the implementation of IoT data can do much more than just as a source to develop digital services from the business perspective, for example. However, research on the operational perspective of digital servitization remains sparse. Despite the fact that a few papers endorse information technology as of benefit to the business aspect of servitization (Cenamor et al., 2017; Dinges et al., 2015), neither IT nor data are investigated for their impact on the operational perspective of digital servitization. Most of the transformation challenges

that scholars have identified are at a high level of discussion. Cultural inertia (Story et al., 2017), the lack of a service orientation culture (Kohtamaki et al., 2015), a lack of information transparency, and a need for more comprehensive project management (West et al., 2018) are mentioned in the literature. The gap between lauding the principle of servitization and struggling with the transformation remians. The servitization paradox (Gebauer et al., 2005) seems to be an inevitable situation.

Similar challenges were identified in the pre-case studies (Chen et al., 2018; Chen & Møller, 2019) and included the impact of the implementation of IoT and its collected data as well. In addition, the latter factor is also considered to be an enabler to develop bottom-up organizational changes (Chen et al., 2020). The main reason is seen as the malleability of the data and its mediator – information technology – which is widely discussed in interdisciplinary research, including in OM's neighboring domain, management information systems. It makes sense to split this big problem into a set of smaller problems (Checkland, 1999; Simon, 1996), engineering a set of smaller solutions, which might together fulfill the bigger purpose of helping a manufacturing firm to develop its organization toward digital servitization. In addition, this process of borrowing knowledge may help to close the missing gap and even be of mutual benefit. In this case, the higher purpose is to look for useful business insights to aid managers in making effective decisions relating to servitization development. So, the distance between efforts and results can be appropriately seen and measured through the transformation journey. Similar arguments are not hard to find in the latest researches regarding the managerial concerns with digital transformation in manufacturing firms (Björkdahl, 2020; Guenzi & Habel, 2020; McGrath, Rita & McManus, 2020) and the challenge of implementing digital servitization (Kamal et al., 2020).

Besides, this is also a chance to review if the existing business system of a manufacturing firm is fit for supporting the missions from digital servitization. The phenomenon of digital ubiquity (Iansiti & Lakhani, 2014; Porter & Heppelmann, 2014, 2015) is becoming a constant issue for manufacturing firms in the Industry 4.0 era. If the business system is not adequate to process these emerging data, what might be changed to develop the back-office with a competent platform to support managers in their decision-making?

In this thesis, I explore why a manufacturing firm struggles to transform the organization toward digital servitization, what the role of IoT data can be, and how new knowledge is generated from the intervention through the experiments conducted. Although being hesitant to argue that this thesis delivers generalizable knowledge for manufacturing firms that are undertaking the digital servitization journey, I do claim that I have, through this thesis, prescribed a feasible systematic methodology to facilitate digital servitization. The methodology is meaningful, as it is driven by live enterprise data to engage stakeholders and to establish a learning platform to enhance the communication on achieving the same business goal. The implications of this prescriptive solution are delineated in the following section.

6.3. IMPLICATIONS FOR PRACTITIONERS

Based on the theoretical and empirical foundation outlined in the previous chapters, the need for a systematic methodology to facilitate digital servitization was emphasized. Also, the detailed managerial challenges, their evolution, and the "product-in-use" design principle were extracted from the iterative experiments. As a result, a four-step model of the data-driven approach was proposed to balance the internal conflicts between the top-down strategic changes and the bottom-up process changes. The data (here referring to the explorative business insights, derived from the consolidated ERP and IoT databases) are seen as the enabler to pinpoint the direction of change, and also to be the leading indicators (Kaplan & Norton, 1996) to stimulate cross-functional communication and collaboration. This section therefore reflects the two main parts of the empirical and theoretical findings of this thesis – the managerial challenges (section 5.3) and the data-driven approach (section 5.4) – and further discusses the implications for practitioners. The intention is to answer why data-enabled digital servitization is of value and its implications (benefits) for practitioners in dealing with organizational transformation (see section 4.1).

