Ville Voipio

THE ROLE OF RADIO-FREQUENCY IDENTIFICATION IN THE SUSTAINABLE DIGITAL TRANSFORMATION OF THE SUPPLY CHAIN

ACTA UNIVERSITATIS LAPPEENRANTAENSIS 1119

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Dissertation for the degree of Doctor of Philosophy to be presented with due permission for public examination and criticism in the Kouvola Auditorium P1027 at Lappeenranta-Lahti University of Technology LUT, Finland on the 15th of December 2023, at noon.

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Abstract

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Sustainability and digital transformation have been two leading themes for businesses as they have updated operating systems in the 2020s. This study focuses on using radio-frequency identification (RFID) to provide visibility in the sustainable digital transformation (SDT) of the supply chain. The purpose is to expose the roles and the levels of value creation that RFID takes. The theoretical background stems from Industry 4.0 (I40), which stresses the role of specific technologies in driving business renewal.

The study comprises a Europewide survey among 685 business and supply chain leaders, and four case studies with 86 days of floor-level operations tracking, 36 interviews, five round tables, and in-depth data from five organizations.

The dissertation reveals that data-capturing practices used are still partly immature and influenced by narrow industry-specific standards. Data quality is a challenge in several industries due to the lack of advanced practices fitting with the product and supply chain structures. The study argues that RFID has a role as an enabler, driver, and connector in SDT. Its key benefits are automation, itemization, and data generation to the SCM, which supports sustainable business configuration, improved customer value, and building future-proof organizations by responding to regulatory and customer pressures and resource shortages. However, feasible use cases of RFID remain limited due to a lack of universal application and reading methods across product and packaging types.

It is argued that the strategic role of supply chain visibility (SCV) has been understood by a few leading global firms, which have succeeded in building data-driven organizations e.g., in consumer-packaged goods industry. Within the SCV research community, the focus has been on inter-firm relationships in the supply chain domain, neglecting the cross-functional intra-firm aspect that is needed in a companywide digital transformation. The top-management influence is invaluable in setting the cross-functional agenda for SDT and internal data sharing and utilization. Through the stakeholder theory, it is argued that while RFID has become a standard in certain industries, the traditional view of innovation diffusion across markets should be replaced with models emphasizing co-existing technology landscapes. This would also support business model conversations, which are present in I40 but have attracted less attention in supply chain 4.0 research focusing on the performance aspect.

Keywords: sustainability, digital transformation, data quality, supply chain visibility, radio-frequency identification, business renewal

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Thank you – friends and extended family for being on this journey with me.

Love you – Leo and Oona, you have grown from kids to youngsters while I was in the basement making *science.* Tiina, you have given me ‘another half an hour to finish a sentence’ just about ten thousand times… thank you for loving eyes and the riverbank.

Ville Voipio
November 2023
Porvoo, Finland

"Ambition without knowledge is
like a boat on dry land"

Contents

List of publications

This dissertation is based on the following papers. The rights have been granted by publishers to include the papers in the dissertation.

I. Voipio, V., Elfvengren, K., and Korpela, J. (2020). "In the bowling alley: acceptance of an intelligent packaging concept in European markets." International Journal of Value Chain Management, 11 (2): 180-197. ISSN: 1741-5357, 1741-5365. DOI: 10.1504/ijvcm.2020.106825. Jufo 1.

II. Voipio, V., Korpela, J., and Elfvengren, K. (2021). "Environmental RFID: measuring the relevance in the fashion industry." International Journal of Fashion Design, Technology and Education, 14 (3): 284-292. ISSN: 1754-3266, 1754-3274. DOI: 10.1080/17543266.20211929510. Jufo 1.

III. Voipio, V., Elfvengren, K., Korpela, J., and Vilko, J. (2022). "Driving competitiveness with RFID-enabled digital twin: a case study from global manufacturing firm's supply chain." Measuring Business Excellence, 27 (1): 40-53. ISSN: 1368-3047. DOI: 10.1108/mbe-06-2021-0084. Jufo 1.

IV. Voipio, V., Elfvengren, K., Korpela, J., and Vilko, J. (2023). "Solving the Employee Shortage in a Food Service Business with an Intelligent Cabinet Solution: a Design Science Approach." Submitted

V. Voipio, V., Elfvengren, K., Korpela, J., and Vilko, J. (2023). "The Future of Work: Skills and Knowledge Perspective on Service Automation in the Foodservice Industry." Technology Analysis & Strategic Management, ISSN: 0945-7325, ISSN: 1465-3990. DOI: 10.1080/09537325.2023.2165440. Jufo 2.

VI. Voipio, V., and Vilko, J. (2022). "Dissemination of Supply Chain Visibility: Intra-Organization Perspective." Proceedings of 12th International Conference of Logistics and Transport, ICLT. Krabi, Thailand. ISBN: 978166547714.

Author's contribution

The author of this dissertation was the primary researcher in the papers, whereas the other researchers mentioned in the article participated in the research article development in group discussions and through draft article review sessions. In addition, in Article III, Dr. Elfvengren co-wrote the literature review section, in Article IV Dr. Korpela co-authored the literature review, and in Article V Dr. Vilko co-created the comparison table used in the research results.

Nomenclature

The dissertation uses specified abbreviations in the text to avoid repeating long phrases, which could otherwise hinder comprehension of the content. The list of key terms is as follows:

BM	Business model
DTW	Digital twin
DT	Digital transformation
DSC	Demand supply chain
EDI	Electronic data interchange
ESG	Economic, social, governance
I40	Industry 4.0
IoT	Internet-of-things
IRI	Inventory record inaccuracy
IT	Information technology
IPA	Intelligent packaging
MO	Market orientation
NFC	Near-field communication (RFID protocol)
OR	Operations research
PIT	Product identification and tracking
RFID	Radio-frequency identification
RP	Research paper
SKU	Stock-keeping unit
SUS	Sustainability
SC	Supply chain
SC4	Supply chain 4.0
SCD	Supply chain data
SSC	Service supply chain
SCM	Supply chain management
SDT	Sustainable digital transformation
SS	Self-service
ST	Stakeholder theory
UHF	Ultra-high frequency (RFID protocol)
VC	Value chain

1 Introduction

1.1 Research background and motivation

Digital transformation refers to companies' processes of leveraging digital capabilities and technologies to enable business models, operational processes, and customer experience to create value (Morakanyane et al., 2017). The sense of urgency to do so comes from several directions. Many have noted that new customers have already disappeared from physical meetings to virtual spaces, and on the other hand, it has been observed that many of today's market-leading, high-growth, and dominant companies are digitally native at their core (Barwise and Watkins, 2018). From an industry-level inspection, it has also been seen that several traditional industries have become targets for digital disruption (Grossman, 2016) where new business models introduced by start-up firms reorganize their work and monopolize their role with data.

According to researchers at IBM, digital evolution has gone through three phases, whereby the first two held an interest in the product (e.g., from music cassettes to CDs) and distribution (e.g., from physical stores to e-commerce) levels of upgrade, whilst the third phase focuses on the business model changes involving advanced analytics (Berman and Bell, 2011). The current phase is widely researched under the industry 4.0 theme, which argues that the fourth industrial revolution is empowered by new capabilities (e.g., internet-of-things, 3D printing, and artificial intelligence) and it creates a profound change in the way companies create value and how the physical society operates (Schwab, 2016).

By 2020, academia also found a growing interest in corporate social responsibility and focused research on the sustainability theme, which measures corporate performance in terms of financial, environmental, and social aspects to build enduring businesses (Abad-Segura et al., 2019). Scholars suggest that sustainability proposes another major business shift, where the winners are not just adjusting to new regulations but rather understanding its essence in the value creation and business models that require strategic orientation over tactical steering (Lubin and Esty, 2011). In listed companies, shareholder value-oriented executives have seen institutional investors reallocate funds to firms where sustainability has been well-considered and reported, thus creating another driver for top management to act (Kollewe, 2022; Lim, 2022).

Sustainability and digital transformation are change forces that challenge companies' strategies and growth plans. According to previous research, a set of sustainable business models are enabled by new technologies, digital solutions, business models (e.g., platform business), and approaches to the markets (e.g., sharing and circular economy), hence they are linked (Tura, 2018).

The dissertation takes a supply chain management view of the previously defined change forces. The supply chain function manages the operating system (including sourcing, manufacturing, logistics, and warehousing) in companies moving physical products, thus it is central to guarding the sustainability aspect and steering physical operations increasingly through data and analytics. One of the findings this study concludes with is that supply chain management is becoming central to the current highly competitive business environment in leading the growth and renewal that is an integral part of the product flow system, dictating cost structures, profitability, customer experience, and impact (economic, social, and environmental).

More specifically, the study examines sustainable digital transformation in the supply chain. The red thread throughout the study is radio-frequency identification (RFID) technology which, as decades-old technology used for product and packaging identification, has become relevant again through its ability to automate and provide item-level identification in a high-volume product flow.

The momentum for RFID technology to re-emerge now can be linked to highly developed cloud services, which in recent years have matured to provide an infrastructure that can collect and manage data. The systems not only allow the use of data but also require loads of it to deliver value and a competitive edge in a marketplace. For that reason, data quality and resolution are also becoming central. An example of supply chain data-driven growth could be Alibaba's entry into SME financing, where the company was able to use data from its platform to assess the financial risk of the customer base more effectively than banks, and thus was able to provide more competitive financing offers (Zeng, 2018). Another example could be the fashion chain Zara, which was one of the early deployers of RFID technology in the textile business. Their precise data from products, stores, and locations allowed Inditex, the mother company, to optimize offering and logistics better than others, and thus provide lower costs and better offering—in short, unparalleled customer value (Aftab et al., 2018).

The study focuses on examining the key questions related to RFID-enabled sustainable digital transformation. Sustainability requires a long-term perspective of "people, planet, and profit," which is the lens dictating RFID inspection in the papers. Is it environmentally sound? What are the consequences to the people involved? Does it provide lasting grounds for financial return? On the other hand, the papers are designed to cover the key themes in the supply chain context, where a traditional product-centric manufacturing supply chain forms one scenario, and a service supply chain provides another. Figure 1 illustrates the explained research focus.

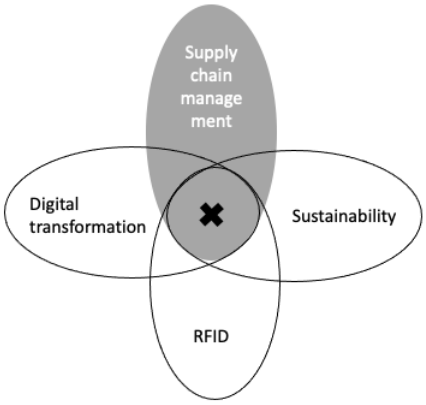

Figure 1: Focus on the dissertation

The motivation for the research stems from an interest to understand how RFID as a technology matches today's needs in the supply chain started by an observation of the momentum. At the time of conducting the research, the author was employed by an international forestry firm, which had been interested in RFID as a technology for multiple uses for several years. Finally, it launched a business area that was set to provide products and services for the digitalization of packaging, for which the author was responsible for commercialization in global markets. As a result of the interest, the author ended up researching and validating RFID in its key application areas. The forestry company referred to has a strong innovation, supply chain, and sustainability orientation, while the author has several years of experience in digital transformation and business management. The dissertation combines these domains as a foundation for the research.

1.2 Research gaps

The previous research positioning of Industry 4.0 (I40) in the context of supply chain management highlights that despite intense research on I40, most of the studies released are conceptual, thus leaving a constant need for interdisciplinary empirical research (Koh et al., 2019). Researchers (ibid.) of I40 have made several references linking I40, SC, and sustainability on a theoretical level, suggesting these areas should be studied together. In another piece of research on I40 and supply chain management, the researchers established an implementation framework integrating digital business and digital supply chains to understand how digital transformation influences SCM (Ghandge et al., 2020). Their research (ibid.) reports that the implementation of RFID and a cloud solution substantially increased the operational performance of a business; however, it concluded that more empirical research in this area is needed to verify findings and support an understanding of the application area.

Literature reviews made from the cross-section of sustainability (SUS) and I40 state that despite vast separate research into these two distinct areas, the integrated research of

"SUS-I40" is still thin (Gajdzik et al., 2020; Machado et al., 2020). Gajdzik et al. (2020) state that research problems of the SUS-I40 would be needed to foster research, while Machado et al. (2019) identify sustainable supply chains as being a part of the research agenda. In a recent study by Caiado et al. (2022), the researchers focused on the challenges and benefits of SUS-I40, reporting that given the high dependency on data, I40 must overcome the data-related challenges where poor data quality and integration represent part of the unsolved problem.

A vast literature review made on RFID, sustainability, and supply chains reports that out of 1,749 papers published on sustainable supply chains and related themes, only 74 focused on RFID (Konecka and Maryniak, 2020). The researchers conclude that this constitutes a research gap as the growing research theme of I40 will need a growing amount of research on applied technologies, including RFID (ibid.). Another literature review confirms the previous by summarizing 1,187 research papers made on RFID and reporting that the peak year of RFID research was 2013 (before the I40 research theme), and among the research topics, sustainability was almost fully absent in spite of its evident link (Musa and Dabo, 2016).

Based on the previous summary of the research made on digitalization, sustainability, supply chain management, and RFID, discussion about the current sustainable digital transformation occurs on a conceptual level but lacks studies with empirical evidence. Research into RFID as a technology has been on the decline in recent years, although it has the potential to become relevant again as a method that delivers high-quality data and near real-time visibility for SCM. It constitutes the research gap this dissertation contributes to: understanding the role of RFID in sustainable digital transformation in the supply chain. As previous research reports (Musa and Dabo, 2016), RFID is not a straightforward technology but has associated risks, complexities, and benefits. Thus, the research approach in this dissertation to fill the gap was set to be dynamic and convergent, where the research forms ties and understanding between disciplinaries (engineering, management, and sustainability), and between the object and the subject. Furthermore, within SCM one of the prevailing trends has been stressing the importance of collaboration among SCM partners (see e.g., Mehmeti, 2016). However, this dissertation takes another look at the transformation from an intra-firm aspect, but expands the view to the cross-functional arena where services, sustainability, and company-wide digital transformation exist.

1.3 Research questions and objectives

As stated earlier, the research focuses on providing an updated assessment of RFID as a key technology in supply chain management renewal. The main research question can be formulated as follows:

The main research question can be divided into three parts: The first defines the actor (RFID technology) that is being studied. The second (sustainable digital transformation, SDT) defines the goal that is being targeted by the actor. Finally, the third part defines the context (supply chain, SC), which sets rules, requirements, trends, and realities for approaching the goal. The "how" in the research question defines that the purpose is to understand, explore, and describe the nature of the actor in its goal and in the set context. This structuring is used to define the sub-questions that help divide the main research problem into smaller and more concrete questions as follows:

1. *What are the state and characteristics of RFID as an identification technology within SCM?* The research goal is to understand the status of RFID as a connecting technology; and how and why it is used across industries.
2. *How does RFID enable sustainable digital transformation?* This part of the research intends to understand how RFID complies with and supports the key components of sustainability ("people, planet, and profit") and how it enables digital transformation in SC.
3. *How does RFID-enabled SDT comply with the emerging SC needs and context?* Lastly, the research aims to understand the cross-functional and cross-vertical context where the transformation occurs.

The sub-questions are addressed through research papers, which translate the sub-questions into practical research projects with concrete cases, methods, and outcomes. The results provided grounds for the established findings that respond to the main question set in the research. In the research practice, the sub-questions were treated as layers of a problem, i.e., research papers were designed around holistic issues that provided insights into more than one question at a time. Figure 2 explains the logic and structure employed.

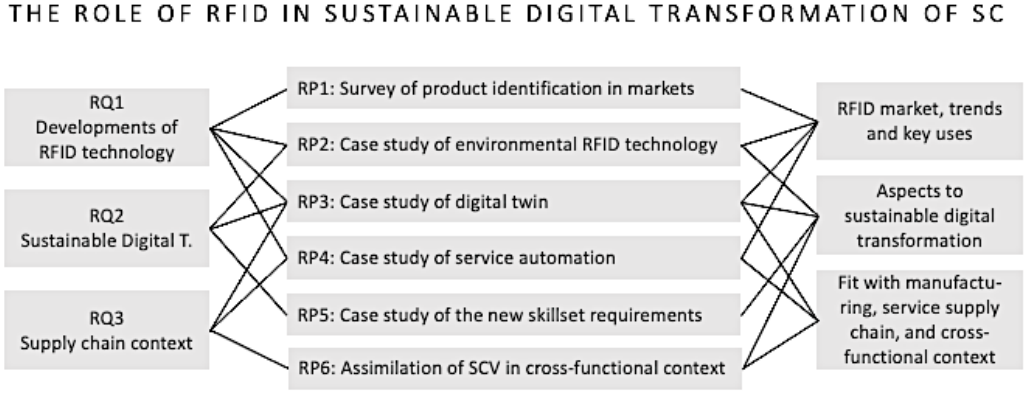

Figure 2: Research questions, research papers, and knowledge creation

Research question 1 was responded to by papers focusing on RFID technology as a method for creating connectivity and identifying products. The objective was to characterize the technology and its role in systems. Paper 1 examined the role of RFID as product identification technology and the markets where it currently proves to be most used. Paper 2 focused on RFID as a consumable radio-frequency reflector, and its technological construction with an antenna, semiconductor, and base material. Paper 3 investigated the role of RFID in a supply chain system, the architecture in a wider view, and how it delivers data from reading points to the cloud. Paper 4 examined RFID in a small systemic entity, in a solution.

Question 2 was responded to by papers focusing on sustainability requirements and digital transformation. Paper 2, as a part of the technology review, investigated the environmental (planet) aspects of RFID and its contribution to sustainability programs set by leading firms in fashion. Paper 3 investigated the profitability aspect, while paper 5 engaged in the people perspective related to running an RFID solution concept, where the availability of human resources in a low-pay service industry and skillsets change are present. These papers also contribute by describing how product and information flows have been digitized, forming new operational and business models.

Question 3 was responded to by papers 3, 4, and 6, which gave context to two different supply chain environments (paper 3 was an industrial product supply chain, while paper 4 introduced a service supply chain context) and the cross-functional reality existing in organizations.

1.4 Scope and key concepts of the study

In this section, the scope of the research and the key terms are introduced. The aim is to further define the positioning of the research as a foundation for the dissertation.

1.4.1 Scope of the study and unit of analysis

Supply chain management (SCM) stems from the fragmented management of activities, which emerged as a research field in the 1960s (Ballou, 2006). At the time, “material handling” was seen as part of marketing responsible for selling and delivering goods to customers (LaLonde and Dawson, 1969). The “total cost,” as a concept found in the early days, demonstrated the need for a more strategic understanding of the area over tactical functional orientation, as it is not acceptable to rely only on the direct cost in a shipment selection, for instance; instead an evaluation of total cost should be made that sums up from several activities required to complete the task (e.g., transportation, warehousing, and capital costs to name a few; Lewis et al., 1956). Soon, logistics became a concept that handled purchasing, materials management, and distribution, which investigated internal and external supply chains intending to find improved and efficiently handled product and service flows (Fawcett and Magnan, 2002; Ballou, 2006). The concept of SCM extended the focus from material to information flows and underlined the importance of

collaboration in achieving a sustainable competitive advantage (Seuring, 2005). Researchers (e.g., Ballou 2006; Mehmeti, 2016) today describe that in a globalizing competitive market, SCM increasingly drives boundary-spanning collaborative practices in virtual settings that enable not only cost savings, but in equal measures also sales increases. They note (ibid.) that SCM is now the new frontier for demand generation—a competitive weapon, where the game with rivals occurs not only between firms but between chains. For this reason, much SCM research has an inter-firm and intra-functional focus, which is challenged in this dissertation by drawing the focus on cross-functional collaboration in an intra-firm context. Figure 3 illustrates this aspect influencing the scope.

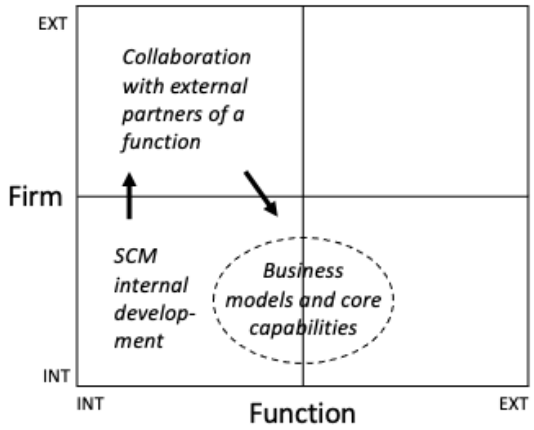

Figure 3: SDT taking place in cross-functional interfaces in a firm

When inspecting factors that have influenced the SCM evolution, information technology (IT) stands out. It has catalyzed progress through electronic data interchange (EDI) practices and the use of enterprise resource planning (ERP) software (Mehmeti, 2016). The role of IT as an orchestrator increases when moving from internal to external company networks (Fawcett and Magnan, 2002). Researchers note (e.g., Ballou, 2006) that succeeding within a partner network requires technical capabilities and trust between organizations. As an example of the power of technology, a well-regarded consulting firm reported a survey study that revealed significant double-digit improvements in common supply chain metrics achieved in the retail industry, where RFID was used as a base technology to provide nearly real-time data from product flows in operations (Unger and Sain, 2016). Visibility can be seen in two ways: while Unger and Sain (2016) primarily connected RFID visibility to efficiency metrics in operations, Schuh et al. (2017) present that connectivity and visibility are the gateways to higher cognition: improved understanding, predictive capabilities (advanced analytics), and adaptability (e.g., via machine learning).

Corporate social responsibility (CSR) has roots in the 1950s, when researchers became interested in the value aspects of a firm and businessmen's ethics (Aqudelo et al., 2019). Over time, a concept of shared value (Porter and Kramer, 2011) emerged, leading the conversation toward the common good and focusing on the concept of value more prominently and the role that a company has as an institution in society. From peripherical relevance, the research became more strategic when the regulation and international collaborative parties started to set new non-financial requirements for businesses. One of the tipping points in the field was in 2015, when the Paris Agreement launched the UN's Sustainable Development Goals, which are followed by many industries and companies today (Aqudelo et al., 2019). This integrating area of research stems partly from the environmental tradition, and partly from a corporate social responsibility background forming the research focus of sustainability today scoped around ESG—environmental, social, and governance—aspects (Hansen et al., 2014; Purvis et al., 2019; Barbier, 1987), or 'people, planet, and profit,' as used in this dissertation. Business sustainability can be defined as the ability to respond to the short-term financial needs of a business without compromising future needs (Bangsal and DesJardines, 2014).

Figure 4 illustrates the research scope and focus of the dissertation. The theoretical roots adopted in this dissertation are stakeholder theory and market orientations, which as underlying management theories provide an explanation of the role and purpose of companies. The recent research stream emerging on supply chain 4.0 (SC4) theory combines aspects of digital transformation (DT) and sustainability (SUS), introducing how technology development has been used to renew the SCM function. Supply chain visibility (SCV) sharpens theoretical understanding by discussing the role of visibility in SCM, which in this dissertation is examined from an intra-firm perspective. RFID is known to be a cornerstone technology for creating nearly real-time visibility of product flows, which provides an empirical arena to test the technology within the context explained. In this research, performance, servitization, and sustainability impact are evaluated through the publications presenting the original research conducted on the topics. These aspects are lifted from SC4 theory as a suggestion for the contemporary agenda of SCM at the time of shared value and digital connectivity. The outcome of the dissertation is intended to expand understanding of RFID as a key technology that provides SCV and drives the SC4 agenda. How the technology fits the purpose, and what kind of limitations, drivers, and future scenarios it leads to, are of interest. The unit of analysis is at the firm level, hence the study also seeks implications and recommendations for organizational planning. Although RFID technology and data are central to the dissertation, it should be underlined that the dissertation focuses on SCM. Thus, the technology and data aspects are briefly introduced in this opening section, and the considerations during the study are limited to managerial aspects.

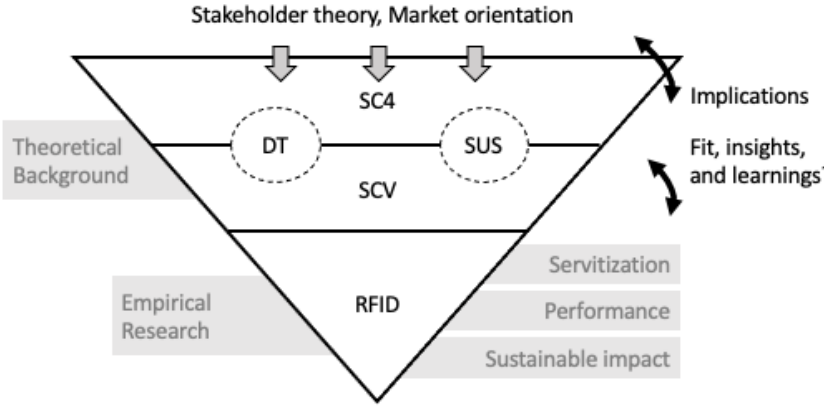

Figure 4: Positioning and flow of the dissertation

1.4.2 **Management theories**

Management theories are introduced here as middle-range theories and as a perspective and starting point for the substantive theories of the actual matter: sustainable digital transformation (acc. Creswell, 2009). As the unit of analysis is at an organizational level, the grand theories present a firm perspective. Why do companies need sustainable digital transformation in their SCM?