In this section, a complete view of Checkland's soft systems thinking is presented to address what changes may be feasible and what desirable changes might follow over time in the organization (see Figure 28). For practitioners, there are two levels of system changes. One is at the technical system level, which is in the domain of hard systems thinking. These changes refer to those that are man-made through iterative experiments to improve the business information system as one particular case of digital servitization. The other is the organization level, which is in the domain of soft systems thinking. Three kinds of desirable changes: 1) structural changes, 2) procedural changes, and 3) attitude changes (Checkland, 1999) take place in this project.

First, the structural changes are within the boundary of the business information system. The goal of these changes is to consolidate the heterogeneous data sources in such a way that the additional business insights of the end-users' markets can be explored to support managers in their decision-making. From the iterative experiments, there are three major changes in both the organization and IT systems. First, the change was made from the viewpoint of the service-dominant logic. Instead of labeling the master data of the product system with its physical design, article 3 (see section 5.1) suggests categorizing them with their functionality at the meta-level. This creates a new format for the digital trace, which can be used to map with the IoT data generated from the actual use condition of the product system on the end-users' side.

In addition, the feasible structural changes foster changes in procedures and attitudes because the invisible concerns, such as the unknown end-users' markets, are digitalized through the exploration of the consolidated dataset. Based on the attribution of the smart products, the algorithm behind the product-service platform is

interrogated to categorize the smart products to match them with the defined digital services. Figure 27 presents a part of the data tree-view: the product categories and their potential business indications. This data tree supports managers in doing evidence-based management.

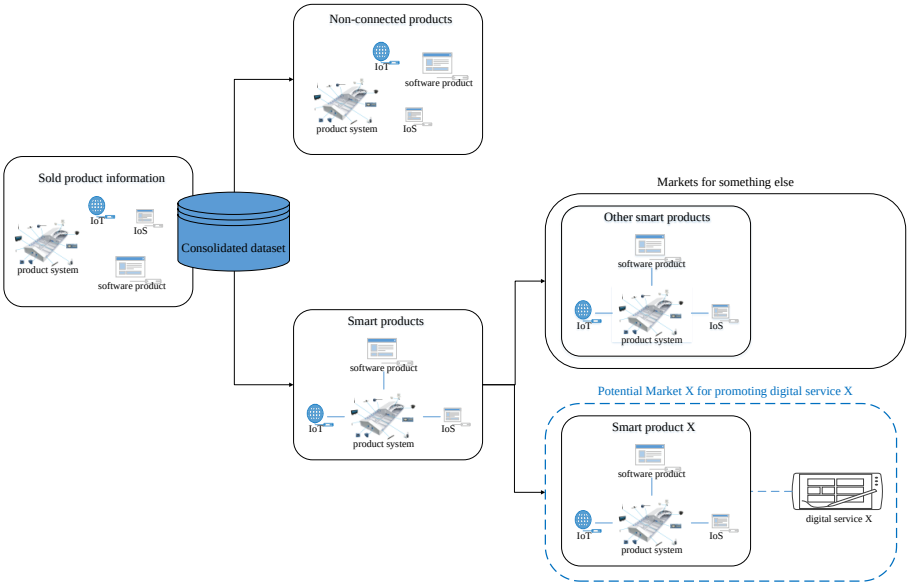
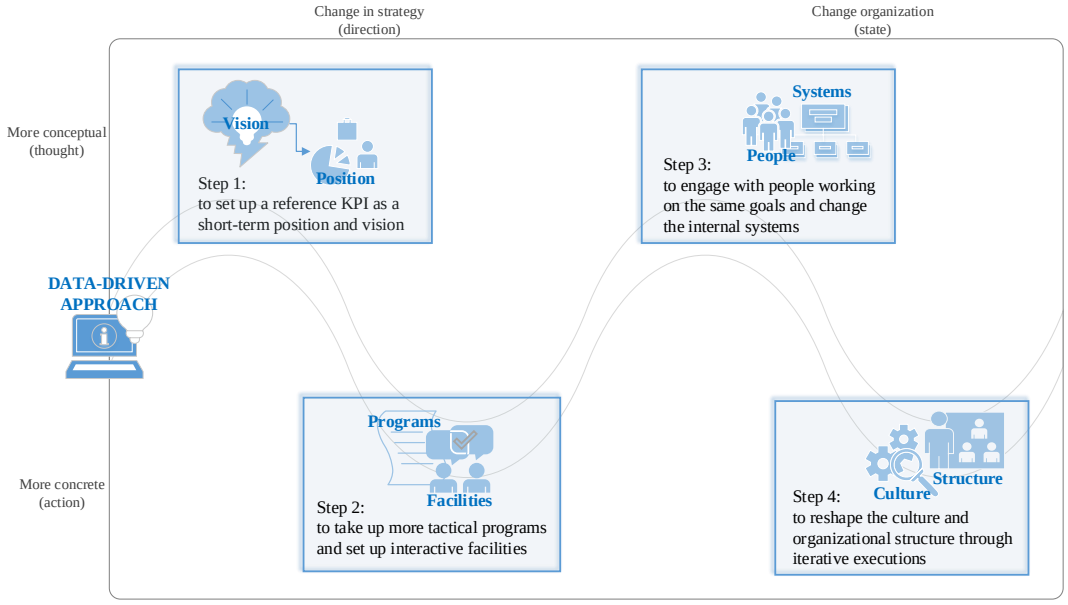


Figure 27. A part of the data tree-view: the product categories and their potential business indications (Chen et al., 2020).

In general, this data-driven approach enables changes of attitude in the organizational transformation in three aspects. First, seeing creates believing. In this case, the potential end-users' markets (in terms of the aggregative number of activated smart products) are digitalized. Through exploring the consolidated dataset, the aggregative number of business customers behind these activated smart products can be identified and used as leading indicators to stimulate the promotion process to engage with business customers (to sell the digital service to the end-users) and also to define the online sales strategy to attract these end-users to purchase the digital service. In other words, it creates space for the procedural change in steps 1 to 3 of the data-driven approach (see Figure 23). The reliable number (from the live enterprise data) as the goal sets the change in direction; however, achieving the desired goal depends on the concrete actions and cross-departmental communication and collaboration efforts.



Duplication of Figure 23. A four-step model of the data-driven approach (adapted from Mintzberg and Westley's contents of organized change (Mintzberg & Westley, 1992)).

In addition, the real performance of achieving the market share (out of the potential markets) can be seen as lagging indicators (Kaplan & Norton, 1996). Repeating this performance comparison process, managers are able to benchmark their own progress with servitization in order to improve the operational performance of this process (e.g., by reference to the gap between the potential (leading) and gained (lagging) markets). In the long-term, it creates a learning platform to monitor the attitude change and to slowly reshape the culture and organizational structure (step 4 of the data-driven approach; see Figure 23) as well.

In summary, the emerging IoT data create the possibility to have this data-driven approach, in which the leading KPI, attached to the potential business markets of the digital service, can be set as checking points. Instead of using quality, revenue, and cost as the performance checking points, this study proposes a more systematic methodology, in which the firm is able to use its data and do internal benchmarking for managers to adjust the organizational actions and direction.