Stakeholder theory (ST) is one of the core management theories describing the role that a company has in society in terms of value creation and in relation to its key audiences (e.g., shareholders, customers, employees and partners, and the government; Freeman, 1984). ST has been seen as one of the founders of the business ethics research stream that has led to modern sustainability research. Furthermore, it has articulated the role that a company has in relation to its owners (shareholders), who require dividends as a return for the risk-taking in investing the capital. It translates to imperatives for a firm to grow and be profitable. The responsibility toward customers is to provide value and reliability, which marketing research has further focused on. At the end of the thesis, the ST framework from Friedman and Miles (2002) is borrowed to encapsulate the role of RFID in SDT, and in firms. In that context, technology is seen as a stakeholder, or an institution, for a firm that needs to decide how to approach the relationship.

While ST presents the imperatives for a firm, market orientation (MO) theories translate how a company shall succeed in the marketplace. A couple of its notions are interesting from an SCM perspective: (i) MO theories have evidenced that companies succeeding in markets have emphasized customer and market focus, and cross-functional collaboration (Narver and Slater, 1990). (ii) The source for understanding stems from market intelligence divided into information generation, dissemination, and responsiveness

(Kohli and Jaworski, 1990). (iii) Research on customer value (see, e.g., Woordruff, 1997) explains the expectations that customers today have in an increasingly digitized society, for instance regarding visibility of availability, shipments, and craving for sustainable and new digitally connected products. (iv) The studies done on competition focus (see, e.g., Katz and Shapiro, 1994) explain the industry standards and context where a firm operates, which has an implication for SCM in terms of capabilities and service levels.

1.4.3 Radio-frequency identification technology

Radio-frequency identification (RFID) technology is based on the reflection of radio frequencies. An RFID system comprises two hardware elements: tags and readers. A reader has one or more antennas that emit radio waves and receive signals back from an RFID tag. Tags can be passive or active; passive tags reflect the antenna signal containing unique data in the reflection from the tag, while the active tag is powered by batteries and independently sends signals to readers (FDA, 2022).

RFID technology was studied between 1940 and 1960, when the technology was discovered as a method for identifying troops in a military setting. In the 1990s, RFID was linked to companies' supply chain management and article tracking (Landt, 2005), which shifted the focus of the technology to commercial applications. The key objective at the time was to increase automation, which established a research theme of automated identification, or the so-called auto-ID market (Sarac et al., 2010). Before auto-ID, manufacturing and logistics had operated through optical coding, such as bar codes, if at all. The active and intelligent packaging research theme came up through food sector packaging studies in the mid-2000s, when smart chemical labels and RFID were linked to the traditional packaging framework, listing the roles of packaging, i.e., containment, communication, convenience, and protection (Yam et al., 2005). Communication in the model included promotional messaging as well as product identification, which RFID technology was linked to, meaning that packaging was regarded as "intelligent." Thus, RFID became technology not only for internal but also for external uses. Technology-wise, RFID was divided into two methods: ultra-high frequency (UHF) for auto-ID and supply chain management, and near-field communication (NFC) for digital marketing and customer experience.

1.4.4 Data acquisition and quality

Data has been recognized as a source of competitive advantage for companies in different industries (Cronholm and Andersson, 2020). The possibilities of capitalizing on data have escalated for two main reasons: the number of data sources has increased, while the costs of handling and using it have decreased (Cronholm, 2017, Fukuda, 2020). On the other hand, researchers note that data models have been developing faster than data quality (Jain et al., 2020), despite the fact that data quality has a direct impact on information quality, decision-making, and business success (Jordan and Mitchell, 2015). Data quality exists as a factor throughout the data life cycle, including collection, processing, storage,

processing, internal use, external disclosure, and use in downstream applications (Hoeren 2018). In the data collection (acquisition) context, three key requirements have been set for data quality: completeness (reliable), accuracy (data resolution), and timelines (non-obsolete), in which comparison RFID as a technology outweighs traditional barcode and manual marking methods (Thorne et al., 2014). Compared with some other modern technologies (e.g., machine vision), RFID does not require a line of sight and it can read up to 1,000 products per second, which makes it useful in many SC circumstances, for instance at departure gates in a transportation terminal (Yan et al., 2006). Furthermore, RFID provides unique identification for each item and can thus separate two similar products from each other (ibid.).

1.5 Outline of the study

Chapter 1 has introduced the background for the dissertation, including the purpose and focus of the study, the research questions, and the motivation for the study. Chapter 2 continues by reviewing the key theoretical foundations, which are condensed into two areas: Supply Chain 4.0 introduces the new paradigms set for operations, while the Supply Chain Visibility section discusses the visibility aspect. Chapter 3 explains the research design with explanations of the theoretical approaches, research strategy, process, and finally the validity and reliability of the research. Chapter 4 presents a recap of the key contents of the publications, which are fully included in Part II of the dissertation. Chapter 5 draws conclusions and implications from the research. Chapter 6 includes references. To illustrate the structure of the thesis, Table 1 below is provided.

Table 1: Structure of the thesis

INPUT	CONTENT	OUTPUT
Why is this thesis needed?	1. Introduction	Goal, positioning, gaps, and structure
What is the current knowledge of the subject?	2. Theoretical background	Supply chain 4.0, supply chain visibility
How is the empirical research carried out?	3. Methodologies	Philosophical orientation; approach to theory building; research strategy, data collection, and analysis
What were the findings?	4. Summary of Publications I-VI	Goals, findings, and contributions
What are the conclusions and contribution to current theories?	5. Conclusions	Summary of findings, contribution to current theories, limitations, and future research needs

2 Theoretical Background

Contemporary supply chain theories related to digital and sustainable renewal are discussed in a research theme initiated by I40 and taken forward as SC4. As presented earlier in Figure 4, theories are approached deductively, proceeding from a broad SC4 theme to a more specific SCV forming the theoretical core for the RFID-specific investigations focused on in the empirical part of the dissertation. Table 2 introduces how the theoretical themes connect with the research papers responding to the presented research questions.

Table 2: Theme of key theories employed in the study

PUBLI-CATION	FOCUS OF THE RESEARCH PAPER	THEORETICAL THEMES
I	Use of RFID in product identification	SC4 (DT), SCV (PIT, RFID)
II	Sustainability of RFID	SC4 (SUS, DT)
III	RFID providing Digital Twin	SC4 (DT), SCV (PIT, RFID)
IV	RFID automating Service SC	SC4 (PIT, RFID), SC4 (servitization)
V	RFID catalyzing organizational change	SC4 (BM, DT9, SCV (IoT)
VI	Cross-functional collaboration	SCV, SC4 (BM, DT)

2.1 Supply Chain 4.0

Industrial revolutions have transformed manufacturing systems and society in the past through mechanization via water and steam power, mass production in assembly lines, and automation through computer and information technology. The current fourth revolution focuses on cyber-physical systems using several disruptive technologies such as artificial intelligence to modernize the production ecosystem through higher cognition: intelligence, automation, and human-machine interactions (Tay et al., 2018; Schwab, 2016; Haradhan, 2019; Williams and Tang, 2020). It has been proposed that like products, supply chains have life cycles that define and explain the evolution of the concept on a micro and macro level (MacCarthy et al., 2016). Technology and innovation form one of the change forces among the six-supply chain life-cycle drivers, while others include markets and competition; economics, policy and regulation; procurement and sourcing; SC strategy; and re-engineering (ibid.). The life-cycle view of the SC underlines that the changes that are now connected to I40 are broader than technology and link, e.g., to policies and economics that should be considered to avoid too narrow an interpretation of the phenomena.

While I40 focuses on the fundamental change in the production ecosystem enabled by disruptive technologies, the supply chain 4.0 (SC4) discussion peaked in 2018 and focused on the changes in logistics in the production system, representing the transformation to a next-generation agile digital supply chain influencing the service, cost, and capital intensity of operations (Alicke et al., 2016; Garay-Rondero, 2020). Researchers (Frederico et al., 2018) report that the concept of SC4 has conceptually been in a formation phase and is mostly driven by investigations on the digital technologies fostering SC process improvements. As illustrated in Figure 5, they (ibid.) observed 21 technologies that are considered to drive nine identified process levers optimizing the strategic impact, customer and supplier focus, and cost and profitability aspects of SC. The technological focus has already been present in the digital supply chain research theme, which preceded the emergence of SC4 (Garay-Rondero, 2020).

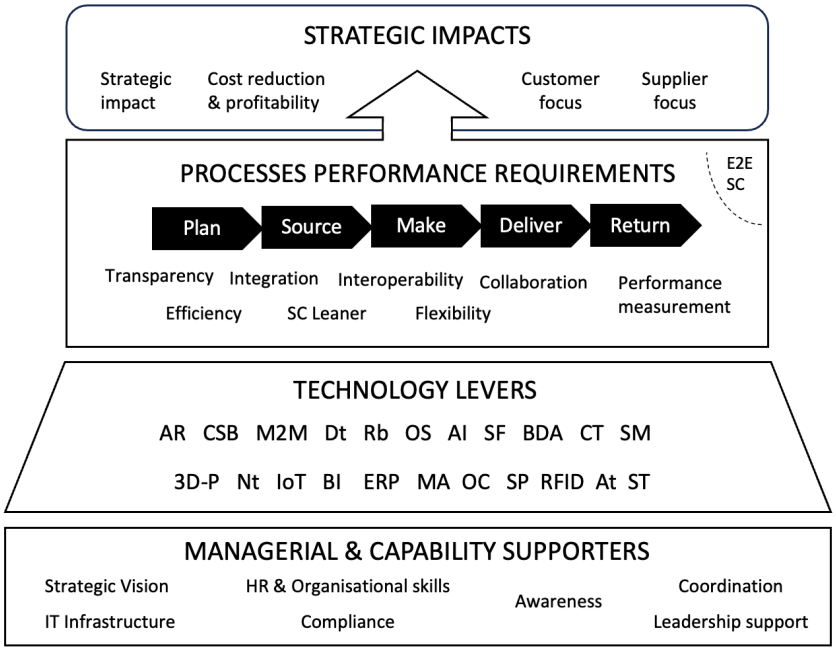

Figure 5: SC4 concept (Frederico et al., 2018)

In SC4, one of the key sources of new value is enhanced supply chain interactions (Ghobakhloo, 2018). It offers system-level efficiency through automation reducing manual work, and it can provide a faster reaction to demand variations (spatial and temporal) and, on the other hand, be used to provide an improved end-customer experience, e.g., through tailoring products and services, and providing better visibility of the delivery (Barreto et al., 2017; Ghadge, 2020; Alicke, 2016). The SC4 capabilities are built on connectivity and data-centricity (Kiran, 2021), which change the key concepts of SCM in terms of how value is created, and operations are managed (Garay-Rondero et

al., 2020). At the top level, researchers believe that technologies will simply reduce the current four-step approach (supplier-producer-distributor-consumer) to only two steps (supplier-consumer) in the longer term (Ferrantino and Koten, 2019). This would entail the erosion of middlemen, whose role it has been to provide demand forecasting and warehousing.

At the same time, customers' expectations are growing; online trends have led to increased service expectations and more detailed orders (Alicke et al., 2016). For supply chain practitioners this means a change in traditional requirements and the need for faster and more efficient, flexible, and precise management of operations using a versatile set of technologies to achieve it (ibid.). The speed of delivery in particular has quickly developed in global metropolitan areas, where e-commerce giants can deliver a product within hours from the order using advanced technologies (Perez, 2021). Despite the centrality of speed as a customer preference and loyalty driver (see, e.g., Shirreffs, 2020), SC discussions have only vaguely addressed it through the themes of supply chain agility (Oliveira-Dias et al., 2022) and last-mile performance (Giuffrida et al., 2022). From the marketing perspective, supply chain scholars note that SC4 can boost customer experience: automation, analytics, smart sensors, and new data sources enable firms to make the customer experience easier and more convenient than ever before (Hoberg and Alike, 2016). However, the new kind of understanding and conceptualization of marketing and services has been neglected in recent years and threatens to make marketing outdated and irrelevant, if it does not respond to new realities open-mindedly (Grönroos, 2020).

From a company perspective, investing in new technologies of I40 (and similarly SC4) requires funding, and it has been proposed that larger companies are better positioned to utilize the opportunities of the new era due to their strength to make needed investments (Wichmann et al., 2019). The key value for companies investing in the next era of technology is their ability to reach a higher level of productivity, where a relatively small number of employees are serving a broad customer base and operations (Kagermann et al., 2013).

The internet of things (IoT) has a primary role as a key technology in SC4 (Tu et al., 2018; Ferrantino and Koten, 2019). The vision of IoT is that every object has its digital identifier, which is readable through reading infrastructure, thus digitizing product identity and closing the gap between the digital and the physical (Porter and Heppelmann, 2015; de Vass et al., 2021). The data captured from the physical world connected with intelligent applications and independent networks forms the three dimensions of IoT (Ali et al., 2015), which is the technical basis for the digital supply chain. The goal of IoT is to create a global network of infrastructure that enables an easy exchange of goods, services, and information (Tu, 2018). In an industrial context, using IoT to manage manufacturing and supply chains is also known as IIoT, where RFID has been identified as one of the key technologies enabling such applications (ibid.). As an example of that, a model measuring companies' SC4 maturity investigates the adoption of RFID in operations to achieve agility, resilience, and reliability, identified as the key supply chain

trends to be aligned with (García-Reyes et al., 2022). This, as an example, signifies the centrality of RFID technology in SC4.

In traditional scoping, SCM has included manufacturing as part of its processes. Manufacturing in this study has been excluded from the investigation in most parts and it has been only regarded from the logistics perspective. I40 has been studied by manufacturing scholars through the lean manufacturing philosophy empowered by smart technologies supporting e.g., optimized use of machinery, quality control, preventive maintenance and increase in safety and performance (Sanders et al., 2016). In both SC4 and I40, manufacturing connectivity remains central, but while SC4 is interested in product flows, the manufacturing theme builds on connectivity to machinery. Lean as a concept is also present in SC4, where its six principles (demand management, waste and cost reduction, process and product standardization, industry standards adoption, cultural change competency, and cross-enterprise collaboration) are claimed to be well-suited but relatively new (García-Reyes et al., 2022).

SC4 drives functional integration within firms, which is followed by the rise of data as the key source for functional steering that is jointly used and nurtured to optimize business processes (Ardito et al., 2018). The outcomes of a renewed "operating system" shows in three areas: customer value, higher performance and efficiency, and societal well-being (Lusch et al., 2009). These value domains are reflected by servitization, digital transformation, and sustainability below.

2.1.1 Servitization

The growth of information technology enables the expansion of service provisioning networks. The reasons for servitization lie in products that become increasingly technical—smart and connected—with embedded intelligence (e.g., microprocessors). It increases the innovation of new (service) concepts such as smart self-serving, followed by increasing abilities to harness digital communication and coordination to further innovate new value streams and services, such as related transportation services (Lusch et al., 2009; Porter and Heppelmann, 2014). Scholars talk about the dematerialization of products, which has provoked the digital servitization research area focusing on analyzing the role of digital technologies in servitized product firms (Vendrell-Herrero et al., 2017). These also include electronic retailers who have disrupted traditional product retailing, such as Amazon in book retailing (ibid.). Figure 6 describes the transition from physical products to services and ecosystems, as presented by Porter and Heppelmann (2014).

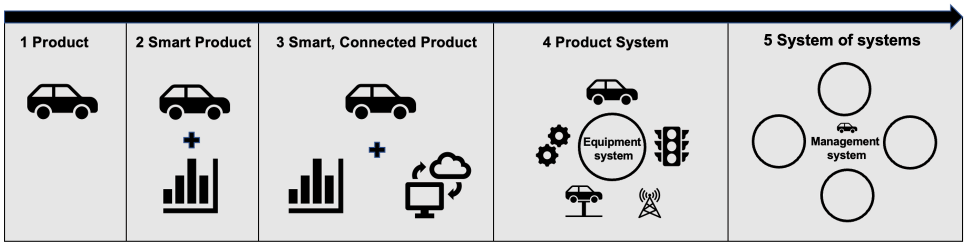

Figure 6: Technology-driven transition from products to services (Porter and Heppelmann, 2014)

On a strategic level, the marketing function in firms has traditionally guarded companies' market insights and customer value creation (Woodruff, 1997; Lindman et al., 2016), but as businesses gear to services in modern markets, their value creation and (internal and external) roleplay seek adjustments. As an example of intra-organizational changes, scholars have lifted the need for tightened coordination of supply chain management and marketing (SCM-M), which delivers value, e.g., through improved availability and better control of stock-outs (Ardito et al., 2018; Lusch et al., 2009). As proof of relevance, integrated SCM-M has been proven to outperform companies operating in a traditional, siloed organization (Esper et al., 2010). Also, it has been shown that servitization changes traditional duties, e.g., in the supply chain servitization leads to operating an infrastructure to produce services (Vendrell-Herrero et al., 2017). From the SCM perspective, research has been conducted to understand the influence of servitization on upstream and downstream relationships and their power dynamics (ibid.). Interestingly both ends of the value chain can retain power through the controlling of resources (upstream) or consumers (downstream), while the role of the middlemen between the two ends remains debatable (ibid.; Grant and Startz, 2022). On the other hand, the emergence of servitization has contributed to the emergence of service operations or supply chain management (SSCM), which analyses the management of a service-led supply chain (Wang et al., 2015; Choudhury et al., 2020). Services can be the only product of the supply chain (Service Only, SOSC, e.g., banking or aviation), or they can form an essential part of the supply chain (Product-Service SC, PSSC, e.g., food services) (Wang et al., 2015; Nagariya et al., 2022). The analysis of research released on SSCM suggests that existing research can be grouped into four key aspects: environmentally environment-friendly practices, market relationships, information technology integration, and adoption of industry-specific case studies (Choudhury et al., 2020). This reveals that sustainability, IT, and marketing are common themes in the SSCM. However, the researchers (ibid.) noted that production process and productivity remain the most prominent areas of interest in the field.

External roleplay changes imply that companies need to form strategic partnerships and ecosystems, which together deliver value to end customers (Porter and Heppelmann, 2015; Kolagar et al., 2022). The purpose of an ecosystem is to complement one's offering with products and services that are needed to capture the full value of the service

(Grandinetti et al., 2020). Over time, managing the ecosystem in a way that distributes benefits, risks, and opportunities evenly can be complex, as well as integrating processes that are needed to make the end-customer experience seamless (Brestlin et al., 2021; Tsujimoto et al., 2018). For these reasons, businesses have struggled to capture the full value from ecosystems so far (Asplund et al., 2021). Researchers propose that business model, culture, and (digitalization) capabilities form key enablers at a firm level to adopt an ecosystem approach (Kolagar et al., 2021). It has also been stressed that ecosystems are not static, but also evolve along with competition and have their dynamics, which determine the destiny of companies participating in the ecosystem-led markets (ibid.). The shift to ecosystems, where the core is smart connected products and their alliances, is a radical change for companies who need to redefine their core business and strategy with effects on relationships, processes, and structures (Porter and Heppelmann, 2015).

This has all led to confusion about functional roles and their substance. For instance, the traditional role of marketing, which was fitted to transactional physical product sales or relationship marketing approach in services, has now led to a renewal of traditional marketing concepts such as "marketing mix." Nosalska and Mazurek (2019) present the 5C model to update the traditional 4P concept as illustrated in Figure 7. Service marketing researchers claim that services in firms are mainly something that the marketing function leads in firms, and thus service school researchers must take this challenge to stay relevant (Grönroos, 2020).

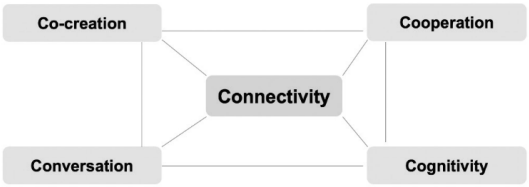

Figure 7: Updated marketing model "5C" (Nosalska and Mazurek, 2019)

2.1.2 Digital transformation

Digital transformation (DT) can be defined as a concept to re-engineer business as a mechanism to capture information technologies' potential, as a profound transformation of organizational activities (Junge, 2019). Common aspects companies consider with DT are operational processes, customer experience, and business model, which allow re-programming, data homogenization, decentralization, and autonomy of processes (ibid.). Scholars propose that DT evolves in organizations through stages of digitization (creation and utilization of digital assets for automation) and digitalization (formation of independent units and networks) before reaching DT, where new business models (BM) and platforms emerge (Saarikko et al., 2020; Verhoef et al., 2021). Technology, competition, and customer behavior drive companies to DT, and during the stages, the

strategic imperatives include digital resources, organizational structure, growth strategy, and metrics and objectives set to propel the journey (ibid.), as illustrated in Figure 8.

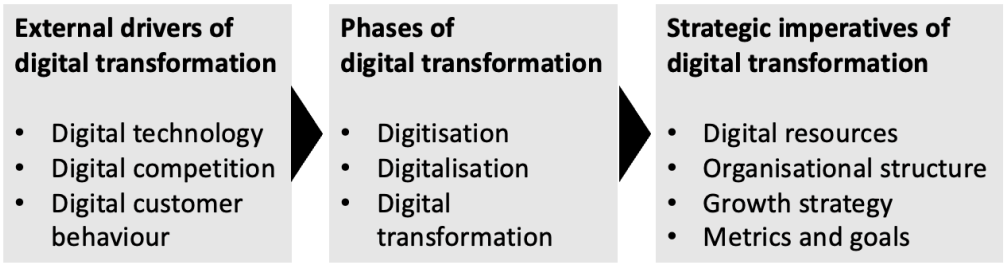

Figure 8: Digital transformation as a flow (Verhoef et al., 2021)

Porter and Heppelmann (2014) propose that IT has historically provided powerful capabilities to companies creating development waves in the value chain. The first wave (1960–70) was driven by automation, the following wave (1980–90) was powered by supply chain integration, and the most recent (2000–) wave was created by digital connectedness (ibid.). While connectedness is currently a universal technological theme, in many industry verticals the more precise "technology stacks" are built around the specific use cases proven and tailored for the industry (Saarikko et al., 2020; Anderson and Caimi, 2022). The main drivers for today's digital transformation are volatility, uncertainty, complexity, and ambiguity (El Hilali and El Manouar, 2019; Hamidi et al., 2018). The declining price of IT components (such as sensors) has been identified as an accelerator of the shift (Buntak et al., 2021).

Despite IT initiating the DT, academia underlines that DT is at the end least about technology (Tabrizi et al., 2019; Nadkarni and Prügl, 2020; Saarikko et al., 2020). It has been proposed that the roots of unsuccessful DT projects are in neglecting strategy, customer experience, employee fears, and company culture aspects, which should be served by technology and not vice versa (Tabrizi et al., 2019). It has been observed that the adoption of DT varies depending on the company type, ranging from product- to service- and technology-oriented firms (Saarikko et al., 2020).

In its highest form, digital transformation leads to updating the business model in a firm and re-engineering the value creation concept for greater profitability and business performance (Reim et al., 2022). Heskett (2017) sees that capital, labor, and technology are key domains in value creation, which influence the capacity and capability that an organization holds. These levers are the basis for innovative value-creation strategies that generate process, product, and transaction innovations to create imperfect competition, destruct existing products, and create new markets and demand (ibid). In the new growth theory, Heskett (2017) argues that commoditization erodes value, while improvements provided by innovations drive value creation. Besides creating value, to succeed an

organization must deliver and capture value; Figure 9 exemplifies how small and medium-sized companies are dealing with fundamental questions of a company intending to reconfigure the role and operational model in dynamic markets by understanding how the digital capabilities are transforming businesses and opening up new opportunities (ibid.; Martin et al., 2019). The "business model canvas" (BMC) has been widely used by practitioners to outline the configuration and key elements of a business model and illustrate alternatives that companies have in organizing the business for revenue, partnerships, and costs (Osterwalder and Pigneur, 2010). However, the researchers have noted (Osterwalder et al., 2005) that the value concept is at the core of the business model design, and questions such as processes and activities link to the enterprise model, defining how the company operates. Furthermore, it has been argued that value creation renewal often—if not always—requires innovative thinking in realizing new opportunities and how to capture it within a contemporary business context; thus, academia talks about business model innovation (see, e.g., Chesbrough, 2007).