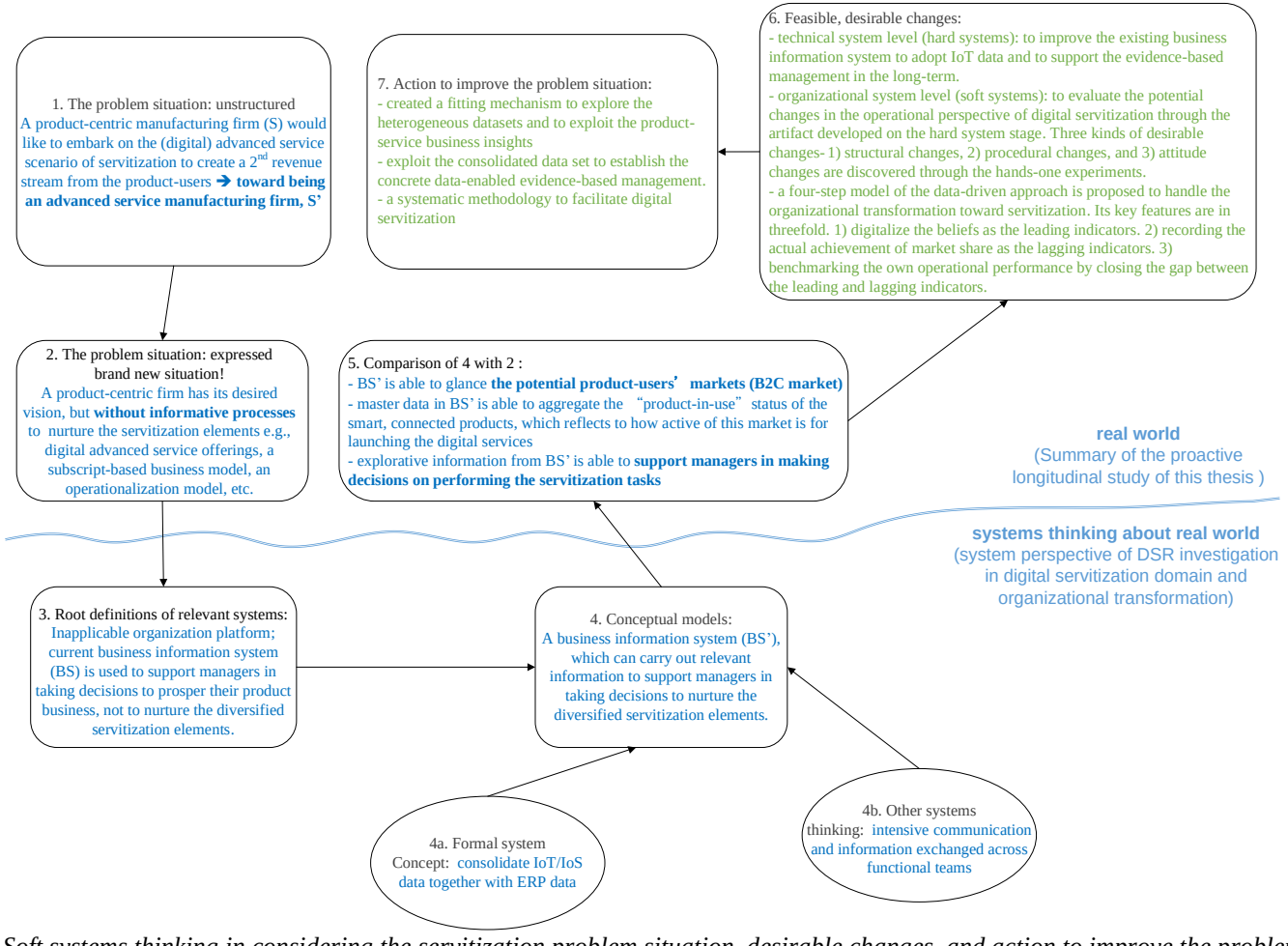


Figure 28. Soft systems thinking in considering the servitization problem situation, desirable changes, and action to improve the problem situation (adapted from Checkland, 1999).

CHAPTER 7. CONCLUSION

This chapter concludes the Ph.D. research on the topic of the data-enabled organizational transformation of a manufacturing company - toward a systematic methodology to facilitate digital servitization. Four sections are presented in this chapter, including the research contribution and implication, managerial propositions, and limitations and future research. In addition, personal reflections on the research and process will also be addressed at the end of this thesis.

The potential of smart, connected products transforms companies and the competition toward significantly leveraging the power of information technology. It brings not only the business potential toward downstream markets (Porter & Heppelmann, 2014) but also the necessity for organizational changes within the firms (Porter & Heppelmann, 2015). Digital servitization is one transformation emerging from this industrial revolution. B2B manufacturing firms are eagerly developing new product capabilities such as digital services to engage with their end-users and further extend their business focus. They are working on leveraging the advantages of the combination of smart products, the implementation of IoT technology, and environmental benefits. The goal here is clear, yet, how to transform firms with a product-centric mindset toward blending this with service-thinking is a challenge. This thesis set out to establish a systematic methodology that adopts data as an enabler to facilitate digital servitization and to support evidence-based management (see Figure 7, section 4.1). Its purpose is to work on the concrete level – to examine how data generated around IoT implementation could strengthen the business system to be able to explore the business insights of end-users' markets (see section 5.1). In addition, the thesis also probes the benefits of IoT for the organization's development toward digital servitization (see section 5.2). As a result, a four-step model of the data-driven approach was proposed to balance the internal conflicts between the top-down strategic changes and the bottom-up process changes (see section 5.4). Through the development of this research with the case firm, three types of desirable changes: 1) structural changes, 2) procedural changes, and 3) attitude changes, are identified and their implications for practitioners are elaborated (see section 6.3).

The following sections discuss the synthesis of the research contributions and their implications, the managerial propositions, and future research in the domain of digital servitization.

7.1. RESEARCH CONTRIBUTION AND IMPLICATIONS

The objective of this thesis was to create a systematic methodology to facilitate organizational transformation in the digital servitization context. Here, the consolidated data is seen as an enabler to enhance the communication across functional teams and to facilitate the potential organizational changes on the process level. The process was

conducted in three research stages, each having its own goal and deliverables, while each set of smaller solutions also served the bigger purpose of helping a manufacturing firm develop its organization toward digital servitization. Figure 29 summarizes the research contributions of each stage and how they are connected to the bigger picture. Stage 1 was to probe the phenomenon of interest in this selected topic. On the one hand, the practitioners face challenges in transforming a product-centric organization toward a product-service oriented business because of the complexity of the new vision that can be formed by the smart, connected product. On the other hand, the researchers discovered identical challenges in the social perspective (Kohtamaki et al., 2015; Story et al., 2017; West et al., 2018) and the servitization paradox (Gebauer et al., 2005). Based on the inputs and the pre-assessment from stage 1, IoT data was considered as an enabler to stimulate the organizational change toward digital servitization. In this stage, the engineering solution(s) were proposed and developed to acquire knowledge around the defined phenomenon of interest. The last stage was to put together the learning from the previous stages and to evaluate how the results of such development contribute to the thesis objective.