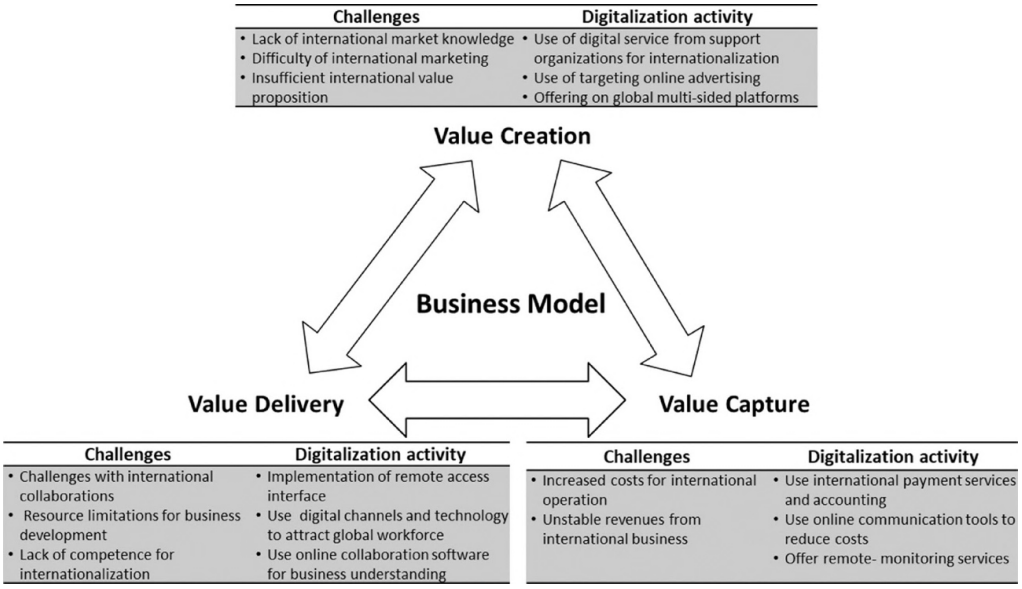

Figure 9: Value aspects of a business model exemplified in an SME context (Reims et al., 2022)

A digital transformation of SC primarily means that the digital lever profoundly changes the supply chain management and function. It also implies that this can lead to fundamental discussions of the whole business model. The previously introduced value perspective remains central to both discussions. Scholars underline the need for a holistic understanding of a business in building new models to create, deliver, and capture value (Martin et al., 2019). They lift multi-actor collaboration that characterizes servitization.

Although BM promises a significant opportunity to upgrade a business by re-engineering value concepts with digital capabilities, it should be remembered that several studies have verified that large-scale transformational changes are often time-consuming, risky, and fail to deliver (Davenport and Westerman, 2018). One of the reasons is the "unknowns of the new digital frontier," and management attention that must be paid to the new, which is different from traditional delivery of business (ibid.). Some scholars are raising the importance and constant need for practical knowledge in IT and digitalization, stating that the current academic discussion of the DT must move to a functional level in firms (Brynjolfsson et al., 2022). This turns the focus back to digitization, which was previously presented as the first step for companies in their DT: one needs to first succeed in digitizing the analog and to digitalize the current business before transformation can happen. This applies especially to large firms that have an ongoing business running in a traditional set-up, which can be costly and slow to even digitize.

2.1.3 **Sustainable supply chain**

Digitalization plays a role in contributing to the UN Sustainable Development Goals. Without transforming the realities of existing businesses, the future cannot be solved sustainably (Bican and Brem, 2020). Researchers (ibid.; El Hilali and El Manouar, 2019) argue that the digitalization theme has acted for years as a change agent in companies that continuously update their strategy to comply with societal change, and thus sustainability as a pertinent requirement naturally absorbs into the renewal agenda and process carried within digitalization task forces.

In the corporate renewal process, innovation plays an instrumental role as a mindset (Bican and Brem, 2020) but is separate from the innovation management practices typically associated with and organized for new product development (Appio et al., 2021; Adams et al., 2006). Digital per se can drive sustainability objectives by rationalizing processes (e.g., from traveling to remote meetings), but it can also create new sustainability challenges, e.g., from an environmental perspective on a new waste stream or expanded energy use, as seen with cryptocurrencies (Bican and Brem, 2020).

On a company level, digital does not automatically drive sustainability, which sets a need to separately scrutinize the sustainability aspects of new tools and projects within digital transformation. However, the direction from sustainability to digital is not one-directional either, as digital capabilities can also be deployed solely to drive sustainability objectives within an organization, for instance by using artificial intelligence to optimize waste, identify green opportunities, and generate ideas (Haefner et al., 2021). In general, digital transformation has been seen as a driver and an enabler in companies, suggesting that for businesses to survive the current market realities, they need to possess adequate digital capabilities and have them aligned with sustainability (ESG) factors (Gomez-Trujillo and Gonzalez-Perez, 2021).

On a macro level, researchers (Dyatlov et al., 2019) argue that the building blocks of a modern society include systems of the circular economy, clusters, networks, business

incubators, and technology platforms. They (ibid.) foresee that technologically nano, bio, information, and cognitive processes are converging, forming the agenda for the digital economy, where sustainability is built in as an integral part of the structure.

I40 and SC4 as trends transforming businesses and operations are expected to drive sustainability, enabled by the better control of waste, predictive actions, and overall optimization (Javaid et al., 2022). From an environmental perspective, the key areas include optimization of natural resources, energy, material, and waste and emissions (ibid.). Real-time capability connected with cloud and data management is at the heart of the solution driving sustainable outcomes, where life-cycle analysis provides the method for measuring impact and making production smarter (ibid.). It has been suggested that until today, SCM and ESG have lacked a link between each other, and thus, it has become topical in firms who need better visibility of the SC and alignment of measures integrating ESG, business performance, SC, and regulation (Dai and Tang, 2022).

However, some prominent scholars from the sustainability field have claimed that the key substance of sustainability lies in its long-term orientation, increasing the relevance of the time perspective in company strategy (Bansal and DesJardine, 2014). Their (ibid.) translation of sustainability approaches the corporate strategy perspective by requesting managers to seek sustainable competitive advantage and focus on the processes and dynamics in creating one. Although this aspect of sustainability is more philosophical, it integrates well with the SC4 imperatives. The traditional and more hands-on view of sustainability with the three pillars of ESG (Barbier, 1987; Purvis et al., 2019) integrates process and performance efficiency driven by SCM with the environmental imperative of ESG (Cezarino et al., 2018). However, sustainability practices in SCM have up to now been more skewed toward product-oriented SC, while the service SC has still been narrowly covered (Nagariya et al., 2022). In their sustainable practices typology (ibid.), technology plays a role in driving operational and organizational performance, but it does not represent only one area aside from many others, e.g., safety culture. Although ESG has formed a management trend in organizations in recent years, it is reported to suffer from unstandardized reporting, which leads several firms to hold back and be confused (Dai and Tang, 2022). It is also reported that the connection between ESG and OR remains understudied in the research literature (ibid.).

2.2 Supply Chain Visibility

This section introduces the value and concept of visibility in SCM. The content is divided into three levels: on the top level, the visibility concept is outlined and discussed, after which the section continues by introducing product identification and tracking as the concept behind the visibility, and finally, RFID as a technology enabling the capture and sharing of data is introduced.

2.2.1 Visibility as a supply chain concept

Supply chain visibility (SCV) is the key challenge for firms in driving the SCM forward and becoming compliant with contemporary sustainability requirements (Dai and Tang, 2022; Barratt and Oke, 2007). It has been verified by several studies as being a management priority in firms, and yet is difficult to achieve (see, e.g., Enslow, 2006; Sarker et al., 2016). Some researchers claim that SCV is transformational to companies through its ability to drive operational excellence and update technical strategic capabilities (Somapa et al., 2018).

The precise definition of SCV has been debated, and there have been inaccuracies in using the term (Agca et al., 2019; Somapa et al., 2018). In this study, SCV is seen as a capability to "capture and share SC information" as proposed by Holcomb et al. (2011). SCV is closely related to IT and automation (Rai et al., 2012), and thus, the technological aspect has importance as a concrete prerequisite (Agca et al., 2019). SC data can be captured through sensors on a mill floor but also from point-of-sale cashier systems, which provide data on demand and from the endpoint of SC (Wei and Wang, 2020). Hence, the scope of SCV data capturing spans from sensors to IT systems. The other part of SCV, data sharing, is practically implemented through the dialog between SC partners' systems, and it is conceptually discussed through SC integration, flexibility, and agility themes (see e.g., Deghedi, 2014). However, SCV has largely been seen as an inter-organizational challenge, affording less attention to much of the intra-firm data capturing and sharing. Prominent marketing journals have raised internal cross-functional information generation and sharing as one of the key contemporary challenges among marketing-led organizations (Jaworski et al., 2016). For such use, SCV could be taken more broadly into use in new product development, marketing promotions planning, and offering decisions as made by some of the leading SC organizations, such as Zara/Inditex and H&M in the fast fashion segment, to drive SC responsiveness (Ferdows et al., 2003; Taplin, 2014). In retailing, visibility is needed to support a modern omnichannel operating system, where online and offline channels are integrated through data to create a unified consumer experience and efficient managerial model (Simone and Sabbadin, 2018). Furthermore, aside from supply chain visibility, academia acknowledges several different visibility sub-types (including product, demand, order/payment, stock, shipment, and supply), which helps organizations to split the broader visibility requirement into specific nodes, needing a solution to create common visibility of the complete chain (Saghiri et al., 2017).

As SCV provides information on customer demand and inventory levels, it has a positive impact on demand forecast accuracy, alignment of production and demand, delivery performance, and inventory levels throughout the SC (Somapa et al., 2018). Achieving visibility in operations has also been seen as a gateway to higher cognition and new value creation levels in SCM (Schuh et al., 2017; Somapa et al., 2018), as illustrated in Figure 10. However, the benefits of SCV exceed operational efficiency and organizational capabilities (Somapa et al., 2018); for instance, accurate information is found to be a key element in SC integration (Swink et al., 2007) and improving resilience at the time of disruptions (Agrawal et al., 2021).

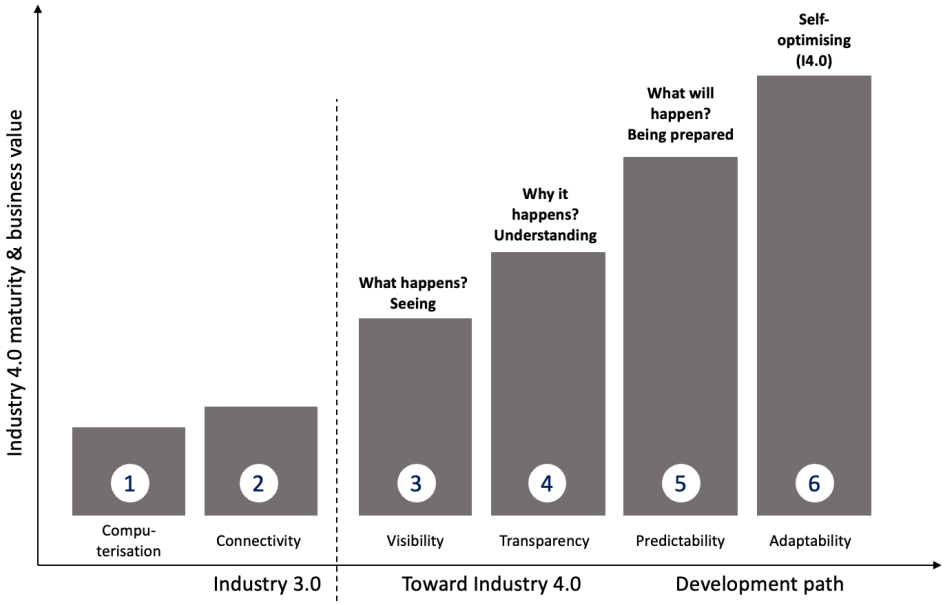

Figure 10: Visibility as a gateway to I40 (Schuh et al., 2017)

Visibility and transparency as terms are often used as synonyms, while e.g., Schuh et al. (2017) use transparency as a step where understanding of the visibility signals is being provided through advanced analytics, for example. SC transparency as a term is also used when analyzing the ESG performance of an SC (see, e.g., Gualandris et al., 2021). In such a context, researchers note that "SC structure influences how transparent the supply chain is, and hence, what kind of ESG reporting can be made." To conclude, it can be proposed that visibility refers to capturing and sharing granular SC data, while transparency refers to classifying and processing data to provide an understanding of what the data means. However, the line between visibility and transparency creates another fuzzy area in SCV; for instance, Cherrett et al. (2015), in their research on automated information capturing, identify other aspects of data, e.g., the fill rate, stock quality, and locations as part of the scope, which includes elementary data processing.

SCV can be arranged in several ways, where the primary goal is to establish a method for product identification and tracking prior to data sharing practices. In setting up the SCV, the starting point is formed by the use cases that are central to the company. For instance, industries involved in fresh products (such as grocery retailers) have a specific interest in controlling the obsolescence of the inventory and manage related product safety (Regattieri et al., 2017), while luxury product industries are specifically interested in SCV solutions combating product anti-counterfeiting (Cheung and Choi, 2011), where for instance in product returns one needs to be able to identify the originality of the product. Typical general SC performance indicators followed within SCV projects include

inventory accuracy, stock-outs, shrinkage, customer satisfaction, mark-downs, and profit margin (Unger and Jain, 2016). Many studies have shown (e.g., Raman et al., 2001; Unger and Jain, 2016) that companies' inventories are widely inaccurate, leading to underperforming SC and push orientation in operations management. Depending on the industry, the inventory record inaccuracy (IRI) has been reported to be at a 30-80% level (Unger and Sain, 2016; DeHoratius and Raman, 2008; Shabani et al., 2021), which has led to several managerial challenges within SC. For instance, in the bullwhip effect, small demand changes lead to exaggerated supply chain reactions and hence additional costs (see e.g., Buchmeister et al., 2008; Lee et al., 1997). Furthermore, it has been proposed that SC collaboration and data sharing practices can resolve the negative consequences of bullwhip and ripple effects (Dolgui et al., 2020; Swink, 2007).

Research has proposed that accessibility, quality, and usefulness characterize SCV (Somapa et al., 2018). Feasible SCV methods depend on the SC context, which further depend on firm and industry-specific factors. Typically, the product assortment dictates how product identification and tracking can technically be done: different kinds of products and packaging types at grocery retailers, for example, vary significantly more than in fashion retailers, where textiles are generally uniform in terms of the product packing and materials involved, and are thus easier for technologies to master. Furthermore, the SC can be open or closed loop in terms of supply chain structure, which influences the end-to-end visibility of the SC (Usama and Ramish, 2020). Within a closed loop set-up, the SC manager has visibility of the point-of-sale in different regions and units, while the open loop supply chain operator needs collaborative frameworks with store owners to understand the demand and inventories at the point-of-sale. Data is powerful in the SCM as it allows driving efficiency in the SC, which further influences the SC cost, and eventually end-customer pricing. For this reason, information-sharing practices drive overall efficiency that benefits all parties in the same SC; increasingly the competition is against other supply chains and not just against individual firms (Nassar, 2011; Swink et al., 2007). Despite the obvious benefits, data sharing has been proven to be a complex topic for organizations, who aside from siloed thinking and budget limitations have fears of sharing business-critical information (Kalaiarasan et al., 2022).

While SCV has been a keenly studied research area in 2010 with studies connecting SCV to sustainable competitive advantage (see, e.g., Nassar, 2011; Nagy et al., 2022), the emergence of SC4 has revitalized the interest in SCV due to technological progress (e.g., artificial intelligence) and updated SC objectives (e.g., ESG). For instance, Usama and Ramishj (2020) suggest integrating forward and return logistics through modern technologies to drive the sustainability objectives of a firm in SCM. In Figure 11 the factors influencing SCV capability design in a supply chain are proposed, where SC4 is raised as a new theme influencing SCV configuration by the new needs it sets for data, and on the other hand, by the tools and capabilities that arise with it. The proposed model summarizes the previous literature with identified key elements. The time sensitivity of a product varies across categories, and in a perishable product offering, one needs a solution that tracks items in almost real-time and on an item level. On the other hand, the product assortment sets requirements on how the data can be extracted from the product. For

instance, RFID is known to require tailoring depending on the materials it is attached to, and thus, a versatile product offering may limit its use. The supply chain design related to SC structure and data utilization sets requirements for SCV implementation. Finally, the emerging SC4 practices provide tools and set requirements on how much and what kind of data the I40 applications (e.g., machine learning) require, for instance.

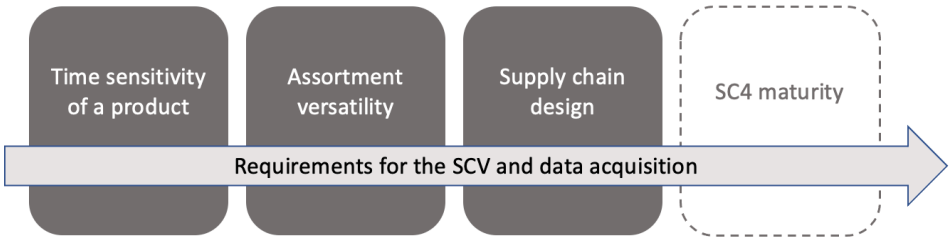

Figure 11: Factors influencing SCV capability configuration.

SCV can be inspected at the micro level in supply chain operations, at the meso level from the company perspective, and within the surrounding context at the macro level. As micro-level research, Agca et al. (2019) propose an SCV model based on a literature review, where information forms the basis for visibility. They (ibid.) analyze end results, means, and underlying enablers, and note that while technology is the key enabler in SCV, the management preparedness, data-sharing practices, and short lifetime of communication technologies and infrastructure costs make an end-to-end SCV implementation difficult. At a meso level, a holistic model by Kalaiarasan et al. (2022) illustrated (in Figure 12) the drivers, barriers, foundations, and effects of SCV in an organization. They (ibid.) point out that while RFID has been the leading technology in providing connectivity in SCV, blockchain has stood out as the forward-driving framework supporting data integration within SC. However, it is worth mentioning that while SCV is often seen as a technology project, both Agca et al. (2019) and Kalaiarasan et al. (2022) stress non-technical matters (culture, process, trust, management commitment, etc.) as antecedents of SCV. As a contextual macro-observation, it has been noted that general uncertainty within an organization's environment decreases the motivation for the SCV and information sharing with external parties (Maghsoudi and Pazirandeh, 2016). Although SCV would provide additional performance, it can be estimated that protective measures drive counteractions in an uncertain context. On top of the three levels of visibility presented, Kim et al. (2011) inspected SCV from the customer perspective, which links SCV to customer experience discussions and to requirements customers present to their vendors in b2b and b2c environments. In e-commerce, it has been observed that consumers tend to favor bricks-and-mortar firms whose inventories are

visible online, thus providing an opportunity for them to confirm the availability of goods prior to visiting the store (Gallino and Moreno, 2014).

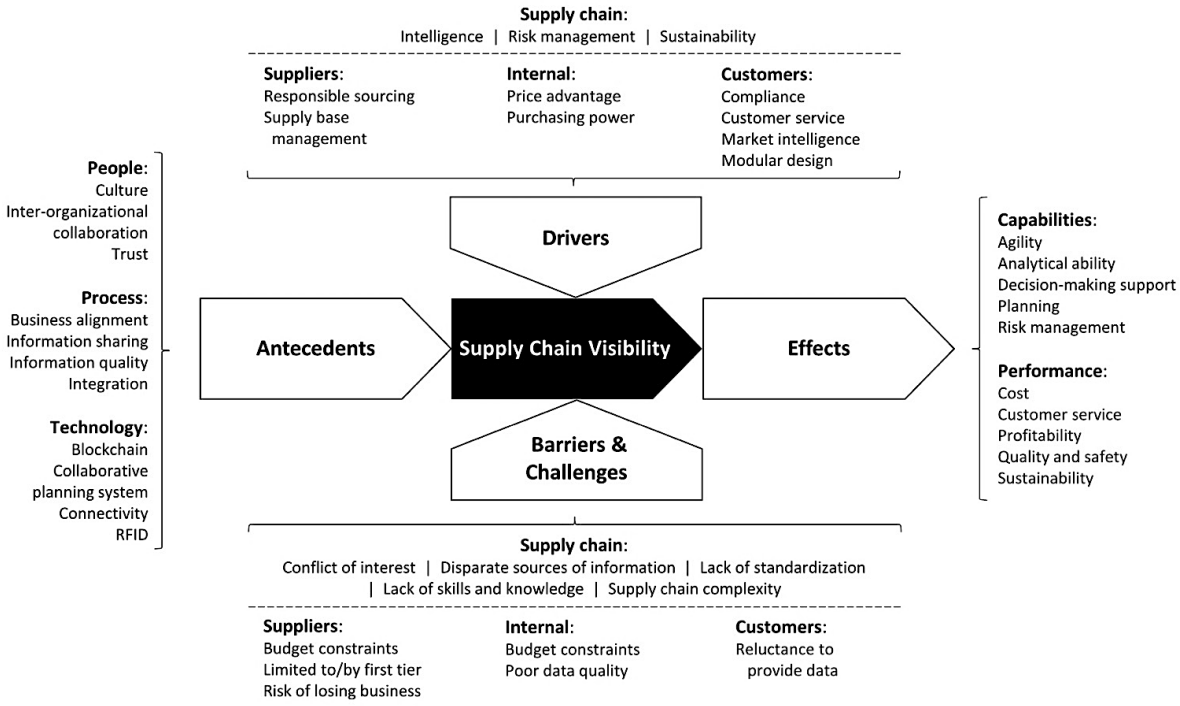

Figure 12: Company-level perspective on SCV (Kalaiarasan et al., 2022)

2.2.2 **Product identification and tracking**

As presented earlier, researchers (e.g., Acga et al., 2019) have stressed that connectivity forms a tangible challenge in SCV, while many other aspects are immaterial by nature: managerial-, conceptual-, and relationship-focused. Wireless product identification and tracking (PIT) solutions provide connectivity in SCV and allow companies to identify and track products or parts in the SC without physical handling (Kärkkäinen and Holmström, 2002). Typical technologies used for product identification include product coding, bar codes, and RFID (Regattieri et al., 2007; Musa et al., 2014). Automation in PIT typically leads to the use of broader IoT solutions, which are invaluable given their ability to drive efficiency gains and value-added tailoring of products, and even totally new business models (e.g., an order of a car with specific features requested to a specific store) at scale (Kärkkäinen and Holmström, 2002; Ben-Daya et al., 2022). In a broader sense, IoT detaches the physical work from its management, which virtualizes industries that have previously been tied to their physical presence.

Differentiated material flows set a challenge for SCs, which are traditionally not built for item-level tracking but for SKU-level handling. Itemization supports concepts such as build-to-order and mass customization, which manage unique product specifications in manufacturing (details related to product specifications), logistics (details related to time and location of the delivery), and require continuous communication and data sharing across the SC (Regattieri et al., 2007). It also highlights that item-level handling of SC is not specific to perishable goods but has a role in other fields.

2.2.3 RFID as an IoT technology

Aside from the commonly used process-based view in the SCM (as used, e.g., by Somapa et al., 2018), resource-based theories have been used to understand what it takes to provide SCV (Ben-Daya et al., 2022). Researchers propose that RFID, IIOT, and blockchain are key elements in providing visibility (Zelbst et al., 2020). In their model, the role of RFID is to provide data capture, while IIOT and blockchain have a role in information dissemination (ibid.).

Researchers report that typical IoT architecture deployment is built on layers, where sensing, networking, applications, and interfaces are separately built and then connected to each other (Xu et al., 2014), as illustrated in Figure 13. In the model, “sensing” refers to PIT, which lies at the core of the model. A data perspective is central in IoT frameworks, which focus on data capture and sharing. Earlier studies have confirmed that data sharing fosters strategic integration in SC, improving business performance and customer satisfaction through improved quality, efficiency, delivery, and flexibility of the SC (Swink et al., 2007; Ben-Daya et al. 2022). However, the key value of IoT as a technology framework is its ability to speed up processes (Ben-Daya et al., 2022). Together with cost reductions, reduced lead time drives performance improvements in organizations that can respond more quickly to demand fluctuations, redirect resources, and minimize inventories. Pull and just-in-time philosophies in SCM stress minimization of warehousing and inventories by aligning the pace of manufacturing with customer demand (Hopp and Spearman, 2004), hence the time aspect.