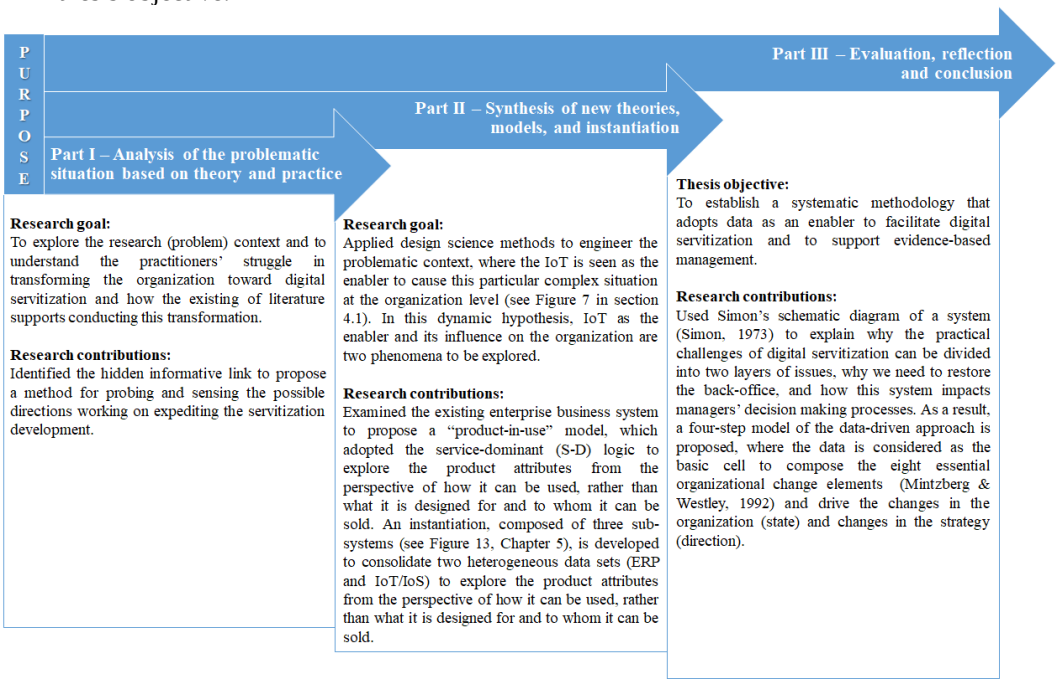


Figure 29. Summary of research gaps and contributions of each research stage

To sum up, the contributions of this thesis are in three areas of the operational perspective of the digital servitization context - the research method, theoretical contributions, and deliverables to the practitioner. First, this thesis emphasizes the importance of prescriptive research, which is a better way to cope with the practitioners' problems and to close the knowledge gap between scientific research and the empirical domain. Section 6.1 delineates this argument in detail. As a result, the collective research process of this

thesis is presented in Figure 26. Second, a part of this thesis contributes also to developing the state-of-the-art research in the operational perspective of digital servitization. Section 6.2 discusses what the role of IoT data can be, and how new knowledge is generated from the intervention through the engaged experiments. Lastly, a four-step model of the data-driven approach is proposed to balance the internal conflicts between the top-down strategic changes and the bottom-up process changes. The techniques of developing such a data-driven approach are applicable to manufacturing firms whose business setup in smart products and IoT technology. In general, this systematic methodology creates a virtual learning platform, where servitization stakeholders are enabled to cope with this challenging transformation journey. The implications of this methodology are discussed in section 6.3.

7.2. MANAGERIAL PROPOSITIONS

This section delineates the conclusion of managerial propositions to practitioners, facing the transformation challenge toward the digital servitization. Instead of taking digital servitization as a single issue, this thesis proposes to split this major problem into a set of smaller problems (Checkland, 1999; Simon, 1996). Therefore, the cross-functional managers can take the lead to engineer a set of smaller solutions, which together fulfill the bigger purpose of helping a manufacturing firm develop its organization toward digital servitization. To do so, they share the common goal of transforming the business toward digital servitization, and also take on mutual responsibilities to develop the organization together.

Three managerial propositions are proposed to the practitioners embarking on this digital servitization crusade. These also enable the improvement of the problem situation in response to my earlier argument (see Figure 27) on soft systems thinking in considering the servitization problem situation.

First, ***to value the power of digitalization and build up the organizational capabilities around it.*** It can be imagined that digital datasets like IoT data will be ubiquitous once smart, connected products (the combination of smart products and digital services) become a standard package in the manufacturing firm's business. Exploring the value of data and exploiting the business insights from the raw data should become an essential capability to deal with this situation.

Second, ***to recognize the value of data as well as to develop and explore its value through continuously utilizing its potential.*** The first point is about creating confidence in using data. A similar situation when human society first began using paper money as the currency. *"The value of money is nothing, unless people are interested in it and feel confidence in it"* (Ritzmann, 1998). The same principle applies to confidence in using data, which is essential if the ubiquitous data and its implementations are to have the chance to demonstrate their value. In addition, managers at this transformation stage might need to work on retraining employees with new capabilities and knowledge (following from the first point) of how to work with data. In a metaphor that inspired this

journey, data is such a universal term like water. If water can be shaped into different forms (based on the environmental conditions, it may be the liquid, gas, or solid) and be of value in the specific scenarios, why should data not be the same? However, this requires the efforts of people who work with data to think about those questions: 1) where to find a technique to apply in this situation, 2) how to create a process to reshape the data form for a specific scenario, 3) what product (e.g., a platform) can be developed by using the available data source(s) and its surroundings? 4) to whom can we explore and exploit the data value from the product? These are questions that practitioners constantly need to consider in this digital era constantly.