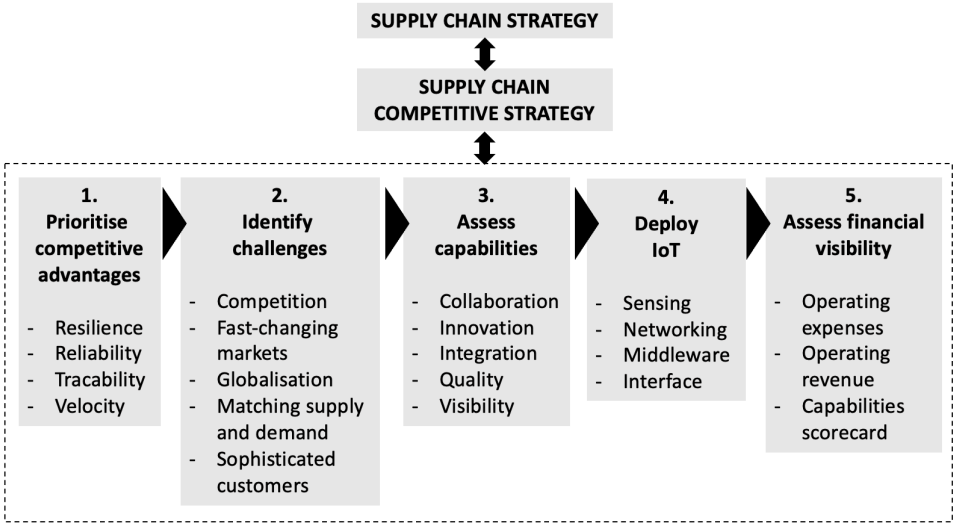

Figure 13: Framework for IoT deployment in SCM (Ben-Daya et al., 2022)

Researchers posit that the emergence of IoT technologies, which enables data capture and sharing, opens up many new questions to be answered e.g., on data governance, shared analytics, sensor network design, and risk management (Ben-Daya et al., 2022). These challenges, especially those related to immature culture and practices on data governance and sharing, are also confirmed by other studies reporting experiences from IoT implementations (de Vass et al., 2021). They (ibid.) report that top management support, stakeholders' inability to change, and new technology costs are pressing, regardless of data-related issues. Interestingly, there has been no questioning of trust in IoT technologies, despite some large-scale failures seen in the early days of SCV programs (Tu, 2018; Noor, 2022).

RFID is a decades-old technology with several widely known cases in the use of SCM (Kärkkäinen and Holmström, 2002). It enables SCV without a line of sight, at high volumes, and with a high data resolution in nearly real-time (ibid.). RFID has been seen as a key technology for sensing and reporting SC flows and driving cross-functional value in a firm's value chain (ibid., Melski et al., 2008; Taplin, 2014; Nagy et al., 2022). In food supply, for instance, the value of accurate and timely data comes from improved management of perishable items, tracking quality defects, and managing product recall (Regattieri et al., 2007). The value of IT in SCM has previously been outlined by Auramo et al. (2005), which is illustrated in Figure 14. Porter and Heppelmann (2014) provide another view on smart capabilities, listing that they monitor, control, optimize, and autonomize systems. This perspective is relevant as RFID on a product packaging also delivers value in cross-functional uses, e.g., in new product development where RFID

(NFC) can provide embedded end-user services such as product return functionality using smartphones.

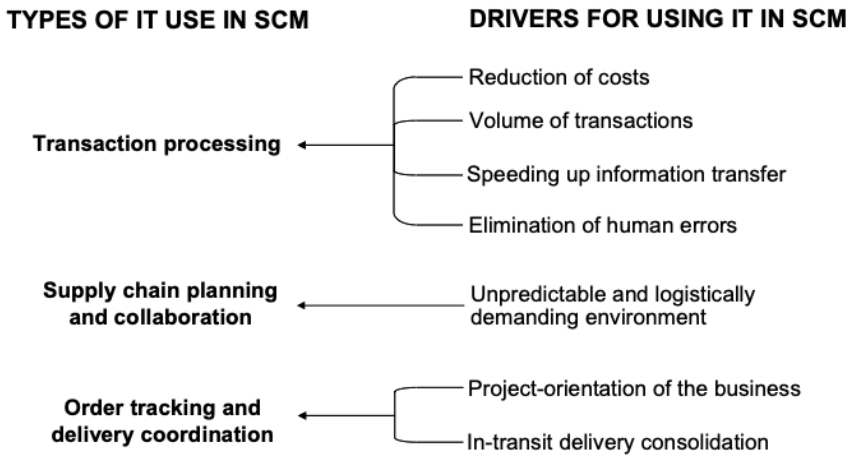

Figure 14: Value of IT in SCM (Auramo et al., 2005)

RFID systems can be implemented in various ways, and it is a strategic question for SCM to decide what an adequate level of visibility is to justify the investment (Melki et al., 2008). The higher the data resolution, the more comprehensive and thus costly RFID infrastructure is needed. This aspect is critical as it has been shown that the total cost of RFID in SC can absorb most of the value created through visibility in traditional SCV uses (Prajapati et al., 2022), which mostly accounts for automation benefits. On the other hand, in parallel to visibility, RFID can also drive value in quality, collaboration, and innovation, and thus it has been stressed that the SCV framework should be started with an end-use in mind to prioritize the competitive advantage (Ben-Daya et al., 2022) and manage the business case calculation defining the return on investment.

Traditional product identification has mainly been conducted through optical methods, which have strengths in terms of cost and integration in products, but lacks in automation and data accuracy as optical methods mostly cannot provide item-level accuracy. Figure 15 presents a recap of a comparison made on RFID and a barcode.

Table 3: RFID vs. barcode (Williams et al., 2014).

	RFID	BARCODES
Read rate	High, several hundred per second	Slow, reading one at a time Overlapping tags can lead to errors
Line of sight	Not required	Required
Robustness	Special tags available for various conditions	Vulnerable; snow, dirt, grime, and other challenging conditions harm reading
Security	Moderate to high, data can be encrypted	Low; labels easy to reproduce or counterfeit
Directional tracking	Capable; tags can be used to track the direction of movement	Not capable
Sensory	Capable; tags can be made to sense the environment	Not capable
Automation	High; wireless and intelligent capabilities exist	Low; reading often requires manual work
Triggering	Capable; tags can trigger events (such as alarms)	Limited due to need for line of sight
Adherence	Tags can be integrated to products and packaging	Only use of external labels
Cost	Moderate to high; from 7 cents to $70	Low; ca. 2 cents/each
Enterprise-wide search	Capable with standards coordination in collaboration with organizations, e.g., EPC	Limited

3 Methodology and Research Design

In this section, the research philosophy, design, and methods applied in the study are introduced. The first part introduces the philosophical orientations and the approach to theory development. The second part continues by discussing the research design with methodology, strategy, and techniques adopted. The third section focuses on the data collection and analysis, and the final section discusses the research quality aspects. The process adopted follows the "Research Onion" model developed by Saunders et al. (2016).

3.1 Philosophy of research and theory development

Research is a process focusing on knowledge creation in a particular field (Saunders et al., 2016). During the project, a researcher navigates by often unconscious assumptions and constantly makes choices that influence the process and its outcomes (Burrell and Morgan, 1979; Crotty, 1998; Creswell, 2009). Hence, it is important to become aware of and transparent about the beliefs and assumptions that lead the process and be able to work coherently so that beliefs are aligned with the research philosophy and design employed in the process (Saunders et al., 2016). This establishes credibility for the foundations the research holds (ibid.) and helps achieve a more profound understanding of the research.

Chia (2002, p. 16) compares research with any kind of manufacturing, where one applies technology (research philosophy) and production machinery (research method), raw materials (earlier studies and understanding) together with local capabilities (researcher's competence), which altogether determine the quality of the output. He also points out (ibid.) that legitimate and acceptable knowledge is judged by the philosophical attitude adopted by a community of researchers currently active in the field. The spectrum of philosophies of science varies, and the selection considered should be adopted from its field of research (ibid.). Business and management as an emerging discipline have absorbed influence from a range of older research disciplines, e.g., natural sciences, social sciences, and arts and humanities (Saunders et al., 2016). One of the key aspects is the relationship with truth, which in natural sciences is external and measurable, while in social sciences more subjective, socially constructed, and contextual (ibid.).

The beliefs and assumptions are described by ontology (what is the nature of the world), epistemology (what is knowledge), and axiology (what kind of values and ethics influence the research; Saunders et al., 2016). The fourth element is logic or methodology, which define how information is generated within the worldview (ibid., Chia, 2002). Researchers focusing on business and management research point out five distinct philosophies, which clarify the variance in the belief system—this is presented in Table 4 (Saunders et al., 2016) and used in this study to map out the alternative philosophical approaches. To

illustrate variance in approaches, Chia (2002), also a management researcher, acknowledges positivism, phenomenology, realism, and postmodernism, while Creswell (2009) simplifies the worldviews as positivism, constructionism, advocacy, and pragmatism.

Table 4: Five distinct research philosophies (Saunders et al., 2016)

ONTOLOGY	EPISTEMOLOGY	AXIOLOGY	METHODS
POSITIVISM			
Real, external, independent. One true reality (universalism). Granular (things). Ordered.	Scientific method. Observable and measurable facts. Law-like generalizations. Numbers. Causal explanation and prediction as contribution.	Value-free research Research is detached, neutral, and independent of what is researched. Researcher maintains objective stance.	Deductive, highly structured, large samples, measurement, quantitative methods of analysis, but a range of data can be analyzed.
CRITICAL REALISM			
Stratified/layered (empirical-actual-real). External, independent. Intransient. Objective structures. Causal mechanism.	Epistemological relativism. Knowledge historically situated and transient. Facts are social constructions. Historical causal explanation as contributions.	Value-laden research Researchers acknowledges bias: world view, experiences, and upbringing. Research tries to minimize bias and errors. Research is as objective as possible.	Retrodictive, in-depth historically situated analysis of pre-existing structures and emerging agency. Range of methods and data types to fit subjective matter.
INTERPRETIVISM			
Complex, rich. Socially constructed through culture and language. Multiple meanings, interpretations, realities. Flux of processes, experiences, practices.	Theories and concepts too simplistic. Focus on narratives, stories, perceptions, and interpretations. New understandings and worldviews as contributions.	Value-bound research. Researchers are part of what is researched, subjective. Researcher interpretations key to contribution. Researcher reflexive.	Inductive. Small samples, in-depth investigations, qualitative method of analysis, but a range of data can be interpreted.
POSTMODERNISM			
Nominal. Complex, rich. Socially constructed through power relations. Some meanings, interpretations, realities are dominated and silenced by others. Flux of processes, experiences, practices.	What counts as "truth" and "knowledge" is decided by dominant ideologies. Focus on absences, silences, oppressed/repressed meanings, interpretations and voices. Exposure of power relations and challenges of dominant views as contributions.	Value-constituted research. Researcher and research embedded in power relations. Some research narratives are repressed and silenced at the expense of others. Researcher radically reflexive.	Deconstructive—reading texts and realities against themselves. In-depth investigations of anomalies, silences, and absences. Range of data types, qualitative method of analysis.
PRAGMATISM			
Complex, rich, external. "Reality" is the practical consequence of ideas. Flux of processes, experiences, practices.	Practical meaning of knowledge in a specific context. "True" theories and knowledge enable successful action. Focus on problems, practices, and relevance. Problem-solving and informed. future practice as a contribution.	Value-driven research Research initiated and sustained by researcher's doubts and beliefs. Research reflexive.	Following research problem and research question. Range of methods: mixed, multiple, qualitative, and quantitative action research. Emphasis on practical solutions and outcomes.

These philosophies have similarities in their ontological relationship to truth, which can be connected to the historical aspect of management research stemming from natural and social sciences, as proposed earlier. The key question of the truth is whether it is objective or subjective in the research context (Saunders et al., 2016). Positivism (as one extreme) represents primarily quantitative, stable, and fact-like philosophy, where mathematical measuring tells the truth and helps to remove wrong constructs and simplify, e.g., decision-making (Creswell, 2009). In social sciences, there has been some criticism about whether positivism suits the research discipline, where context and object differ from the natural sciences (see e.g., Kuhn, 1970; Saunders et a., 2016). Interpretivism, as a qualitatively oriented philosophy, most commonly represents the other extreme of philosophies and is also called anti-positivism; it claims truth depends on whose perspective you look from (Saunders et al., 2016). Pragmatism in the philosophical spectrums is often the outlier, which tends to suggest that both previous extremes can be true if they seem to work, i.e., support an action (Kelemen and Rumens, 2008). Pragmatism emphasizes a utilitarian perspective and flexibly ties the empirical approach to the problem at hand (Creswell, 2009).

Saunders et al. (2016) point out that subjectively oriented philosophies (interpretivism and postmodernism in their categorization) have a different underlying orientation to change. The poles in this context represent perspectives described as “regulation” and “radical change” (ibid.). The first represents social orientation seeking to understand how to retain order, integration, and consensus, and focuses on the actual. Conversely, the radical change perspective seeks conflict, contradiction, and domination. (ibid.) The notion from Saunders et al. (2016) is valuable as it helps to understand the differences in the qualitatively oriented philosophies based on their underlying orientation and concern. Creswell’s (2009) “advocacy” (radical change orientation) and “constructivism” (regulation) follow the logic that Saunders et al. (2016) present.

From an epistemological standpoint, the two basic habits of knowledge creation have been identified as empiricism and rationalism (James, 1909; as cited in Chia, 2002). Empiricism has a habit of explaining universalities from an experience, while rationalism habits explain them based on universalistic and idealized categories (Chia, 2002). Thus, knowledge is a result of the extrapolation of concrete experience or logical verification of immutable laws. One could believe that in Saunders et al.’s (2016) framework, rationalism aligns well with subjectively oriented philosophies, whose theories are built on social constructs. Consequently, the empirical habits observed match the positivism and critical realism philosophies well.

The axiology deals with the values that the researcher and participants hold in the process. Choosing one research topic or research method over another reflects underlying values as it reveals what is being seen as important, and hence, worth investigating (Saunders et al., 2016). The methodology aspect defines how a researcher aims to generate knowledge by either inductive (general to specific), deductive (specific to general), or abductive (interaction between general and specific) approaches (ibid.; Williamson et al., 2002; Goddard and Melville 2004; Kovacs and Spens, 2005). The inductive approach is

commonly used in qualitative studies, where for instance thorough exploratory research materializes as proposals of a new theory. The inductive approach is typical of quantitative studies, which validates or falsifies theories by, e.g., studying variables and their correlations in claimed theories. Researchers note that Western traditions have favored inductive and deductive approaches (Kirkeby, 1990; as cited by Kovacs and Spens, 2005), and suggest that an abductive approach can provide a rich new aspect to theory building. Abductive reasoning proposes a plausible conclusion to a surprising observation by matching earlier knowledge that provides a likely cue as a solution (Kovacs and Spens, 2005), which is also called "an educated guess" by some scholars (Glick and Carrasco-Labra, 2019). They (ibid.) note that deduction starts with a rule that is tested in a case to drive conclusions, while induction starts with a case to make conclusions that are proposed as a rule, and abduction starts with a rule to make conclusions that are tested in a case. Spens and Kovacs (2005) clarify the differences with a process flow chart illustrated in Figure 15 of the approaches.

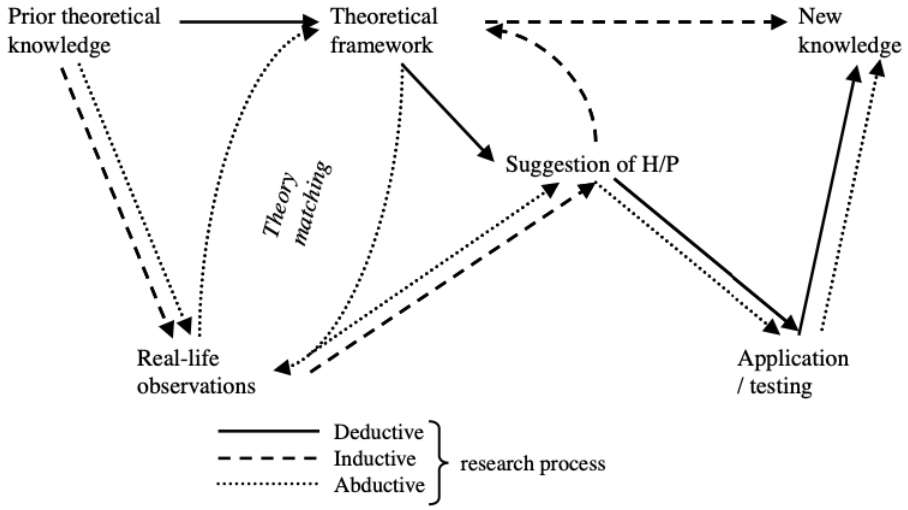

Figure 15: Approaches to theory building and reasoning (Spens and Kovacs, 2005)

This research builds on pragmatism as a research philosophy, which is connected to the personal values emphasizing innovation and entrepreneurship that the researcher holds. The researcher perceives reality as a rapidly developing dynamic system of crossing pragmatic processes, which is rich and external by nature. While it can be difficult to capture the complete reality in any given theory precisely, focused and pragmatic theories can in many cases reveal underlying logic and help to solve specific problems. As a reflection of values, a key aspect of science is a need to create understanding and implications for practices. Because of the pragmatic view, the research does not distinguish strongly scientific and practitioner aspects but rather sees them both needing information and exploration of the underlying patterns. Furthermore, science should not alienate itself from reality and create internal long-standing debates of grayscales, but

rather be able to tie itself to concretes and utility. Finally, methods should not be limited but be thought of openly and utilized according to individual needs in each case.

3.2 Research design

Saunders et al. (2016) propose in their research onion that after the foundational research philosophy, the key decisions are made in an approach to reasoning, research strategy, methods, time horizons, and techniques related to data collection and analysis. This section focuses on introducing the research strategy and methods selected in the study.

3.2.1 Reasoning

This study takes a pragmatic approach to theory building, and accordingly, uses flexibly methods in each of the reseaech papers. Table 5 introduces the research papers and research design decisions made. Research Paper I uses abductive reasoning by first employing deductive reasoning and then inductively proposing a framework model based on the specific research for wider utilization. Research papers II–V follow inductive reasoning by using the case study strategy inspecting variables and drawing proposals for wider testing and utilization. Theoretical Paper VI makes observations from extant theories to propose a conceptual model to integrate theories.

Table 5: Research design in research papers

RESEARCH PAPER	REASONING	STRATEGY	METHODS	DATA AND ANALYSES
RP I: Intelligent Packaging	Abductive	Survey	Quantitative	Data from 685 units. Statistical analyses and proposal of a model.
RP II: Environmental RFID	Inductive	Multi-case study	Quantitative	Archival data from three case companies and proprietary LCA. Statistical analyses.
RP III: Digital Twin	Inductive	Single case study	Mixed method	Interviews, group discussions, archival data, and observations. Statistical analyses and proposal of a model.
RP IV: Automated Service	Inductive	Single case study	Mixed method	Interviews, group discussions, archival data, and observations. Statistical analyses and proposal of a model.
RP V: Future of Work	Inductive	Single case study	Mixed method	Interviews, group discussions, archival data, and observations. Thematic analysis.
RP VI: Cross-functional collaboration	Inductive	Theoretical paper		Literature on theories. Discourse analysis.

3.2.2 Research strategies and methods

Studies on IoT, logistics, and innovation adoption generally employ a single research method, although they are too narrow to describe the complex technology adoption

context (Tu, 2018). Furthermore, the logistics and SCM research is observed to be typically positivist, normative, and quantitative by nature (Golicic et al., 2005). A mixed research method instead utilizes quantitative and qualitative research methods together and provide a richer view of the phenomenon at hand (Venkatesh et al., 2013). For this reason, IT research communities in particular encourage broader use of methods (ibid.). Similar claims have been stated regarding the SCM research, where the research has been too uniform according to scholars (Kovacs and Spens, 2006; Golicic and Davis, 2012). Furthermore, Creswell (2016) presents that the mixed methods approach is commonly used with pragmatism, while the quantitative approach is often used with surveys and experiments. The combination of survey and case study has been encouraged by supply chain management scholars as a model for being able to combine a helicopter view and deeper insights in delivering effective research (de Donk and der Vaart, 2005).

Table 6: Research method approaches (Creswell, 2016; as cited in Tura, 2018)

COMMONLY USED	QUANTITATIVE APPROACH	QUALITATIVE APPROACH	MIXED METHOD APPROACH
Philosophical Assumptions	Positivist knowledge.	Constructivist, transformative knowledge.	Pragmatic knowledge.
Strategies of Inquiry	Surveys and experiments.	Phenomenology, grounded theory, ethnography, case study and narrative.	Sequential, concurrent, and transformative.
Employed Methods	Closed-ended questions, predetermi-ned approaches, numeric data.	Open-ended questions, merging approaches, text, or image data.	Open and closed-ended questions, emerging and predetermined approaches, quantitative and qualitative data, and analysis.
Research Practices	- Tests or verifies the-ories or explanations. - Identifies variables to study. - Related variables in questions or hypotheses. - Uses standards of validity and reliability. - Observes and measures information numerically. - Uses unbiased approaches. - Employs statistical procedures.	- The researcher positions themself. - Collection of participants' meanings. - Focus on a single concept or phenomenon. - Personal values involved. - Study in the context or setting of participants. - Validation of the accuracy of the finding. - Creation of an agenda for change or reform. - Collaboration with participants.	- Collection of quantitative and qualitative data. - Develops a rationale for mixing. - Integrates the data of different stakes of inquiry. - Presents visual pictures of the procedures in the study. - Employs the practices of both qualitative and quantitative research.

Table 5 presented the research strategy, which employs a survey and case study in responding to the research questions in the empirical papers. A survey strategy was used in the first paper that aimed to form an understanding of the current state of RFID in SCM use, i.e., in the product identification use. Quantitative methods were utilized with descriptive statistics in the research paper reporting current market development. Research papers II–V used a case study strategy; however, the methods varied from quantitative to mixed methods in papers. Research Paper II utilized life cycle assessment results from an environmental RFID tag product and reflected through quantitative analysis its impact on sustainability programs released by three case companies. Papers III–V used both archival resources as well as interviews in the analysis. From the time perspective, all the studies represented cross-sectional research. Research Paper VI is a theoretical paper adopting inductive reasoning and using literature in responding to the research question.

3.3 Data collection and analysis

Data collection and analyses carried out in the study are detailed in Table 5. Descriptive statistical analyses were followed in quantitative papers as well as in mixed research papers. In one case study thematic analysis was used, while discourse analysis was the primary method in the theoretical paper.

The case study method became the most used research strategy in the study. The cases to be studied were selected based on two aspects: (i) the case should have significance in relation to the research topic, and (ii) the cases selected should vary in such a way that they exposed different instrumental roles that the RFID held in the SDT. The data selection strategy hence follows the information-oriented selection, where the cases represent maximum variation (Flyberg, 2011). Survey was used in one of the empirical papers, and thus, was the only other data collection methods apart from case studies.

Case study

The case study investigates a phenomenon in a real-life context (Yin, 2003) and is powerful in exposing the new areas and their variables for theory development (Stuart et al., 2002; Voss et al., 2002). It is used across the methods and is not meant to apply only to qualitative studies, although a case study is more common in such use (Stake, 1994). Stake (ibid.) points out three kinds of case studies: intrinsic (interest in a phenomenon itself), instrumental (interest in a specific issue, problem, or to refine theory), and collective (often regarded as a multi-case study used to understand a phenomenon).

The case studies used in the research were mostly instrumental, except for the research made on environmental RFID, which was a multi-case study. The critics of case studies note that too high a number of case studies report successful outcomes for problems they focus on, and one can hardly ever find a failure, which raises questions of reliability (de Donk and der Vaart, 2005).

Case studies are often considered to be vulnerable to the researcher's own bias. However, Flyberg (2011) argues that qualitative researchers often find contradictory evidence during case research that forces them to change opinions in relation to the preconceptions held. The mixed method research used in the study utilizes several data sources to reduce the risk of systemic indication error that could be related to one data source (e.g., to interviews and biased interpretation) and followed the concurrent triangulation design (Saunders et al., 2016). The data sources in the single case studies utilized employed interviews, archival resources, observations, and group discussions, which served as inputs for e.g., selecting key variables, extracting quantitative data for analyses, and for providing qualitative, explanatory input for the results. The multi-case study conducted used archival resources and quantitative statistics in analyses.

Survey

Survey research strategy plays an important role in business and logistics studies (Kotzab, 2005). It allows the collection of a large amount of data in an efficient manner by using questionnaires that enable the generation of standardized and comparable data, e.g., for descriptive statistics (ibid.). However, the reliability of the survey strategy has been questioned in situations where the method is used for measuring perceptions instead of requesting information from real measurements (de Donk and der Vaart, 2005). Also, typical challenges and tactics are related to sampling, coverage, measurement, and response (Salant and Dillman, 1994).

In the survey research, sampling followed a multi-stage approach to ensure a balanced number of respondents in terms of geographies and industries involved (Saunders et al. 2016, 279).

In the survey research, attention was paid to the questionnaire design to avoid overly lengthy interviews that could negatively influence the response rate, and on the other hand, in question formulation to avoid narrow perception-focused inquiry that would lead to non-credible results. Data collection utilized phone interviews and semi-structured questionnaires that both enabled the quantification of data and the collection of qualitative data, which was encoded to nominal intervals.

3.4 Quality of the research

The evaluation of research quality is sensitive to the methodological approach (Venkatesh et al., 2013). In this study, quantitative and mixed-method strategies were used as research methods.

In quantitative studies, reliability (stability, repeatability) and validity (accuracy; internal and external) have traditionally been the key constructs for research quality evaluation (ibid.; Yin, 1994; Saunders et al., 2016). In the survey study, research quality aspects were taken into consideration by careful sampling and research questionnaire design.

In qualitative as well as in mixed method studies, Lincoln and Guba (1985) have proposed credibility, transferability, dependability, and confirmability as key topics in the evaluation. Venkatesh (2013) simplifies that quality comes from the right research design and interpretations carried out. Hong and Pluye (2019) argue that despite differences in research traditions between quantitative and qualitative studies, there is also responsiveness between their orientations. They identify that trustworthiness (internal validity, credibility about the context and respondents), applicability (external validity, transferability i.e., generalizability), consistency (reliability, dependability i.e., repeability), and neutrality (objectivity, confirmability i.e., control over researcher's bias) are common quality factors between the two.

Hong and Pluye (2019) propose three aspects for quality validation: methodological rigor, conceptual clarity, and reporting qualities. Table 7 details the actions that were taken to ensure research quality in the study.

Table 7: Research quality mitigation (adopted from Honge and Pluye, 2019)

QUALITY DOMAIN	DESCRIPTION	ACTIONS TAKEN
Methodological Rigor	Extent to which a study's design, conduct, and analysis have minimized selection, measure-ment, and con-founding biases.	o Research methods were defined, documented, and reported in research papers. o Research papers were scrutinized through international peer-reviewed journals and conferences. o Triangulation was generally used to broaden the data sources and ensure aligned results.
Conceptual Clarity	Extent to which a concept is clearly articulated to facilitate theoretical insight.	□ Key constructs in papers were illustrated to ensure clarity. □ Key constructs were based on known theories and terms to support joint understanding.
Reporting Quality	Extent to which a paper provides information about the design, conduct, and analysis of a study.	o All research papers addressed the research design with an illustration of the model. o The research process, data, and quality were addressed as a part of the content. o Linguistic support was used to ensure clarity of expression where needed.

4 Summary of results

This section summarizes each of the research papers with goals, findings, and contributions. Table 8 summarizes the research papers, gaps, and topics.

Table 8: Research papers, gaps, and topics

RESEARCH PAPER	ADDRESSED GAPS AND TOPICS
RP I: Intelligent Packaging	○ Identified current trends, utilization, and geographical and industry-specific interest in RFID in the product identification. ○ Analyzed the intra-organizational process ownership and feasibility of RFID across industry verticals.
RP II: Environmental RFID	□ Identified the environmentally harmful waste streams of RFID tags and the difference between traditional and environmental RFID. □ Analyzed how the shift from traditional to environmental RFID tags impacted the sustainability programs in three global companies using a high volume of RFID in their SCM.
RP III: Digital Twin	○ Identified the cost and revenue sources in a global manufacturing SC, where RFID provides an immediate impact. ○ Analyzed the immediate monetary value of RFID utilization as an indication of the magnitude.
RP IV: Automated Service	□ Identified how RFID delivers value through sales automation in a last-mile concept developed for the service supply chain. □ Analyzed feasibility, drivers and barriers, and issues of concern when transforming to digitized self-service.
RP V: Future of Work	○ Identified how the service work changes when moving from manned to automated digital self-services. ○ Analyzed the skill and knowledge gap, and potential scenarios.
RP VI: Dissemination of SCV	□ Identified how SCV as a concept can deliver cross-functional value in an organization. □ Analyzed the theoretical background and how to support cross-functional value creation with an integrated SCV-MO concept.

4.1 Research Paper I: In the Bowling Alley—Acceptance of Intelligent Packaging Concept in European Markets

Background and objectives

The purpose of this paper was to understand the current state of RFID adoption in automated product identification across different supply chains. Connected products and

packaging were seen to represent the "intelligent packaging" concept, which uses RFID in itemization and interacting with end-users. Although there have been studies on RFID as a technology, there has been limited data and understanding of its adoption. The research questions focused on understanding (i) maturity, (ii) dynamics, and (iii) feasibility aspects of the concept. Moore (1991) has suggested that innovation take-up spreads in markets through different innovation-savvy segments. It also proposes that the key moment occurs when innovation reaches main markets and is being tested in various scenarios in tightly specified categories named "bowling alleys." The paper used a Europe-wide survey as a research method among business decision-makers to understand the general adoption of the technology and to find meaningful patterns.

Main findings of the study

The main findings were that RFID-connected intelligent packaging is in a validation phase; and described as a bowling alley in the Chasm theory (Moore 1991, 1995). In this phase, consulting projects are used to probe technologies and provide recommendations for an organization. The study proposed the "Crave" framework as a model to assess the feasibility of intelligent packaging for a business, which identifies key success factors that typically indicate a strong fit with the technology. It was also found that the market has geographical patterns, where the south has driven the new technology use, while central Europe and the Nordics are coming late to technology utilization. This finding was thought to link with industrial landscape differences: southern Europe has had more focus on the textile business, while the laggards were more focused on industrial equipment manufacturing.

Main contributions to the dissertation

This research paper pointed out that digital transformation starts with automated product identification, which was raised by respondents as the primary reason for their interest in the technology. Furthermore, it underlined that solutions are use-case specific and vary significantly between industries, which was understood to rely significantly on the product and supply chain types. Finally, it revealed that automated product identification is partly immature. RFID as a technology has become best practice in certain industries, such as in the fashion and apparel vertical, and in certain automotive industry sub-verticals.

4.2 Research Paper II: Environmental RFID—Measuring the Relevance in the Fast Fashion Industry

Background and objectives

The purpose of this research paper was to evaluate the relevance of environmental RFID tags. The interest in this perspective came from the emergence of "green RFID" tags that were printed on paper, and thus avoided plastic layers traditionally used in RFID tags and

provided biodegradability. However, since the tags are relatively small, it was also considered that the significance of environmental aspects on RFID tags was unclear. While there have been some studies on green supply chains, this research paper stood out as the first to investigate the environmental aspects of the tag. The empirical research utilized a life-cycle assessment and quantitative extrapolation of the results against the sustainability programs released by three global fashion companies consuming a high volume of RFID tags each year. The intention was to evaluate the impact if an organization shifted from traditional to environmental RFID tags.

Main findings

The paper reported that an environmental RFID has a significant impact on greenhouse gas emissions, circular economy, and avoidance of single-use plastics, which have been commonly used sustainability pillars among fashion retailers. Each of the case companies would have been able to reduce 2–3 million kilograms of plastic waste, a similar amount of carbon dioxide gas emissions, and reach ca. 40 percent lower eutrophication and a similar amount of acidification level compared to traditional RFID tag usage. The paper posits that the environmental RFID tag has a limited significance to numbers in a whole company's perspective, but argues that the environmental RFID has relevance, since fast fashion companies are likely to be required to select systematically green alternatives in all areas to reach the set sustainability goals. Furthermore, the paper argues that to consumers, such constant choices are signs of the "right" values that help to reduce anxiety related to the consumption of fast fashion.

Main contributions to the dissertation

This research paper confirmed that RFID can provide an environmentally sound solution for automated product identification in SCM. The technology itself can be produced in ways that comply with the circular economy approach without single-use plastics and with limited greenhouse gas and chemical emissions. In addition, it was noted that a high level of data resolution and accuracy drive SC optimization, which avoids excess production and thus supports the sustainability agenda within a company. In the future, other aspects of sustainability than the environment (i.e., social and governance) will need high-resolution data for decision-making and management.

4.3 Research Paper III: Driving competitiveness with RFID-enabled Digital Twin—Case Study from a Global Manufacturing Firm's Supply Chain

Background and objectives

Since the first research paper (section 4.1) presented that the RFID uptake was slower in the Nordics and the research suggested that this was potentially linked to the industry landscape that was more skewed toward industrial equipment manufacturing, the third

research paper focused on investigating RFID in that context. The purpose of the paper was to evaluate the immediate business implications when an organization adopts RFID to reach a digital twin in a global manufacturing SCM. Schuh et al. (2017) had previously argued that technology delivers value on multiple levels: the immediate level focused on in the study was provided by visibility, while the longer-term value was related to the higher cognition tools that were enabled by visibility and used advanced analytics, machine learning, and similar higher cognition tools to further optimize the SCM. The empirical research used a mixed method approach and multiple data sources from a single-case company in evaluation.

Main findings

The study produced a REDO framework that was developed for the evaluation, which established the understanding of the key contribution areas and dynamics that drive the competitiveness of a supply chain. The study identified seven concepts that were found to be relevant in the case company. The findings reported that the ability to cut person-hours and reduce supply chain costs provided the highest contribution at the immediate level. However, it also noted that the top-line improvements that were enabled by automated consignment stocks and availability were calculated conservatively, yielding a one percent increase in sales, and even a 3–4 percent increase would surpass the cost savings identified in the case. Hence, the study underlines that the common approach to basing the new technology utilization on cost savings can be questioned and can lead to missing the opportunity provided by them.

Main contributions to the dissertation

The paper creates an understanding of how digital transformation drives economic sense and helps also to rationalize the SCM that cuts excess productions, and thus reduces environmental loading of the SC. The paper points out that the technology used for providing visibility in the supply chain cannot be isolated from the benefits accounting, as the main technological alternatives have different characteristics and influence the SCM differently. Itemization, automation, and near real-time visibility of the products enabled unique concepts in returns management, for instance, which requires an understanding of a unique item, its originality, and automation. Furthermore, it was noted that from a helicopter view the contemporary SCM tools need a wealth of data that cannot be manual.

4.4 Research Paper IV: Solving the Employee Shortage in a Food Service Business with an Intelligent Cabinet Solution: a Design Science Approach

Background and objectives

The purpose of this research paper was to understand how RFID as a core SCV technology drives value creation in service supply chains by enabling new self-service concepts in industries that suffer from cost pressures, new customer experience desires, and human resource availability. The paper took the New Retail concept, which used an intelligent cabinet solution to drive automation in physical product sales and evaluated its value in a food service business context. As a key theory, the paper utilized Shopper Focused Decision Calculus by Inman et al. (2017) to demonstrate the perspective of an organization on the new technology utilization.

Main findings

The paper reported that in hard measures, the solution created its own loyal audience, which indicated that certain segments tend to favor self-services when they are available. The solution also extended the sales to off-hours when the manned point-of-sales was closed and the technical concept was calculated to require 14 months to break even, which was higher than anticipated. In soft measures, there were some concerns about the employee perspective by mainly the internal stakeholders, and on the other hand, a sense of excitement due to flexibility by the end-users. The paper argues that a technology deployment at the customer interface leads to a wider discussion of the business model and change management with stakeholders in order to succeed. The paper closes with a proposal of service-focused decision calculus as an improvement to the extant theory, which exposes the implications of new technology to the service concept by integrating the aspects of people, business, and brand.

Main contributions to dissertation

The paper shed light on how RFID enables digital transformation in the service supply chain, focusing on the last mile. RFID has a role in this context to enable sales automation and manage inventory in terms of obsolescence and availability. However, one of the key contributions to the dissertation was that when extending to the customer interface, the digital transformation entails discussion of the business model more prominently, which also has a much stronger focus on the people perspective than what might otherwise be expected from tactical technology uptake. Hence, RFID also has a strategic role to accelerate, enable, and catalyze the digital transformation throughout the company's value chain. From the sustainability perspective, the key aspect was seen to be related to the growing elderly population in Western societies, which has led to employee shortages, and thus established a sustainability challenge to deliver services in low-wage industries.

4.5 Research Paper V: Future of work — Skills and Knowledge Perspective on Service Automation in the Foodservice Industry

Background and objectives

Research Paper IV exposed that human resource management is impacted when supply chain digitalization proceeds in an organization. The purpose of Research Paper V was to understand how RFID-catalyzed change influences competence requirements in an organization, and what kind of specific skills are needed when operating an RFID-based system. The paper used the skill-gap analysis model to compare the current and desired skillsets to understand the competence aspect.

Main findings of the paper

Based on the literature, the paper identified that service automation involves three skill and knowledge areas (management, design, and customer) that were incorporated into the Lenses framework developed for the empirical part of the research. The competencies needed to operate traditional manned services were best learned from earlier work experience from similar traditional service outlets, while the unmanned services required competencies that were linked to the platform economy, and such experience could be retrieved from other digital platforms where digital marketing, offering optimization, and operational procedures exist. The competence renewal challenge in traditional industries (e.g., in food service as in the paper) was related to modest competence levels identified to exist in the low-cost service industries. The paper suggested that the so-called geek economy mentioned in the literature could provide relief in solving labor availability, which, on the other hand, was seen to require changes in human resource management practices.

Main contributions to dissertation

The people aspect is present in the sustainability concept, which investigates digital transformation from profit, people, and planet perspectives. The people aspect is often regarded as fairness to employees, but it also asks the question of whether the change evaluated has endurance in the longer term from the human resource aspect. As commonly known, age pyramids and high education levels indicate that there might not be resources available for traditional low-cost service models. RFID integrates into the platform business as a data acquisition technology, and thus, the key competencies needed from systems operators stem from the platform economy.

4.6 Theoretical Paper VI: Dissemination of SCV

Background and objectives

The purpose of the theoretical paper was to discuss the intra-firm utilization aspect to supply chain visibility. The observation was that the SCV discussion had evolved from the product identification capability aspect to the inter-firm collaboration aspect, which intends to understand how the relationships and practices with partners can deliver visibility and transparency of the supply chain. However, some of the prominent examples from organizations suggest that the internal cross-functional dissemination of supply chain visibility can be even more relevant to performance and has been neglected by academia in recent years. The paper acknowledges that the perspectives that exist in SCM and other business functions, such as marketing, are significantly different, and therefore the objective of the paper is to provide conceptual integration between underlying theoretical discussions to foster cross-functional theoretical understanding and discussion.

Main findings of the paper

The paper identified that Market Orientation (MO) theories have identified that the sources of MO are information generation, dissemination, and cross-functional collaboration. It suggested that SCV should be seen as a function of information generation, and hence, by connecting SCV to information dissemination functionalities, an organization can drive innovation that shows in the offering, new product development, promotions, and business decisions related to distribution and channel management. The presented conceptual framework and relationship model enable further examination of the causalities, practices, and wiring of different kinds of organizations across industries.

Main contributions to dissertation

For the dissertation, the main contribution is the notion that supply chain transformation extends to a cross-functional dimension. Ultimately, successful organizations can be observed to be internally closely integrated and armed with capabilities to operate a business through data. The cross-functional utilization of data has an implication for data collection and sharing practices, which cannot be defined generally but imply that they must be considered in designing the SCV capability in a firm. It requires top-management attention to avoid harmful organizational politics, where units tend to operate in ways that maximize their autonomy, thus avoiding hierarchical conflicts.

5 Conclusions

This section draws conclusions from the research papers in the wider context, as established at the start of the dissertation, where research objectives and questions were listed.

The purpose of the dissertation was to expand understanding of the role that RFID plays in the sustainable digital transformation of SC. The research questions focused on (i) scrutinizing the current state of RFID by understanding the recent developments of the technology and its use, (ii) understanding the roles RFID has in the sustainable digital transformation of SC, and (iii) evaluating the fit of RFID with the main SCM structures, where the goal is to ensure that the technology complies with context and emerging needs. To draw conclusions, the responses to the research questions are as follows:

(i) RFID was studied as a product identification technology in product and packaging flows managed by SCM. In that use, the technology was identified to be significantly vertical-specific and use-case–sensitive. For instance, in the fashion industry, RFID is a best practice and is utilized by nearly all major international fashion brands in inventory management, which is supported by actors in the industry clusters who have ensured compliance with RFID as the key technology being broadly used. Hence, contract manufacturers are equipped with tag encoding capabilities, personnel are trained to understand and use RFID tags, and the industry has software and service providers who offer tailored solutions to the brand owners. However, outside of textile industry the RFID utilization depends significantly on how the technology matches with the supply chain structures followed by the industry, and for instance, how tag integration and reading in products have been solved. In many industries, there is a lack of solid concepts that could be adopted and replicated. Despite the vulnerabilities, RFID technology continues to be one of the few technologies that enable high-volume reading and high-quality item-level data when the context is technology compliant, which is difficult to reach with any other methods e.g., optical tracking.

(ii) Sustainability was reviewed as a long-term orientation toward people, profit, and planet. In this scheme, RFID acts as an enabler, driver, and connector for SDT. This enabling role is a way to create the financial and environmental efficiency of a company with a sound and compliant technological method. The capability to drive SDT comes through with the new services and business models that the use of RFID inspires in the companies in support of problem-solving, e.g., in solving human resource shortages and fitting in with modern lifestyles favoring green urban living. Finally, the connecting role of RFID is about supporting external ties within an ecosystem, as well as with direct partners to work in a coordinated manner that drives industry-wide sustainability improvements. For instance, with RFID-related data management, one can integrate order management from one company to another to specifically re-order in such a way that reduces excess

production and manual work, and in a logistically rational way to minimize negative impacts. Table 9 summarizes the role of RFID identified in the thesis.

Table 9: Roles of RFID in SDT

ROLE	DESCRIPTION
Operational enabler	RFID enables SDT as an intra-firm and intra-functional data capturing capability.
Strategic change driver	RFID drives SDT by fostering new service development, and business model and competence renewal at an intra-firm and inter-functional level.
Ecosystem connector	RFID connects an organization to its partners, supporting ecosystem-level SDT and sustainability performance at an inter-firm and intra-functional level.

(iii) The RFID-enabled SDT was tested in a traditional manufacturing context with a digital twin concept. Furthermore, it was tested in a service supply chain, where a self-service automation concept was implemented using an RFID-enabled intelligent cabinet solution as an example of a modern approach for last-mile delivery. Finally, RFID was viewed as a data source of SCV in an intra-firm cross-functional context. Based on the evidence from extant empirical studies, RFID has wider compliance with information needs within an organization outside SCM, and thus, a theoretical paper proposed an integrated model for the dissemination of real-time supply chain information.

All in all, trends identified within SCM were related to the vision of a smarter organization i.e., SC4 discussions on virtualization, service orientation, and the shift from push to pull logic. In SC4, SCV was seen core capability and RFID as one of the strongest technologies delivering SCV in known use cases. SCV also allowed building a link between sustainability and the digital transformation as it supports optimizing people, plant and profits through itemization, automation and data. Figure 16 illustrates the how sustainability and DT connect in the creation of SCV.

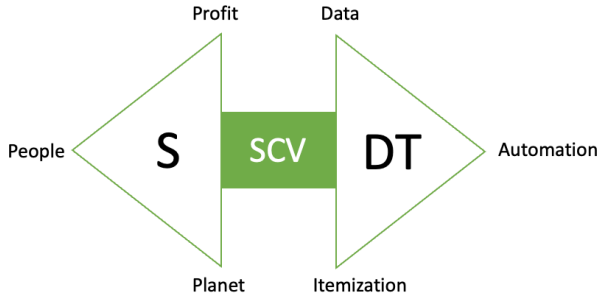

Figure 16: Connecting sustainability and digital transformation

Concluding the research, digital transformation is a wider topic that lives in several functions in an organization. A key requirement for the digital transformation in SC is visibility, which provides data from inventories and accelerates steering and collaboration across boundaries. Data quality requirements depend on the vision that a company holds for DT and the use cases defined for visibility. As a technology, RFID has unique benefits in automation and accuracy, and as the technology has developed, it has been able to solve technical challenges of radio technology, which previously limited its use on certain base materials. Today, the core barriers of RFID are related to tag integration when there is a high variance in product types and building the reading infrastructure, which is partly a determinant of data accuracy and a cost element. These settings depend significantly on the SC context and sustainability aspects. Sustainability limits what kinds of solutions are regarded as acceptable for understanding the impact on the environment for example. On the other hand, sustainability also sets needs for DT to solve.

5.1 Scientific implications

The study has leaned on theories from SC4 and SCV in creating an understanding of the role that RFID holds in the SDT of SC. The research papers have discussed in detail the scientific implications of each of the papers, but commonly, the papers have focused on providing insights and exposing key variables related to the research questions at hand. Furthermore, the theory-building research approaches have generated proposals of theories to support the scientific discussion in the SCV and SC4 research streams. In this section, four broader themes are lifted from the study related to RFID technology, sustainability, SCM, and innovation.

Roles of RFID contributing to research and theory-building of use cases

Research paper I argued that SCM needs itemization for automation, efficiency improvements and new service development, but the bottleneck lies in lack of use cases. In SCM, the vertical specific best practices dominate the systems and tools that are being

used, and thus, generic technologies without industry-specific use cases are often not taken into use. The main theory in the paper (Moore 1985) talked about the same phenomenon naming it bowling alley as a metaphor for winning in "categories" (verticals) one by one to make a "full strike" (become broadly accepted).

The use case centricity was present in all papers, which verified the importance of them for the organization in taking any new technology into use, and yet, only very few of the use cases (such as product level tracking in textile industries) have reached maturity in the supply chain uses.

In the result section, the dissertation identifies three roles that RFID plays in the SDT of SC (see Table 9). This contributes to the theoretical understanding of RFID in SCM uses, and analyzes areas, where RFID has a role and a favorable ground for use case research and development.

Inward looking SCM capability development

Aside from the implications raised by the research papers, a more fundamental question is where the SCV research stream should next focus on. It has been claimed in the research papers (RP VI) that the focus has been predominantly on supply network management, neglecting intra-firm cross-functional collaboration. Halldorsson et al. (2007) have studied the SCM research evolution and underlined the role of SCM as the orchestrator of supplier network as defined by, e.g., Harland (1996) and Christopher (1998). Within the SCM discussion, there has been a consensus that the scope includes not only the physical flow of goods but also information (see, e.g., Ballou, 2000; Heikkilä, 2002, Monczka and Morgan, 1997 as cited by Halldorsson et al., 2007). Later on, there has been a proposal for shifting from SCM to Demand Chain Management (DCM), where the focus transitions to value-creation in working processes (Christopher and Ryals, 2014). The research agenda set for DCM includes defining practices that drive integrated business planning practices encompassing how an organization taps into demand signals (ibid.) triggering supply flows. Also, the discussion of the responsive supply chain provides another angle to the same requirement to form a tightly integrated organization where accurate demand information orchestrates SCM (Aftab et al., 2018).

This dissertation has proposed that shifting the emphasis in SCM from external to internal cross-functional relationships would accelerate value creation and support a sustainable digital transformation that cannot be planned and carried out in functional siloes but requires a company-wide operating system. Although this aspect of intra-firm orientation was already present in the research scope (see Figure 3), this alignment has during the research proven to be relevant not only for this study but as a proposition for the wider SCM research community due to the need for upgraded business model, operating system and SDT approach. However, although the thesis provokes for the need to fix the homebase as a starting point in the upgraded second-generation model, it does not mean that the inward-looking capability development should be done in isolation. The theory from Porter and Heppelman (2014) explains the move from dumb products to smart ones,

and finally to ecosystem. It is obvious that the business model and capability development discussion needs to sit in a context and tap into the future markets and competition dictating the work at hand.

Connecting sustainability with digital transformation of SC

Academia has requested empirically grounded integration of sustainability to digital transformation, specifically to SC4 theories. In studying the roles of RFID in the SDT of SC, the dissertation has proposed links where digitality and sustainability co-exist. Stakeholder theory (Freeman 1984) has pointed out the variety of audiences and their needs that organizations exist to serve, which the later matured academic conversation on sustainability has further simplified to people, planet and profits perspectives as outlined earlier in the thesis.

The people aspect of sustainability has been linked in this dissertation to service supply chains and SC automation. It has been proposed in the dissertation that technology (and more specifically itemization, automation, and data management) plays a central role in forming the second-generation SCM models, which solve some of the urging people related sustainability challenges e.g., employee shortage, workforce skilling, and changing lifestyles of people.

The planet aspect was discussed in the paper studying the environmental impact of the digitalization and was able to point out the existence and impact of the digital transformation of SCM to the sustainability aspects of the living nature.

Finally, the profit aspect has been presented in service and manufacturing supply chain studies carried out in the dissertation pointing out not only the direct savings potential, but also the indirect topline performance improvements that DT provides. In order to organization to exist sustainably, it needs to be financial performant and constantly increase their returns to owners, who carry risk of the equity loss.

Academia has pointed out that common challenge with the sustainability theories is that they hardly exist in frameworks and concepts. This notion has been also observed in this study. The dissertation has contributed to the theory building by analyzing how SCV connects sustainability and DT with broad empirical insights updating the discussion of traditional IT in SCM (see e.g. Auramo, Figure 14) to the level required in SC4.