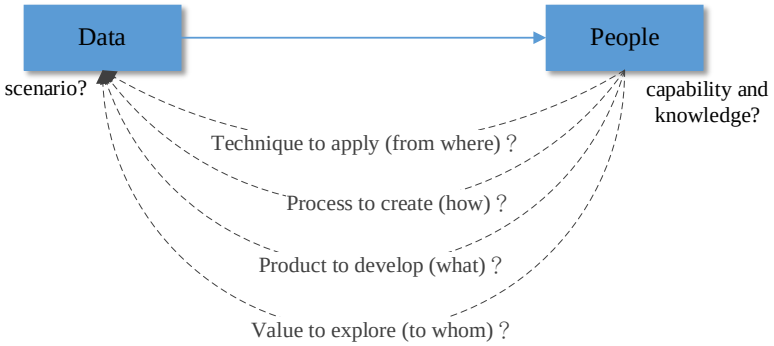


Figure 30. Four questions model to work with data

Third, ***to establish a learning platform in order to escalate the pace of transformation.*** According to Mintzberg and Westley, all changes begin with learning (Mintzberg & Westley, 1992). Here, this learning platform refers to the effects established by using the IoT data and its implications (e.g., the product-service platform and the business intelligence system, which are delivered as the empirical results in this thesis.) Through the iterative process of using the explorative data to undertake the Plan-Do-Check-Act process in approaching the potential digital service markets, the virtual learning platform will be formed around the stakeholders who are in charge of this development process.

7.3. LIMITATIONS AND FUTURE RESEARCH

The research presented in this thesis primarily covers the initial phase of organizational transformation toward digital servitization. The major contribution of this thesis is to argue that emerging data such as IoT datasets can be used not only in business development but also to facilitate internal organizational change. As a result, a four-step model of the data-driven approach is proposed to support this line of reasoning. A horizontal approach is taken to extend the theoretical understanding of digital servitization from the operational perspective. Thus, the detailed social impact factors in the development phase are largely omitted. Further work should include discovering those constraints. In addition, the proposed systematic methodology needs to be followed up in specific naturalistic settings to evaluate how the effectiveness of this methodology circulates the explorative information to balance the transformation tension between the

top-down strategic changes and the bottom-up process changes. Nevertheless, this data-driven approach mitigates the servitization challenges within the firm, such as the lack of information transparency (West et al., 2018), and nurtures a new culture to counter the cultural inertia (Story et al., 2017), for example. Besides, this KPI approach sheds light on supporting future research on the efficiency of the growth agenda in manufacturing firms (Björkdahl, 2020; Guenzi & Habel, 2020; McGrath, Rita & McManus, 2020). Although this thesis has engaged in-depth with the practitioner to examine a full cycle of research development in this particular phenomenon of interest, the results from one specific study are a clear limitation of this study.

7.4. REFLECTIONS ON THE RESEARCH AND PROCESS

Transformation

This research has been concerned with the domains of the servitization paradigm, digital transformation, and organizational change management, where many studies focus on discovering the phenomena in the domains rather than developing the theories. Thus, one of the big challenges of this research is to inspect the critical and relevant question that needs to be studied in both academia and practice. Where might such a study lead, and how?

As pointed out by Porter and Heppelmann (2014. 2015), the potential and influence of smart, connected products will profoundly change the industry in many areas. This requires far more coordination across functions and disciplines than the conventional approaches (taking in the industry and/or research). This is the first concern in this research project. Many struggles and set-back appeared during the investigation and development phases. From the research perspective, those challenges include but are not limited to 1) what is the relevant knowledge, 2) how to integrate that valuable knowledge from across-disciplines, 3) why do those disciplines need to be involved in one study, 4) how to takes one small step at a time, but to link the contributions to the bigger purpose, and 5) how to reflect the complexity of the real world problem in the research. All these questions were constantly asked in developing this research project.

In theoretical studies, servitization or digital transformation or organizational change management each have their individual concerns (e.g., the context of the development background and initial factors), and can develop into very niche domain knowledge over time. They seem to be connected but also distant. This research project is an example of this dilemma. To investigate the concern with developing organizational transformation in the servitization context, at least twenty-five areas of concern were opened up from three perspectives in connecting to the knowledge from several domains (Ziaee Bigdeli et al., 2017). My reflection upon this dilemma would be to work around the similarities and differences in the context of theories (from cross-disciplines), and to link and to contribute to those kernel theories for a more specific phenomenon of interest. So, the delivered knowledge (e.g., methods, tools, constraints, etc.) is more suitable and useful

for the expectations of supporting modern manufacturing firms to keep growing in this Industry 4.0 era.