Fragmented innovation landscapes

Traditional perspectives on innovation adoption and technology acceptance models hold an ethos of a linear expansion of new technology usage across audiences and markets, as the technological advantage becomes more widely known, learned, and further developed (see, e.g., Moore, 1991). The empirical results from this dissertation (for instance research papers I and IV) somewhat contradict such theories and underline that the technology landscape is rather fragmented and reliant on industry-specific practices combined with the limitations of a technology. Whether this is a development phase of an industry or the

final destination of technology remains unclear when it comes to RFID. Radio technologies have provided clear advances in identification and automation, and the question is whether these advances are transferable to other industries and if expanding the technology use to broader markets depends partly on application research, as pointed out earlier. However, it could also be that technology becomes a niche solution, and hence discovers its limits. Fragmentation of a technology landscape has been theoretically a lesser studied topic than adoption, acceptance, and transformation.

Theoretical discoveries made in spatial studies focus on time, context, and location in their efforts to understand how progress truly materializes. The spatial research perspective argues that the traditional assumption of rationality is only a half-truth as, according to scholars, there is often a matter of a coincidence in place too. In this research, evidence was found that supports the premises of spatial research. RFID is an innovation that was first seen in the research from a rational perspective, until it became apparent that geographical adoption of the technology varied significantly. The explanations for the differences were rooted in the dominant industries that were found locally: locations where the textile industry played a significant role were commonly more advanced and favorable to RFID technology. Interestingly, these countries were not traditionally seen as high-tech countries and yet they outperformed the tech-savvy countries in their advanced frameworks on real-time data capture and utilization. Looking into these cases more closely, it became apparent that one single organization can create advances and consequently a trend within a country and an industry that creates a following if successful. Furthermore, in an organization the decision to focus on a certain technology can also be rooted in single visionary and influential individuals. Apart from these context-specific triggers, the research found evidence that new technology adoption is often cost efficiency-driven at a company level, even though most of the quantifiable benefits would be found outside the cost reduction area. The rational explanation for this would be that savings and bottom-line performance are commonly seen as less hypothetical than top-line growth, which is objectively taken as not validated but intuitively assumed. Understanding the biases in decision-making can be expected to significantly influence innovations, which in larger organizations and markets are assessed weekly in terms of whether to continue or kill the project.

5.2 Managerial implications

The key themes in the dissertation have been SC4 and SCV, which focus on the data capturing and sharing taking place in the SCM. The approach from broad to more specific has been used in the dissertation to employ SCV as an instrument for companies' efforts to materialize the SC4 aspirations with a highly efficient and sustainable operating model, and modern responsive services. One of the challenges with I40 and derived SC4 concepts is their broad definition, along with the vast related opportunities. In this dissertation, RFID has been evaluated as a change catalyst that can be employed to drive renewal from tactical product identification up to the business model. Figure 17 illustrates this bottom-up approach to digital transformation.

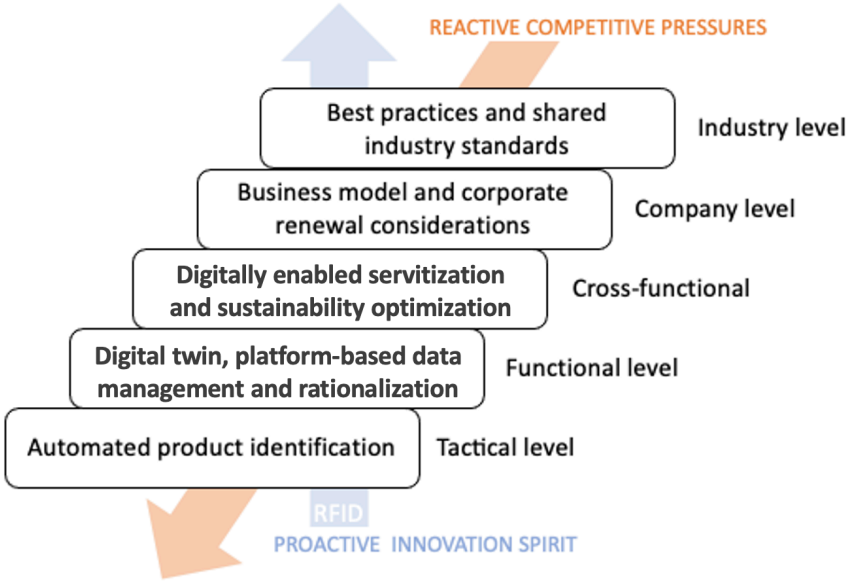

Figure 17: Bottom-up approach to SDT in SC, levels of value creation

The bottom-up model implies that while the innovations spread from practices to functions, companies, and up to industrial standards, the competitive pressure takes an opposite direction to spread proven technologies from top down. In such a situation, a certain technology becomes widely used within an industry, forming a best practice or operative standard that influences business models, services, sustainability requirements, and data management and product identification practices followed in a company. Research Paper I, which tracked RFID utilization, revealed how the practices were industry-specific, and later inspection across the industries showed how, for instance, the fashion industry has adopted RFID as best practice (as shown in Research Paper II), while some others are still seeking concepts that would solve the data acquisition issue (as shown in an example in Research Paper III).

As the dissertation has proposed, RFID is a "case sensitive" technology where the starting point for utilization depends on the feasibility, which the Crave model addressed (Research Paper I). Technologies are commonly constantly developing, hence the relationship between industry-specific SC and RFID is likely dynamic. Borrowing from the stakeholder theory presented by Friedman and Miles (2002), relationships between a company and an institute (or technology as presented here) can be evaluated through quadrants illustrating compatibility and necessity, as presented in Table 10. Position A represents a situation where RFID is necessary and compatible, as seen for instance in the fashion industry context. Position B could be the food service industry, where RFID (according to RP III) proves to be compatible but is not broadly adopted, i.e., the utilization is contingent and depends on the specific associated benefits. Position D could

be an example from the automotive industry, where a parts supplier is required to have an RFID to serve a customer using an RFID-based inventory management solution, but its own procedures are incompatible with the technology. It would need to compromise somehow by providing the RFID tagging and data for the customer's needs, even though it would not make sense from its own perspective. Finally, position C illustrates situations where suitable cases have neither been found nor are required by any stakeholder.

Table 10: Analyzing the strategic relationship of an industry with RFID (borrowed from stakeholder theory proposition by Friedman and Miles, 2002).

	NECESSARY	**CONTIGENT**
COMPATIBLE	A Protectionist, Defensive	B Opportunism, Opportunistic
INCOMPATIBLE	D Concessionary, Compromise	C Competition, Elimination

As stated, the relationship between technology and utilizer is dynamic due to constant development not only in technologies but also among industry standards, as proposed by the bottom-up model. Figure 18, borrowed from Friedman and Miles (2002), illustrates the application of the model when inspecting dynamics that a company held with an institution (Greenpeace) over time. The proposal here is that similar dynamics exist with institutions when they are regarded broadly. The underlying observation is that technologies have become increasingly central and influential to organizations' existence and their status should not be undermined, but they should be considered as institutions. Whether technology can be regarded as a stakeholder or an institution is a scientific discussion of its own, which has been approached by scholars from time to time (see e.g., Lightfoot, 1998; Ishmaev, 2017; Ferreira et al., 2021).

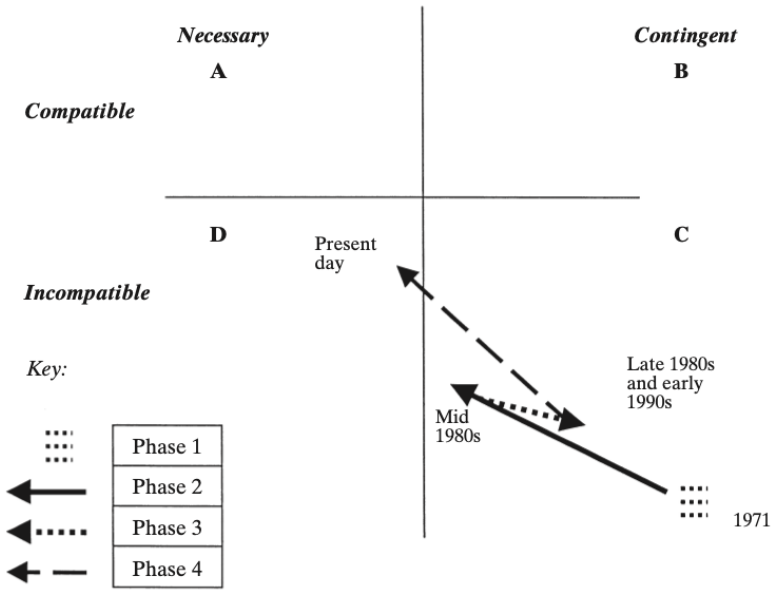

Figure 18: Example of the dynamic nature of a relationship between organization and stakeholder (Friedman and Miles, 2002)

The managerial implication is that the orientation a company holds toward competition influences the attitude and approach to innovation and new technology (Table 9). In Figure 17, innovativeness leads to a proactive orientation to SDT, which is described as a bottom-up approach, while reactive orientation follows pressures when they come from industry standards. This is well captured in the Fieldman and Miles theory (2002). Innovation adoption theories explain the same phenomenon through segments, which hold totally different attitudes and behaviors toward innovations (see Moore 1991, 1995). Managerially, it provides an interesting and insightful perspective for a company to understand how strategy and culture, especially in large firms, influence the destiny companies to create for themselves.

5.3 Limitations and future research

In this section, the research limitations and futures are discussed. Research papers reported specific topics that were present in them, and this section takes more of a helicopter view to summarize the overall challenges and opportunities that the researcher was left with.

Research limitations

This research has some limitations. In general, the read-thread in the dissertation has been understanding the role of a specific technology (RFID) in a wider phenomenon (SDT) in

a specific yet wide context (SCM). The research ends up forming an interpretation of how the technology relates to the transformation at hand and achieves that by taking relatively practical aspects in building the links. For instance, the research paper focusing on environmental RFID has targeted studying the environmental impact of an RFÌD tag as data connector, while much of the environmental benefit should be gained by the improved data management in the supply chain allowing minimizing waste and excess production. Similar challenge is also present in other research papers that study the aspects of sustainability and digital transformation. These themes are unfortunately wide, currently quickly expanding and evolving, and thus one dissertation can only make one conceptualization of the links and roles. This means limited generalizability to the question of the research quality.

Despite the focus on a specific technology in the dissertation (RFID), the study is not meant to be technical or engage with the engineering perspective more than what is a minimum requirement for discussing the organizational aspect. This applies especially to the discussion of the fit, which, when it comes to RFID, would call for mapping the technical feasibility with different base materials and the surrounding environment where RFID is applied. However, it is regarded as an engineering field, and thus is out of scope of the research focus. Sometimes it is difficult to keep the technology substance isolated from the management discussion as it tends to form theoretical views of reality that do not materialize in practice as conceptualized. For instance, the research paper that outlined the financial value of RFID to SCM pointed out that the calculated benefits dependent largely on the quality of the technical solution, which remained hypothetical although the study took relatively close pairing with the technology to avoid the bias.

The research has been integrative, i.e., it has reflected the chosen technology in various contexts of SDT in SC. As a researcher, one has needed to analyze several different theoretical conversations to define the context, then analyze the role of RFID within the space. Scanning the sectors in this way has supported technology analysis and validation, but of course it has limitations in terms of how thoroughly one can participate in theoretical conversations in each of the scientific fields. From research quality aspect it is a concern, if the research has too many focus areas to master, and thus, is vulnerable for not notifying all key aspects in studied areas. This influences especially interpretations formed in each paper, and to mitigate this concern, it has been conscious to mostly report pragmatic findings. As an example, the paper discussing the influence of the technology to employments and work-force shortages scratches a major discussion that has many aspects known by the scholars in human resource and customer management research fields. Furthermore, the dissertation moves in the fields of financial management, sustainability and environmental engineering, marketing and service theories, information technology and data management. RFID has a role in all of them, but to position the role wisely is demanding and of course a risk for making false interpretations in analyzing the results.

Future research

The scientific implications already presented two wider theoretical areas that the study reveals as needing attention: internal data sharing and utilization, and the connection of data quality and business models within the supply chain management research. The role of RFID has been proven to foster SDT, but to understand how to utilize the technology correctly, the two named areas need conceptual frameworks and understanding. Today, the ingredients for these can be found scattered in a number of research pieces, and integrative research that specializes in these aspects will be needed.

From a technological perspective, the study highlighted that the RFID tag market has developed each year in double digits in terms of compound average growth rate (CAGR), which indicates that the utilization is on a steady growth path. At the same time, academic interest in RFID technology and applications has reduced according to the number of systematic literature reviews (SLR) made on the area. That would imply that concepts have been discovered and practitioners are harnessing them, which explains the market growth. However, the study has observed only a handful of use case concepts that have achieved best practice status and observed that modern supply chain analytics and software need a constant flow of real-time accurate data in order to provide performance. The technology and market study (Research Paper I) also stressed the importance of proven vertical-specific concepts as "industry standards" in scaling solutions for data capturing and observed that most of the markets are still using analogue data capturing methods. This indicates an important research gap that calls for studies from engineering, SCM, IT, and management science scholars. An alternative approach to solving IRI would call for a more conceptual understanding of the SCD, context, and technologies, which would support the best practice development by theorizing.

The stakeholder theory approach presented in the managerial implications section to understand the technology decisions and dominant design is an alternative way to investigate technology adoption. While traditional bell curve theories have taken a linear look at the adoption, this stakeholder theory approach builds an understanding of how a technology decision is attached to competitive pressures and the orientation a company has chosen to follow. This type of setting where multiple realities co-exist can be found, although researchers and theories rather like to reflect unified approaches to markets, as described by Moore (1991), who compared sub-categories to a bowling alley. Theoretical discussions and research that can contribute to the understanding of the dynamics of the fragmented markets were found to be interesting and yet narrowly covered.

Out of the theory fields employed, sustainability stands out as one of the most prominent, where practitioners need constant theoretical support. The area needs more standardization when it comes to life cycle assessment procedures, which became evident while doing Research Paper II. Standardization should clarify what shall be counted and how when doing calculations. On the other hand, it should establish clear objectives for practitioners that could set objectives for concept development and companies' efforts. One of the challenges with sustainability is its connection to three broad areas—profits,

people, and the planet. It remains philosophical until there are more concrete theories and frameworks that can detail and guide the theory-building.

Today, sustainability as a term is often intuitively understood as the aspect of environmental friendliness. This thesis has included some of the people and profit aspects as part of the sustainability requirement, but leaving behind the observation that more theoretical understanding and conceptualization are needed to handle the non-environmental aspects more solidly. Conversations about technological unemployment may have been seen as part of the sustainability aspect, but they also contain a rather negative notion of the impact of technology. The thesis has argued that the technology-supported self-service concept can conversely have a positive impact on sustainability from business profitability and needs-responsiveness perspectives. Sustainability, services, and especially self-service, were found to be interesting research themes that would need further organizational understanding for how to build enduring operational models in times of ageing population, data analytics, and changing lifestyles.

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Publication I

Voipio, V., Elfvengren, K., and Korpela, J.

In the bowling alley: acceptance of an intelligent packaging concept in European markets

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In the bowling alley: acceptance of an intelligent packaging concept in European markets

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Abstract: Academia has discussed intelligent packaging as a concept to drive business performance using item level data throughout companies' supply chains. Despite the vivid discussion of the conceptual benefits, the market acceptance perspective has often been despised; this research paper aims to close that gap. The theoretical background comes from technology diffusion models, against which a survey across six European countries was conducted. According to the results, category-specific best practices dominate new technology acceptance, and the digital transformation of packaging is linked to supply chain and marketing rather than IT to be handled. Surprisingly, the geographical location of respondents came up as a side influencer and customer experience had less of an importance. At the end of the paper, a feasibility model is presented offering five parameters (volume, value, experiences, complexity and innovation spirit) to predict the success of intelligent packaging as it undergoes category-specific validation in the markets.

Keywords: intelligent packaging; radio-frequency identification; RFID; innovation diffusion; supply chain digitalisation; internet of things; IoT.

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1 Introduction

Radio-frequency identification (RFID) technology has been a widely studied and discussed topic since 1940–1960, when the technology was discovered as a way to identify troops in a military setting. In 1990, RFID was attached to companies' supply chain management and article tracking (Landt, 2005), which shifted the focus of the technology to commercial applications. The key objective at the time was to increase automation, which established a research theme over automated identification or so called auto-ID market (Sarac et al., 2010). Prior to auto-ID, manufacturing had been operated through optical coding, such as bar codes, if any. The active and intelligent packaging research theme came up through food sector packaging studies in mid-2000, when smart chemical labels and RFID was linked to traditional packaging framework listing the roles of packaging, i.e., containment, communication, convenience and protection (Yam et al., 2005). Communication in the model included promotional messaging as well as product identification, which is where the RFID technology was linked to, making packaging regarded as 'intelligent'. At that point, RFID became technology not only for internal but also for external uses. Technology-wise RFID was divided into two methods: ultra-high frequency (UHF) for auto-ID and supply chain management, and near-field communication (NFC) for digital marketing and customer experience. One of the recent key developments in the markets occurred in June 2017, when Apple announced iPhone to open its NFC capability for open use, together with Android providing a globally relevant install-base in consumer smartphones for NFC reading.

Traditionally the packaging market has been divided into two sections: durable and disposable packaging, which sets different requirements for the technologies and materials applied. Technology-wise, in addition to the tag, RFID solutions require a wider set of systems including readers, software, and business applications. From a customer perspective, the market is arranged traditionally by end-user segments, such as food and beverage, healthcare and cosmetics, apparel and fashion, electronics and small appliances, industrial manufacturing, and spare parts.

The most common perspectives to analyse the intelligent packaging market are therefore:

1 usage (disposable vs. durable packaging)

2 systems (tags, readers, software, etc.)

3 end-user segments (e.g., retail, healthcare, etc.).

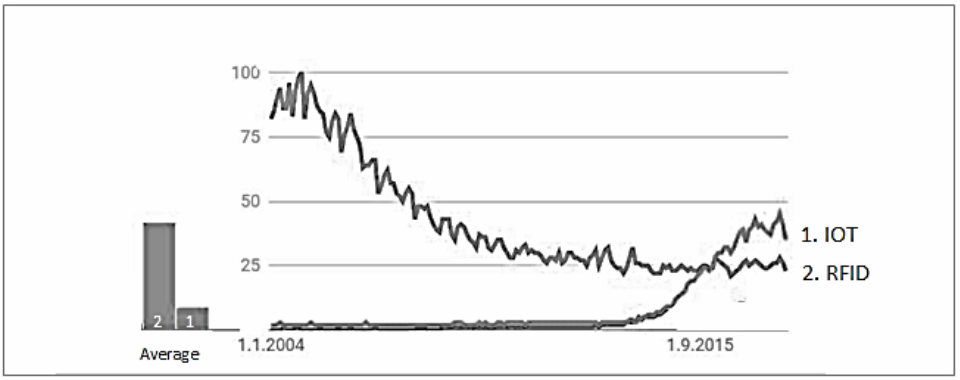
In this research paper, the end-user approach is central as it most commonly dominates the practices and the two other areas, i.e., usage and systems.

1.1 From RFID to IOT perspective

During the years, the technological development of RFID has been constant. RFID tags contain micro-chips or ICs (integrated circuit) in the heart of a tag, which has decreased in size to a quarter of what it once was. At the same time, wafer sizes have increased proving more powerful tag performance (reading speed, distance and steadiness). RFID tags contain adhesives, which have been reduced by 90% between 2002 and 2015. The manufacturing technologies of RFID tags have also moved from sawing to laser cutting, decreasing waste and increasing speed in IC manufacturing. During the previous 15 years, significant change has occurred in memory use as well. In the early 2000, the item-specific data needed in business applications was stored in the IC chip, while today an RFID tag only contains a serial number (most often following a so called globally standardised EPC coding), which is connected to the data of the specific product at hand in the cloud services. This has decreased the need for memory in the chips, increasing the reading speed and unit cost of an RFID tag. Finally, improvements in technology and its applications have led to higher market demand followed up by a production increase from million to billions of RFID tags annually. Higher production volumes and technological advances have led to decreases in market prices: during the years RFID tags have sank from Euros to eurocents making it viable identification and communication technology to several low-cost daily goods (Maijala, 2017).

Bendavid et al. (2013) used innovative methods for finding out the common interest (indicating maturity) of an RFID technology. In addition to bibliometric data, the Google Trends data analysis tool was used to compare RFID and internet of things (IoT) search volumes. In the study, researchers noticed a pattern of a decreasing volume of RFID searches as opposed to IoT search volumes. Repeating the Google Trends analysis shows today that the IoT has passed RFID as a search phrase in September 2015, although cumulative RFID volumes are still higher today than the IoT (see Figure 1). This implies that the focus in interest has shifted from a well-studied technology perspective to business applications and architecture.

Figure 1 Searches all world, January 2004–January 2018

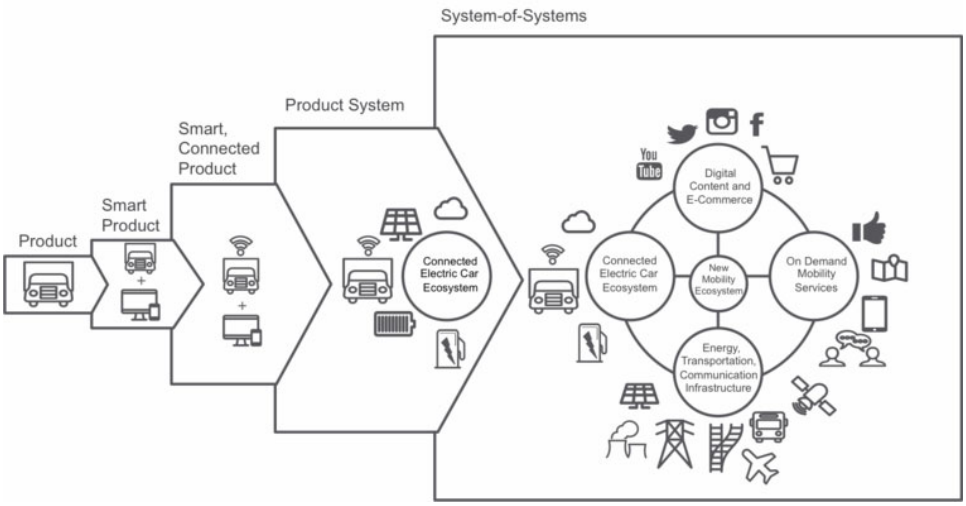


Source: Google (n.d.)

The previous implication is also supported by cost allocation studies made from RFID-based asset tracking projects. According to Entigral Systems (2017), a US-based provider of asset tracking solutions, today software and services account for the largest

single area in the total cost of ownership (TCO) by a 60% share of costs. Tags and sensors are only half of the previous with 30% of the TCO. Support accounts take up the remaining 10%. As the investments move to software, the core of the discussion changes from hardware to systems. This follows the findings presented by Michael Porter on innovation and competition (Porter and Heppelmann, 2014).

Figure 2 From smart connected products to systems



Source: Porter and Heppelman (2014)

Following Porter and Heppelmann's thought, the value of intelligent packaging does not consist only of the automation that the technology can provide with RFID coding, but also of how it provides value in the systems dimension as a part of the connected offering or ecosystem it is a part of.

1.2 Research questions and plan

This research paper aims to understand intelligent packaging acceptance. The research questions are:

- What is the current overall acceptance of intelligent packaging in the markets?
- What explains the current development phase of intelligent packaging?
- Which characteristics determine the feasibility of intelligent packaging in a specific market?

The research plan is to first review theories on typical technology diffusion process. Secondary data is then reviewed to form a preliminary hypothesis of the current market development phase against the theories. Empirical data is finally used to validate the hypothesis and to deepen the understanding of explanations and dynamics.

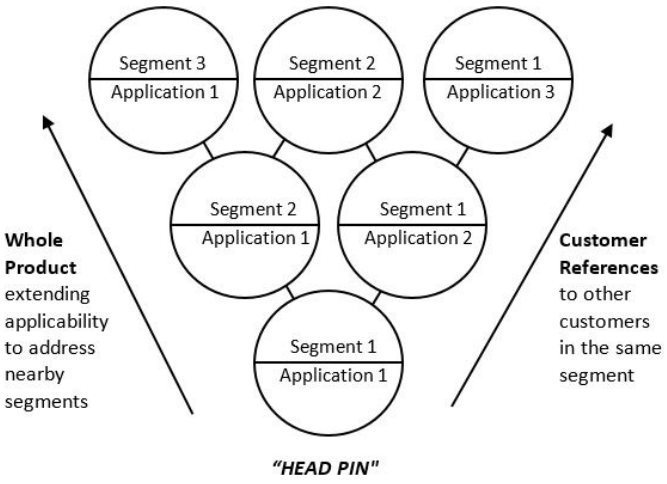
The theoretical background in the study comes from technology diffusion models, mainly leaning on Moore's (1991) chasm theory. Based on general observations, one of the prior hypothesis for the research is that intelligent packaging technology has passed

the so called innovators' phase, but not yet reached major markets. This phase is called the Bowling Alley, where technology is tested simultaneously in several sub-categories described as bowling pins. If several categories accept the technology and a strike is bowled, the technology concept moves on to major markets as widely accepted standard technology. Otherwise it might get reduced to a niche role, becoming a single technology for a specific market segment and user.

2 Technology diffusion and intelligent packaging market

The technology acceptance model (TAM) was developed by Davis et al. in 1986–1989. Its outcome was that the intention of a company to shift to new technologies stems from two main factors: perceived ease of use and usefulness (Davis et al., 1989). In practice, these factors can be understood as a cost-benefit evaluation.

Figure 3 Bowling alley market development



Source: Moore (1995)

Technology acceptance has also been studied under the diffusion of innovation (DOI) theories by Rogers (1962) and later it became more widely known with Geoffrey Moore's bridging the chasm theory (Moore, 1991, 1995). The main contribution of Rogers' theory compared to TAM was the psychological effect in innovation diffusion and the fact that companies are not only rational in decision-making. Rogers' theory (1962) focused on two notions:

- *First*, innovations spread systematically from one segment to another, where the segments consist of companies arranged based on their mental attitude towards innovations and change. Rogers named the segments as *innovators* (venturesome, educated, multiple info sources), *early adopters* (social leaders, popular, educated), *early majority* (deliberate, many informal social contacts), *late majority* (skeptical, traditional, lower socio-economic status) and *laggards* (neighbours and friends are main info sources, fear of debt).

- *Second*, the rate of adoption of innovations is dominated by five traits: relative advantage, compatibility, trial ability, observability, and complexity. Moore (1995) added three more traits into Rogers' list of five (voluntariness, image, and result demonstrability) and noted that innovations spread by one use case or category at a time.

Moore's main theory became to be the notion that not all technologies reach the major markets. According to him, the major markets start in early majority, which learns from the experiences of early adopters and does not continue implementing the technology without positive pragmatic experiences. According to Moore, the chasm is passed by a bowling alley (Figure 3), where the new technology at hand must be proven one use case after another through customer references. At the same time, partial solutions extend into whole products as the usage increases (Moore, 1991). Since then, several studies have argued that, out of the eight factors listed by Moore influencing the innovation strength, only three factors are above others; those being compatibility, technical complexity and relative advantage. (Bradford and Florin, 2003) As a result of the DOI theory, this list is similar to the one suggested by TAM. The comprised suggestion would be that if a new technology succeeds in benefit-cost comparison (both regarded widely), it has a high probability of reaching mainstream markets.

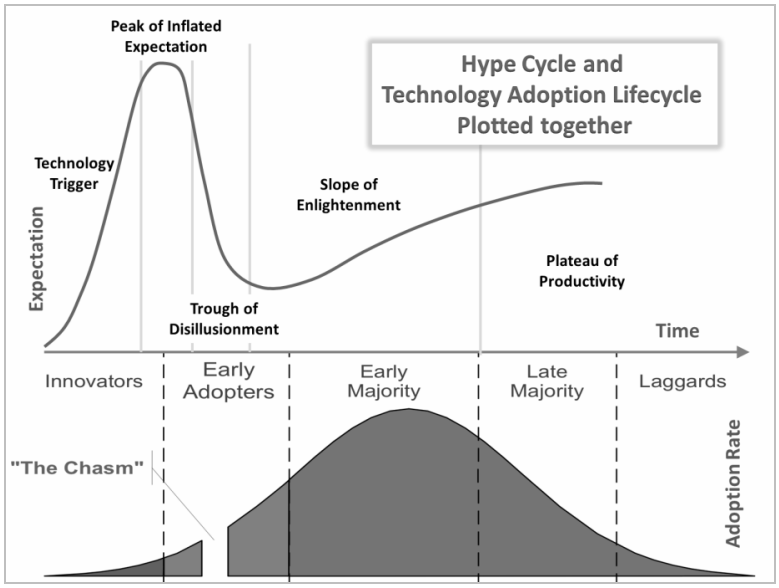
2.1 Secondary market data

References on intelligent packaging adoption can be made from secondary studies. According to the estimations of research company IDTechEx (2014), RFID market value will grow over 300% between 2014 and 2024 from USD 8.89B to USD 27.31B. Its research reports that, in 2014, the largest segment was passenger transport/automotive (USD 3.36B) and financial/security applications (USD 2.82B), while in 2024 the largest segment is estimated to be retail (USD 7.83B). Retail segment growth passed USD 1B in 2017, after which it has been breaking the following USD 1B value level almost annually.

IDTechEx also provides data on a number of global case studies or commercial pilots conducted. According to IDTechEx, the US leads RFID activity (1.612 pcs, 48%), while Europe comes in second (incl. UK, Germany, France, Italy, and Netherlands; 1.068 pcs, 32%) and Asia third (incl. China, Japan and Australia; 667 pcs, 20%). As IDTechEx notifies, Asia has become the leading manufacturer of RFID tags. Therefore the numbers of studies or pilots implemented represent the continent's activity level better than its RFID tag production volumes. (Das and Harrop, 2014) In the study by IDTechEx, Europe represents an average market stance and could therefore be a potentially solid reflection of the global market place on average.

From a business function point of view, the main utility of RFID has been supply chain optimisation (Williams, 1991). In 2017, Research Company Gartner released its hype cycle for logistics and transportation, nominating RFID as the single most transformational and ready-to-use technology for companies. It had reached the so called plateau of productivity (Gartner, 2017). The hype cycle model is another model focused on identifying the market maturity of a technology in a specific use. As it is Gartner's property and measures only a specific functional point of view, it was considered to provide and incomplete view on intelligent packaging market acceptance. Hype cycle has been broadly matched against Moore's chasm (Figure 4 provides an example) as an idea.

Figure 4 Hype cycle (on top) vs. chasm



Source: Don McBribe (2009)

2.2 Information gaps

From a theoretical standpoint, Moore's bowling alley accurately describes the preliminary hypothesis of the study on where the intelligent packaging market is expected to currently stand: proving the value in different sub-segments. The secondary data from research companies provide forecasting data on development, but they do not clearly state the current market maturity phase. Primary data are needed to describe the current experiences and dynamics in order to match the data against the chasm model used as key framework in the study. Descriptive data shall answer issues such as the following:

- Is RFID usage concentrated or evenly spread?
- Who owns the RFID territory within companies?
- What kind of drivers and barriers explain current RFID usage?

According to technology diffusion theories, both the emotional attitudes and rational fit within categories or functional needs influence how well the technology is accepted. Emotional attitudes can be related to aspirations companies want to attach to themselves as technologically advanced or environmentally friendly citizens. Therefore, in addition to rational reasons, the emotional drivers should be looked at as well.

2.3 Market maturity model

In order to clearly define market maturity, the research classified technology penetration based on Moore's chasm theory. It contains five development phases (see Table 1) with distinct audiences leading the technology activation during the stage. Each segment holds

emotional and rational causes driving the adoption. Innovators want to be ahead of everyone else, while early customers seek for edge in their company to drive performance, whereas the early majority adopts moves when a new technology has become a dominant design within the industry. One way to study current technology acceptance is to seek information on which segment is adopting the technology and what kind of drivers – emotional and rational – are given among the adopters.

Table 1 Maturity stages, adapted model

Stage/segment		*Share*	*Emotional drivers*	*Rational drivers*
1	Innovators	2.5%	Aspirational: 'I am ahead of others'	None: innovators do not buy for economic reasons, if paying at all
2	Early adopters	13.5%	Aspirational: 'I am looking for edge'	Unique to customer
3	Early majority	34%	Comfort: 'Others are buying this too'	Unique to category
4	Late majority	34%	Fear of missing out	General across categories
5	Laggards	16%	'Why should I care?'	Served as value-added bundle with other goods provided

Source: Forth (2010–2016)

3 Survey design

The intelligent packaging market survey was conducted in Europe, which was from a research economy perspective global and versatile enough, and yet concise enough to collect empirical data.

The survey was conducted via web panel collected and implemented by Survey Sample International Research Company. Table 2 explains the audience composition by country, industry, and functions. The intention was to collect a well-balanced sample in all areas. A couple of exceptions were allowed:

1 The main rule for sample creation was to find representation from major companies, but in Finland and Sweden the panel constellation did not allow accepting only respondents from major companies. Therefore, the sample from the north also includes from SMEs. As it later shows, Finland and Sweden did have differing views on RFID, which may be the result of this constellation issue.

2 In Finland, the panel size was too small to reach 100 respondents that fit the defined criteria. Therefore the sample size was left to half of the intended size.

The survey was conducted in November 2017 and the results were analysed within three weeks after field work. The survey contained 685 respondents, who answered a structured questionnaire in a web panel.

In regard to the other research settings, it should be said that the questionnaire was translated into the native languages of each country, the alternatives in each question were rotated to avoid false results, and the questionnaire length was designed to 5–10 minutes.

In addition to the abovementioned, the audience was picked to represent the industries most suitable for intelligent packaging, comparing the size of the industry in

packaging (e.g., food), the applications that intelligent packaging offers to them (e.g., healthcare and manufacturing) and predictions of RFID growth (e.g., retail). Therefore, industry selection was based on a suitability analysis.

Table 2 Survey respondents by country, industry, and function

Country	*N =*	*Industry*	*N =*	*Function*	*N =*
Germany	107	Food and beverage	65	IT	268
France	112	Healthcare	166	Sales and marketing	201
UK	101	Manufacturing	258	Supply chain	216
Spain	106	Retail	196	*Total*	*685*
Italy	104	*Total*	*685*		
Sweden	104				
Finland	54				
Total	*685*				

The survey was targeted at the decision-makers of the companies, which means that the respondents had to be responsible for or participate in decision-making in their firms. On a functional level, the panel was gathered from IT/data management, sales and marketing, and supply chain management, which reflect the RFID value domains of revenue generation, operating margin and capital efficiency.

As a traditional survey study, the research was based on a structured questionnaire method and the results were quantitatively analysed. The questionnaire used a scale of 1–7, where values 1–3 were interpreted to point to negative and values 5–7 to positive answers for the question set. The research questionnaire was designed to proceed from generic themes to detailed questions on utilisation areas. The questionnaire was carefully planned to not give such information during the questionnaire which would systematically direct the results. Also, when asked about intelligent packaging, descriptions were given to confirm that the respondents understood the key terminology in the intended way.

The total sample size of 685 provides reliable results and represents a population of up to 250 million respondents with 99% confidence level and 5% confidence interval. Regardless, the country- or industry-specific results may show variation especially in areas where the number of respondents fell under 100 (i.e., Finland, food and beverage). Validity was preserved by careful questionnaire design.

Lastly, the survey included a questionnaire containing 24 questions. With cross tabulation, this leads to over 150 charts after analysis. In this report, only the most remarkable charts are being individually reviewed. In each of the levels, however, learning is discussed to summarise the wider learning discovered from several charts touching the specific area. The key themes in the survey included comparison of identification technologies, change drivers and barriers in renewing product identification, functional ownership of identification technologies in companies, and understanding future plans and expected changes from the companies' perspective.

4 Results

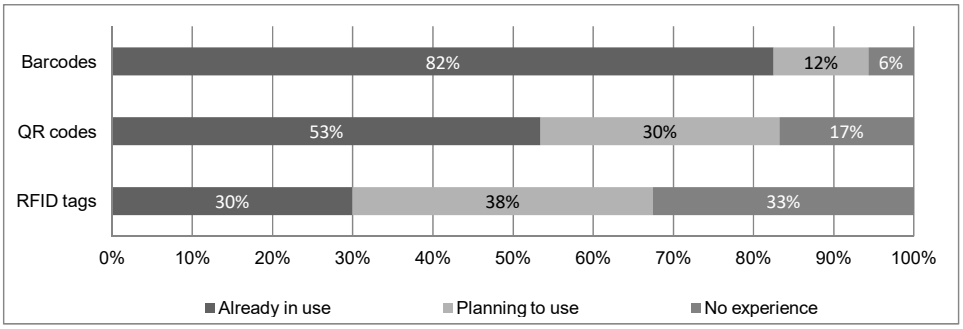
This chapter reviews the results from the conducted primary survey study as empirical data on intelligent packaging. Presented below are the most central findings related to penetration, usage areas, dynamics (barriers and drivers of the technology), and variance.

4.1 Market penetration

The key end-benefit of intelligent packaging provided to companies is the ability to extract data automatically from products and packages during the supply chain and customer engagement. Broadly speaking that means the entire value chain starting from raw-material handling and ending with end-product delivery to the customers' hands and the consumption phase. Data in this context can help companies make more efficient supply chain operations, lower their tied-in capital and drive revenue growth in various ways.

According to the survey, companies see product-related data important in their business (87% of the respondents), and currently they report using mostly optical reading to do it (barcodes 82%, QR codes 53% and RFID 30%). It became evident that companies use many alternative technologies at the same time. The technologies used for identification are likely to be changing, as 38% of the companies report plans over RFID, 30% over QR and 12% over barcodes. The result underlines the fact that there are always functions within companies that still lack any identification and that traditional barcodes can be a useful tool to start with. For instance, in several industrial areas, technical products lack any formal identification, and inventory management is based on manual item recognition and cycle counts. Figure 5 summarises the answers to the survey question 'What kind of barcodes/QR codes/RFID tags related to the identification, monitoring and traceability of products and packages is your company using at the moment or planning to use?'

Figure 5 RFID vs. optical codes

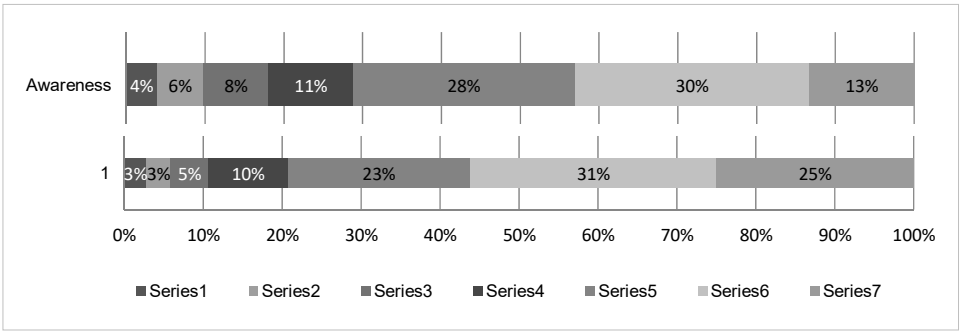


Note: Current vs planned use.

For RFID this result is strong, but would require further studies to sharpen this information in order to understand the areas where RFID is being used in more detail. In this study, it did not specify further what level of implementation was in use and in which role.

In addition to the intelligent packaging adoption rate, the level of interest was studied. This was needed to isolate current plans from the underlying engagement to RFID. The thought behind this question was to understand whether identification technology was something forced from top-down or whether it represented a theme widely considered engaging. The value of this information is to be able to evaluate whether RFID is able to spread from one segment to another, which would be important in understanding Rogers' theory of DOI. The spread is specifically based on experiences, which are not only rational but also based on emotional messaging between people (Rogers, 1962). Figure 6 summarises the answers to the survey questions 'How well do you know what 'intelligent packaging' means on a scale of 1 to 7 (1 = not at all, 7 = very well)?' and 'How interesting is the use of intelligent packaging from your company's point of view, on a scale of 1 to 7 (1 = not at all interesting, 7 = very interesting)?'. The intelligent packaging concept was described before the question on interest was asked. According to data, RFID had the highest take up rate with 38%. On average, this number describes the anticipation, although it is clear that technology use typically proceeds category specifically – segment by segment according to Moore's theory.

Figure 6 Awareness of interest in intelligent packaging



4.2 Variance

The survey also explored country- and segment-specific deviations of intelligent packaging attractiveness. This was central in order to understand whether there was significant variance that could corrupt the overview of the intelligent packaging market maturity.

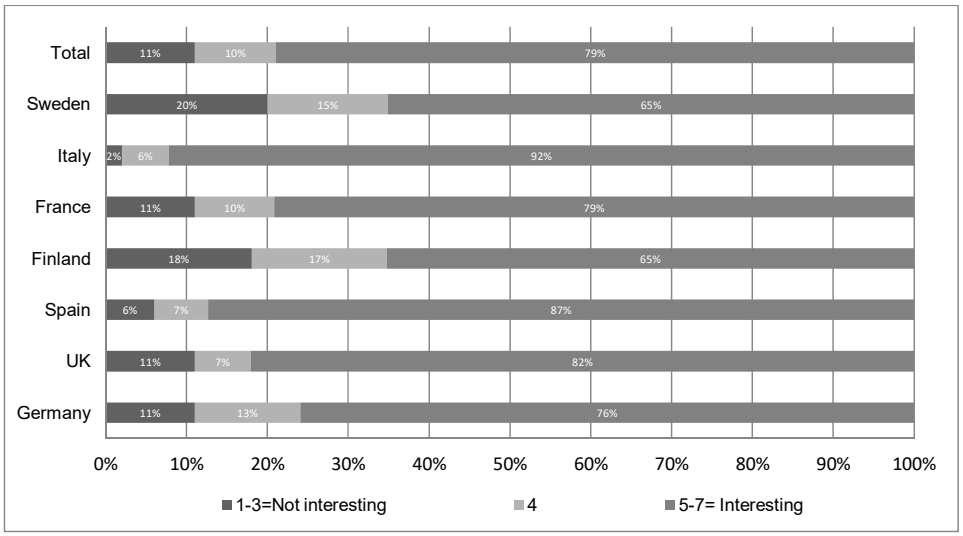
The finding of the survey was that, while the industry segment or functional variation in the attractiveness was low or insignificant, the answers between countries were categorically different and showed significantly different attitudes toward RFID usage. As the country set was designed to cover Europe from north to south, it soon became evident that the south (represented by Italy and Spain) showed the highest interest and enthusiasm in RFID, while the north (Sweden and Finland) was most hesitant to it. Figure 7 summarises the answers to the survey question: 'How interesting is the use of intelligent packaging from your company's point of view, on a scale of 7 to 1, where 7 = very interesting and 1 = not at all interesting'.

This finding of higher market maturity in the south compared to the north can be related to cultural openness to new opportunities and the greater size of domestic markets. In the north, companies do not require a similar level of automation for

profitability compared to the larger markets in the south (Finland has 5M inhabitants, Sweden 15M, while Italy has 60M and Spain 46M). In the business sectors, Italy and Spain have more RFID-friendly industries, such as textiles, but all the countries have strong industrial segments, which have known use cases in the supply chains and the Industry 4.0 theme. Also for instance Sweden has one of the largest global textile firms (H&M), so the situation is not all black and white. Besides, the research audience was constructed similarly in all countries, which is why industry deviation as an explaining parameter does not fit with the result. As an outcome, the south proves to be one step ahead of the north in the utilisation of intelligent packaging technologies.

The result of the variance is that in Finland and Sweden the interest level is at 65%, while in Italy and Spain the same values are 92% and 87%, respectively. Spain also has one leading example in Zara (Inditex), which is known as one of the most efficient supply chain firms globally and using RFID in its operations. According to data, technology acceptance is geographical in addition to the industry-specific segment influence. It is understandable taking into account that industries are also geographical.

Figure 7 Country variance demonstrating attitude differences



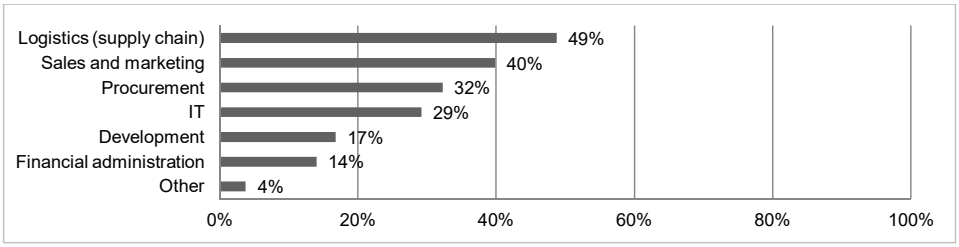
4.3 Functional ownership

Intelligent packaging offers business benefits for several functions ranging from supply chain to brand protection and customer engagement. Depending on the organisation, the ownership of RFID utilisation in products/packaging can belong either to one of the functions or to a third party within the organisation, such as IT management. Often intelligent packaging is connected to the digitalisation agenda of a company, and the owner of the digitalisation can be someone in top management, such as Chief Operative Officer, Chief Digital Officer or Chief Strategy Officer.

Figure 8 summarises the answers to the survey question: 'Which function makes the decisions on the use of RFID tags in your company?'. Generally, IT has been regarded as the function that leads digitalisation within companies. In the survey, however, it was

noticed that packaging-related RFID use is mainly connected to supply chain and logistics management (61%) and marketing (56%) instead of IT (29%). This view comes through systematically; for instance another question determined that the smooth function of the supply chain and customer experience were considered more important than connectivity to product users and data capture from them.

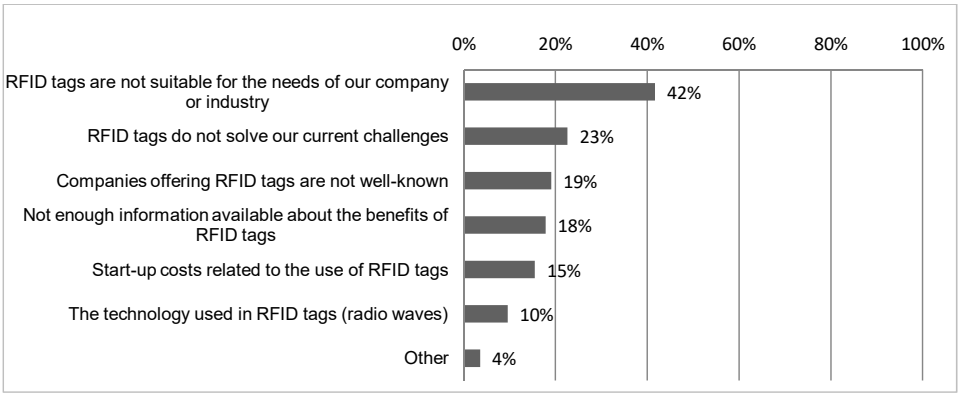
Figure 8 Intelligent packaging stakeholders in the companies



4.4 Dynamics: barriers and drivers

Thirdly, the survey intended to find answers to what were seen as the main barriers of implementing RFID in products and packaging. This represented a floor level view of intelligent packaging in practice. The issues given as potential reasons were adopted from typical technology utilisation barriers, and the classification 'other' was offered to identify potential other areas impacting technology adoption. Figure 9 summarises the answers to the survey question: 'Select the most important reasons for not considering the use of RFID tags to be interesting'.

Figure 9 Barriers found avoiding intelligent packaging acceptance



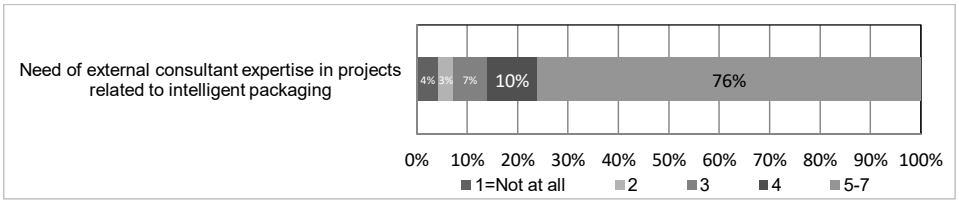
Reasons 1–2 in the figure should be studied further as they do not include information on whether companies are knowledgeable enough to evaluate the suitability of RFID for the company, industry, and challenges. For instance, in the past metal and liquids have been problematic materials to radio-technology, but today's advances in RFID technology have overcome these areas (Maijala, 2017). This was further analysed on a country level, and it was found out that the level of challenges reported was in counter correlation with

the reported enthusiasm on RFID. In Italy and Spain, 29–33% of respondents raised the issue of fit with the company and industry, while 56% of respondents in Finland said the same. Later in Figure 10, these three countries were in reverse order in reporting enthusiasm over interest in intelligent packaging. The obvious reason for the deviation would be technology adoption, as the respondents' constellation followed the same industrial structure in all countries.

Figure 10 summarises the answers to the survey questions 'How much will your company need the expertise of external consultants in projects related to intelligent packaging, on a scale of 7 to 1, where 7 = very much and 1 = not at all?' and 'How much will your company need the expertise of external consultants in matters related to business development, on a scale of 7 to 1, where 7 = very much and 1 = not at all?'.