Engaged scholarship vs. engaged practice

Besides all the hard work needed to learn the relevant knowledge and research methods, I would say it is also challenging to work between two worlds, where many uncertainties and stakeholders are involved. On the one hand is the research world where the primary deliverable is (useful!) knowledge and theory; on the other hand, the empirical world demands quick responses and value-adding solutions. My personal observations and experience in those different expectations reflect the different maturity of knowledge bases and experience in the fields. One thing that could be done better in such an industry based research project is to create this layer of understanding at the very beginning and continue to work on it together with project stakeholders. First, this might save some time to get the agreed point in the phenomenon of interest and have sufficient resources and capability on board to push the development of a project forward. In addition, it might create a positive loop to sustain this kind of industry-based research, if stakeholders involved in the different stages of the development remain engaged, sharing their knowledge and learning from each other. For me, this research project has been just such a learning experience from a journey beginning with struggle. Instead of regretting the flaws, it is better to absorb the lessons learned from the process and outcomes, make changes, and do better in the next steps. ☺

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APPENDED ARTICLES

ARTICLE 1 – A THOUSAND-MILES JOURNEY BEGINS WITH THE VERY FIRST STEP: THE CASE OF A PRODUCT-CENTRIC MANUFACTURING FIRM TRANSFORMATION TOWARDS SERVITIZATION

Kuan-Lin Chen and Charls Møller
Published in 2019 in *CIRP Journal of Manufacturing Science and Technology*, vol. 27, pp. 102-113.

Chen, K. L., & Møller, C. (2019). A thousand-miles journey begins with the very first step: The case of a product-centric manufacturing firm transformation towards servitization. *CIRP Journal of Manufacturing Science and Technology*, *27*, 102–113. https://doi.org/https://doi.org/10.1016/j.cirpj.2019.06.002

ARTICLE 2 – EMBARKING ADVANCED SERVICES ON SERVITIZATION TRANSFORMATION, MAKING SENSE USING SYSTEM THINKING

Kuan-Lin Chen, Astrid Heidemann Lassen, and Charls Møller
Published in 2018 in the Joint International Conference of Service Science and Innovation and Serviceology; Service +, Pursuing Excellence in Service Research Taichung, Taiwan, November 2018.

Chen, K-L., Lassen, A. H. & Møller, C. (2018). Embarking Advanced Services on Servitization Transformation, Making Sense Using System Thinking. Proceedings of ICSSI & ICServ, 2, 243-247.

ARTICLE 3 – BOOTSTRAPPING PRODUCT-SERVICE BUSINESS: AN EXPERIMENTAL DATA-DRIVEN APPROACH

Kuan-Lin Chen, Chen Li, and Charls Møller
Published in 2019 in The International Society for Professional Innovation Management (ISPIM); Manchester, June 2019.

Chen, K., Li, C., & Møller, C. (2019). Bootstrapping product-service business: An experimental data-driven approach. Manchester: The International Society for Professional Innovation Management (ISPIM). Retrieved from https://search.proquest.com/docview/2297092414?accountid=8144

ARTICLE 4 – EXPLORING THE VALUE OF IoT DATA AS AN ENABLER OF TRANSFORMATION TOWARD SERVITIZATION – AN ACTION DESIGN RESEARCH APPROACH

Kuan-Lin Chen, Astrid Heidemann Lassen, Chen Li, and Charls Møller
Submitted to European Journal of Information Systems (submitted).

Chen, K. L., Lassen, A. H., Li, C., & Møller, C. (2020). Exploring the value of IoT data as an enabler of the transformation toward servitization – An action design research approach. *European Journal of Information Systems (Submitted)*, 1–42.

ISSN (online): 2446-1636
ISBN (online): 978-87-7210-812-4 AALBORG UNIVERSITY PRESS