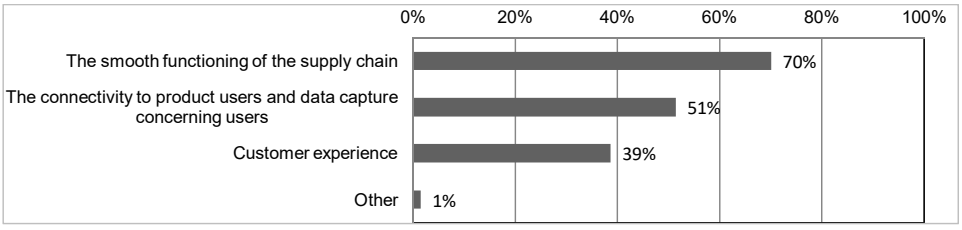
The respondents reported using consulting services (76%) in order to overcome the barriers. To compare its importance, the comparison was made against business development as another functional area. In comparison, intelligent packaging reported a number 6 percentage points higher in terms of the need for external consultants when compared to business development.

Figure 10 Use of consultants in implementing intelligent packaging



Lastly, the key driver for utilising intelligent packaging was linked to a smoothly functioning supply chain. It is a natural outcome looking at the historical background of RFID technology, which has been widely studied as auto-identification technology in supply chain and logistics uses. However, looking at current zeitgeist, where artificial intelligence and analytics are rapidly expanding with a strong background in digital marketing, it could at some point entail a shift from supply chain technology to a data capture and customer experience tool in the future. Figure 11 answers the question: 'Which of the following information obtained using intelligent packaging is particularly interesting?'.

Figure 11 Motivations for intelligent packaging usage



The above variation is logical, when considering the number of standard use cases commonly known in each function. The supply chain has several known RFID-based

uses, while customer experience as a relatively new practice derived from marketing only has a few.

5 Conclusions and introduction of 'crave' – the IPFS

The purpose of the survey was to get information on intelligent packaging market maturity. The used model used was described in Table 2. The answers were reflected against the chasm model to find evidence on which phase the answers point to. Table 3 summarises the conclusions derived from the data collected through the survey.

Table 3 Conclusions derived from the survey responses

Theme	*Results and data points*	*Conclusions*
Market penetration	• 71% of respondents know what intelligent packaging means and 79% are interested in it (after description of the meaning of the concept). • 30% of survey respondent firms already use RFID tags related to the identification, monitoring and traceability of products and packages. Current use of barcodes and QR codes is higher. • 38% report planning to use RFID in the future.	1 Intelligent packaging has reached the early majority segment. The percentage value exceeds the innovator and early adopter value shares (cumulatively 15.5%). 2 It is not likely that intelligent packaging would be limited to a niche role, but rather expand in segments and use cases.
Variance	• Italy and Spain have the most interest on intelligent packaging (43% and 39% very interested, respectively), while the Nordic countries report the lowest interest (respective values 11% and 13%).	3 Variance in overall technology acceptance is related to geographical markets, which can be related to the combination of cultural attitude on newness and domestic market size.
Functional ownership	• Supply chain is the most common owner (49%) and utilisation area (70%) within companies.	4 The supply chain function leads the utilisation of RFID within companies.
Dynamics: barriers and drivers	• Current challenges related to the fit for use cases (by 42% of respondents). • 19% report not knowing RFID providers well enough and 18% claim not having enough information on the benefits. • 76% of companies need external consultants' expertise with intelligent packaging. • Motivations are related to supply chain functioning (70%), data capture (51%) and experience (39%).	5 Challenges in the current development phase are related to pragmatic questions typical to early majority. 6 Quantified and detailed segment specific information and education would be needed in the market place. 7 Data and customer experience perspectives are currently under represented within intelligent packaging compared to key trends in the business markets.

Table 4 Intelligent packaging feasibility score

Factor	*Description*	*Points*	*Comment*
Complexity	Does the company run a simple closed loop or complex open loop supply chain, where organising reading and data delivery will set limitations?	+1, if closed loop	E.g., in a retail setting, the so called close loop retailing model, where a company sells its own products allows higher governance of goods throughout the value chain allowing a better environment to set up tracking.
innovation spiRit	Is innovation and leading the change supported by the company's strategy and management?	+1, if forward looking industry/company	It is hard to give an objective value for this, as it is more dependent on gut feeling and understanding the organisation.
vAlue	Does the value assessment support item level tagging by high item level value, allocation of waste or strategic importance.	+1, if value >5€/each	Despite the rule of thumb of 5€ retail price, some exceptions apply: e.g., in the food sector, RFID can significantly decrease waste, lowering unit costs and offsetting the added cost of intelligent packaging framework.
Volume	Intelligent packaging is at its best when keeping high volume product streams in order, which manual work does not do in reasonable quality level and cost.	+1, if >1.000 pcs/day	Typically fewer than 10.000 units when manually operated – no need for automation. Large customers managing >1B annual volumes.
usE case maturity	Use of intelligent packaging connects to various use cases. The use case maturity predicts the feasibility.	+1, if trialed and proven use case	E.g., industrial supply chains, certain retail and apparel and fashion currently have known use cases available.

To answer the research questions presented in the introduction, the following conclusions should be made:

- *Maturity:* Intelligent packaging is currently in the validation phase, a maturity step described as the bowling alley, where several categories test the technology simultaneously. The result confirms the hypothesis of the research.
- *Dynamics:* The current challenges are linked to further expanding the repertoire of use cases and educating the market on the pragmatic issues: providers, benefits, prices and methods in niche areas. Drivers and motivations are mainly linked to smooth supply chain operations, but customer data and experience potentially play an increasing role in the companies' interests.

- *Feasibility:* To answer the third research question on predicting the feasibility of RFID connected packaging in any given business, an intelligent packaging feasibility score (IPFS) model was formed. The model further develops the technology diffusion model traits of Rogers (relative advantage, compatibility, trial ability, observability, and complexity) into intelligent packaging market specific parameters, which have come out during the research, forming an arguably improved version when assessing RFID connected intelligent packaging diffusion. The parameters are also created by industry experts (Huhtasalo, 2017) who have worked on similar tools in practical business settings. The parameters and scoring are presented in Table 4.

The IPFS framework forms an acronym ('crave'), and it is intended to measure the amount of desire the business case owner should have for working with the case at hand. Points 5/5 signify strong potential for further assessment, points 3/5 signify some reservations, and below 3/5 signify weak potential for the case at hand.

The value of IPFS comes from offering a simple framework for practitioners to quickly assess the business potential of RFID usage for the business at hand. Such a model, when working well, serves casual conversations in work related events, where anyone could use a simple check list to evaluate the potential of a case before stepping into more detailed feasibility studies. Such a tool saves time and effort from companies and their vendors, and also open markets and the eyes of decision-makers to see the potential in their own businesses to start transforming physical product flows with digital twins and intelligent software.

6 Future studies

Prior to this paper, there has been a limited amount of models available for intelligent packaging evaluation in practice. Ideally there would be several alternative models available, which would provide a wide range of models and eventually consensus on key parameters and usage.

As a model, IPFS is hypothetical and further studies are also needed to test the IPFS on real-life examples to gain experience on how well it predicts feasibility – and where the potential blind spots lie.

Lastly, more industry-specific data on intelligent packaging implementations are needed. They will help the growing number of implementations to set the right expectations already in the planning phase, and to succeed later with the implementation. As the world seeks ways to drive more sustainable businesses, efficiency in supply chains is one key component needed to transform industries into greener models.

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Publication II

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Environmental RFID: measuring the relevance in the fashion industry

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Environmental RFID: measuring the relevance in the fashion industry

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ABSTRACT

Fashion industry is globally one of the largest consumers of radio-frequency identification (RFID) tags, which has provided a best practice to manage inventories and respond to local desires. As the use of RFID has grown, the sustainability thriving fashion industry has turned to "green tags". The purpose of this paper was to evaluate the relevance of environmental RFID tags. The research was conducted in two stages: First, waste and emission reductions were accounted on a tag level. Second, the reductions were extrapolated to the brand-owner level analysing the impact of green tags by absolute measures and contribution to sustainability goals. According to the results, environmental RFID provides substantial improvements on a tag level, but limited impact holistically. Researchers note that although tags represent a small waste stream in the big picture, fashion companies may not have a choice. This paper is one of the first studies on environmental tags.

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Sustainability; radio-frequency identification; RFID; fashion and apparel; lifecycle assessment

1. Introduction

During the past decades, RFID has been a growing technology in an industrial digitalisation, especially in the areas of supply chain management, manufacturing and asset tracking (see, e.g. the profound literature review by Musa and Dabo (2016) and Zelbst, Green, Sower, and Reyes, (2012). Even so, Bose and Yan (2011) argue that there is little discussion in the literature on the environmentally responsible management of RFID. Findings from 13 case studies on the use of RFID in green projects reveal its potential to enhance environmental sustainability, and also to reduce costs and generate revenue by creating new business opportunities (Bose & Yan, 2011). In the study, RFID utilisation was defined as 'green' if it added economic value to organisations and improved environmentally responsible practices related to information technology.

A recent study by Garcia-Torres, Albareda, Rey-Garcia, and Seuring (2019) presented a profound literature review of 89 research papers related to traceability and how it can contribute to sustainable supply chain management in the apparel industry. RFID technologies were a topic of several articles reviewed in this study. According to Garcia-Torres et al. (2019), traceability for sustainability can leverage advanced technology (e.g. IoT, RFID, and blockchain) to achieve sustainability goals in supply chain management, because it facilitates the ability to track and trace as well as manage social and environmental issues (Figure 1).

Another literature review by Denuwara et al. (2019) focused on reporting case studies to highlight the sustainability benefits of RFID technology. Denuwara et al. (2019) concluded that the relationship between RFID technology and the sustainability of the apparel industry is important, due to the increasing use of RFID tags in apparel stores. RFID tags can be used throughout the value chain to provide social and environmental benefits that are greater than solely economic benefits. Navodya, Maijala, and Hakovirta (2019) underlined in their research on sustainable RFID that increasing interest in sustainability consists not only of environmental but also economic and social aspects. Thus, the perspectives of sustainability deal with holistic fairness of the fashion industry, where some of the critics are related to child labour, fair distribution of profits, and the short lifecycles of fashion products that increase landfill after a brief use of such products by consumers.

In the fashion industry, according to Bertola and Teunissen (2018), tracking technologies such as RFID or advanced product lifecycle management software can potentially link the entire value chain from suppliers to retail channels, and follow products to their end. Many brands, e.g. Max Mara, Fendi, and Michael Kors, are integrating RFID in their products with tracking purposes, mainly to identify fake products, or support interaction with customers in retail shops

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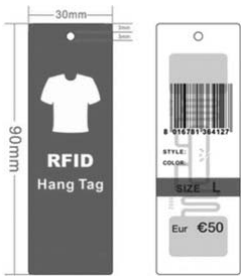

Figure 1 . Apparel hangtag with an RFID tag placed inside the board (Seiko RFID, 2020).

(Bertola & Teunissen, 2018). According to Kabukcu (2017), RFID in the fashion industry helps to improve inventory management, improve the efficiency of operations, integrate the fashion business model, and increase the responsiveness of the fashion cycle. Kabukcu (2017) also concluded that RFID technology can play an important role in order to propose new solutions for a greener sustainable industrial world. In Florea, Corbos, Popescu, and Zamfir (2016), the study concluded that item-level tagging can bring benefits to the entire supply chain from manufacturer, the logistics companies, and through to retail. According to Azevedo and Carvalho (2012) the deployment of RFID in the fashion supply chain, despite the potential advantages, must overcome the problems of integration with existing systems. Moreover, the tag cost of RFID systems must be reduced to a more acceptable level, so that item-level tagging can become a reality (Azevedo & Carvalho, 2012). However, the study is 12 years old and, according to market researchers, fashion today consumes approx. 12 billion units and 60% of the global RFID products (Das & Harrop, 2019). This represents approximately 5–10% of the global fashion manufacturing, which is estimated to produce approx. 100 billion garments in a year (see, for instance, Common Objective, 2018).

RFID technologies themselves as well as their manufacturing are also being developed in an eco-friendlier direction. According to Angeles (2013), with increasing concern for environmental sustainability, researchers and practitioners have been exploring the role of RFID in supporting 'green supply chains'. The study by Angeles (2013) applied the technology organisation environment (TOE) framework by Tornatzky and Fleischer (1990), as a useful tool in explaining the RFID system deployments for environmental sustainability. Kanth et al. (2012) introduced the paper-based RFID antennae that yield lower organic emissions to the environment while considerably higher inorganic emissions to the air. Their study results revealed that air is highly affected by toxic emissions in comparison with freshwater, seawater, and industrial soil. In addition, Mukendi, Davies, Glozer, and McDonagh (2020) reported recent technology developments by a Finnish–Swedish forestry, pulp, packaging, and renewable materials company, Stora Enso, which offers an environmentally friendly manufactured 'ECO RFID' tag.

As the literature review shows, RFID and sustainability are central themes in the global fashion industry. However, until today there has been very little academic research published on sustainability when it comes to RFID tags themselves. This paper addresses that theme by evaluating the relevance of the environmental RFID tag concept for the fashion industry. The subquestions for the paper are: What is an environmental RFID tag? How do the environmental benefits materialise in green tags? And finally, how relevant is the environmental RFID tag concept for the fashion industry and its brand-owners in understanding the sustainability goals that companies are committed to?

The focus of the paper is on RFID tags, thus the sustainability impact of the Internet of Things framework or advanced data handling is not studied. To keep the research manageable, the focus of the research is limited to one specific sustainable RFID tag technology picked as an example to be compared against legacy tags. Hence, the research does not examine the various types of environmental tags. Furthermore, the comparison does not take into consideration that the chip used in the tag as the focus of the comparison is purely on the antenna component. Sustainability is generally a wide topic, and in this paper, only the environmental domain is taken into examination; thus, in the terminology, 'environmental', 'sustainable' and 'ecological' are loosely used as synonyms.

The research utilises a case study approach in conducting the evaluation; it combines quantitative and qualitative data in analyses. In the secondary research, the authors used common research databases from Google Scholar and the university database Primo (see exlibrisgroup.com) for searching topics of sustainability, RFID and fashion throughout the largest scientific publishing houses. As the topic was somewhat new, reputable commercial research institutions were also utilised in the study, such as IDTechEx and McKinsey.

The rest of the paper is organised as follows: Section 2 introduces the research method and the two-fold approach adopted. Section 3 talks about RFID as an inspection unit, including sections that discuss the waste and emissions of traditional RFID tags and an introduction of ECO RFID as an example of an environmental tag product. Section 4 summarises the results

both from the tag and end-user perspectives. In the last section, the paper discusses the conclusions and future studies.

2. Methods

The research was conducted as a case study on the ECO RFID tag technology, which was picked as an example of an environmental RFID tag for comparisons. The purpose was to explore what specifically makes a green tag environmental, as well as how relevant the environmental benefit of an RFID tag was for the fashion brand-owners. According to Voss, Tsikriktsis, and Frohlich (2002), the case study approach allows questions of why, what, and how by focusing on one concrete area of investigation. As stated, the research was meant to be an exploration that provides details of environmental RFID topic and enables further studies in the area.

The research method adopted a two-steps approach in conducting the evaluation: ECO RFID was first inspected at a tag level using lifecycle assessment (LCA) to identify the technical improvements that the tag provides in terms of the reduced amount of emissions and waste. After accounting for the single unit reductions, the results were secondly analysed within the context of the fashion industry and brand-owner to further analyse the relevance of the environmental tag in the market.

LCA is a concept that stimulates production from the cradle-to-crave in order to analyse the inputs, processes, and output of a manufactured unit, accounting for raw material and energy use, emissions and waste; along with end-products with their side streams. However, the way that the LCA concept is applied varies from one context to another, and academia thus notes that even the simplified LCA methods cannot provide a 'one size fits all' approach (Hur, Lee, Ryu, & Kwon, 2005). In this paper, the LCA results leaned on ISO 14047 technical report on impact categories and CML2001 on impact assessment method. LCA measuring took the cradle-to-crave approach but excluded in evaluating the impacts of antenna material and indirect production (such as energy consumption, lighting and heating in the production unit). These two areas are most speculative by nature and lack sufficient data that one could use for argumentation. Furthermore, their impact on the final verdict was seen to be marginal and not change the conclusions per se.

3. RFID tag level inspection

As RFID technology has developed and gained increased adoption, the focus has turned into the environmental impact of the RFID tag itself. Key questions in this area concern, e.g. what the effect on the environment of these tags is once the underlying item is eradicated, what the recyclability of these tags is, and how these tags are able to support the concept of the circular economy. There is also increased vigilance and regulatory norms especially in Europe, like REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) and WEEE (Waste of Electrical and Electronic Equipment), which enforce buyers of RFID tags to be more aware of what goes into the tag and its impact on the environment.

3.1 Waste and emissions

While a single RFID tag has a very small chemical and physical footprint to make a sizable impact on the environment, the waste accumulates when environmental impact is accounted for from billions of tags. According to IDTechEx (Das & Harrop, 2019), 18 billion RFID tags shipped globally in 2019 with growth projections to 55 billion tags by 2029. Figures 2 and 3 present the situation in Europe related to the number of RFID tags used in addition to the CO_2 emission impact (RAND Europe 2012).

The environmental impact of a traditional RFID tag appears in three areas: (1) Carbon footprint – the ecological impact of producing RFID tags, including components that go into an RFID tag. (2) Chemical effluent impact – the amount of chemical effluents and use of water in the manufacturing process that can be measured in terms of eutrophication and acidification impact related to nitrogen oxides, sulphur dioxide, and COD water emissions in the manufacturing process. (3) Plastic waste – the amount of plastic material being created as part of the finished RFID tag product that influences recyclability of tags itself and eventually goes to landfill (Figures 4 and 5).

The chemical used during the production process has been one area that new sustainable RFID technologies have addressed with alternative production methods. The solution has included using laser-cutting and additive printing methods. Both processes use paper as a base material instead of polyester plastic that has been the traditional substrate used in RFID tags. In traditional tag processing, the heat-stabilised polyester film and aluminium foil are first laminated. Excess aluminium is removed with a wet etching process using chemicals and water and causing waste. Additional face paper has then been used to convert the inlay to a tag, together with release paper and label adhesive.

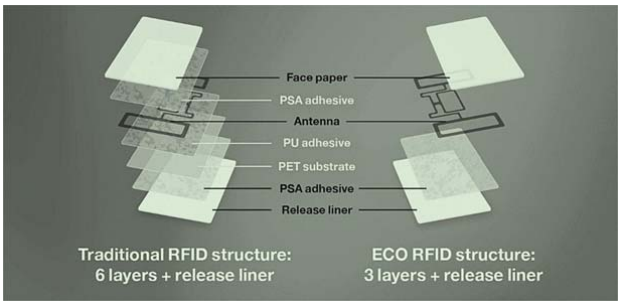

Figure 2 . Traditional RFID compared to ECO RFID (Stora Enso, 2018).

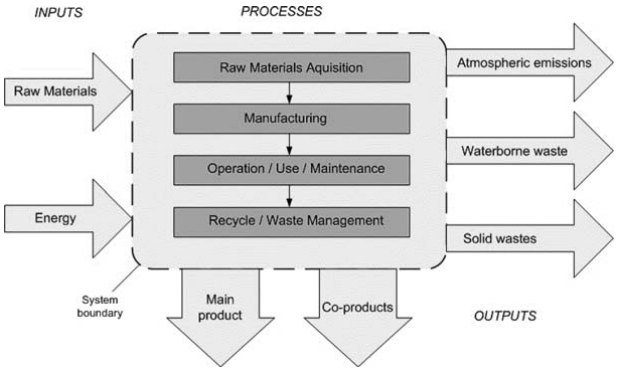

Figure 3 . Main stages and typical inflows/outflows considered in lifecycle assessment (PennState University, 2020).

The RAND report estimates the carbon dioxide footprint of the traditional RFID structure across three size footprints (small 894 mm^2, medium 2219 mm^2, and large 4171 mm^2). The unit of analysis focuses on the raw-material consumption, where the highest refers to large according to previous sizes.

The polyester substrate and the acrylate layers used as adhesives account for the highest CO_2 footprint. The sustainable technology option, which eliminates the use of these chemicals, has a direct impact on the carbon footprint.

Similarly to the recyclability perspective, flame retardants or pigments used in plastic parts in traditionally manufactured RFID tags – such as potassium or bromine – may also be carried into the recycling or disposal processes, and are seen as environmentally critical in polymer recycling, so the recyclability of tags with polyester substrates is much more difficult. The RAND report estimates a large size tag (4171 mm^2 area) to have around 290.7 mg/tag of polyester plastic.

3.2 ECO RFID as an example of the environmental RFID tag

ECO RFID technology produces RFID using an additive approach to print the antenna directly on paper. The key benefits of ECO RFID are the lack of plastic layers in an RFID tag, avoiding the use of chemicals common in the traditional etching process, and significantly lower carbon footprint achieved by a less-energy intensive manufacturing process. ECO RFID is reported to provide similar performance, reliability, and comparable cost structure as the traditional RFID tags. Thus, it is expected to provide similar financial and operational benefits as traditional tags. As the so-called carbon tolls discussed in politics have not yet been decided, environmental tags also do not have an influence on regulatory costs as of yet.

Figure 6 illustrates the comparison of various manufacturing technologies commonly desired by retail brand-owners counting as the highest RFID use segment globally. The dimensions used in the graph

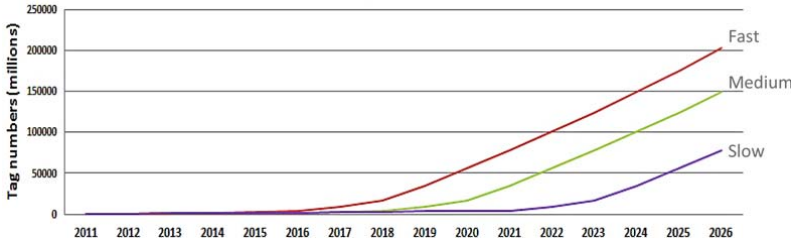

Figure 4 . Estimated relevant passive tag numbers for Europe/technological development scenarios (RAND Europe, 2012).

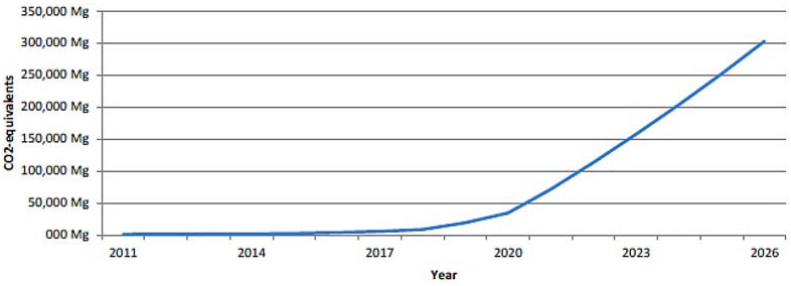

Figure 5 . Estimate CO_2 emission in Europe from the medium scenario of RFID tag volume growth (RAND Europe, 2012).

illustrate the requirements set by practitioners on RFID tags. First, the technology must be *performant*, which allows solid reading results in a variety of settings. Second, the technology must be *reliable;* as the tags that become defected will result in lost items in a system ran on RFID. Third, the *price* for the future must allow high volume use of RFID. Fourth, the comparison takes into account a *price roadmap*, which varies significantly between old and new technologies, and is typically central in renewable innovations facing markets today. While old technologies are at their peak with efficiency, the innovations are still at the early phase of scaling and are yet to achieve efficiency through market adoption and incremental technology development. Lastly, the product must be *sustainable* in order to support the brand-owner to meet his sustainability targets at every frontier (Figure 7).

4. Results

This chapter reviews the results at the tag level, and reflects the accounted improvements in the fashion industry and brand-owner perspectives to evaluate the relevance.

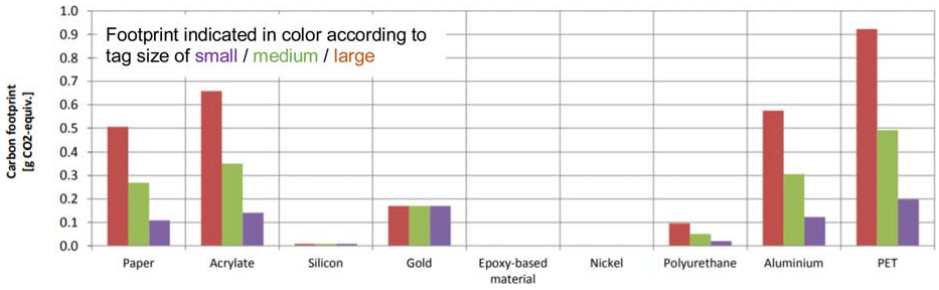

Figure 6 . Raw-material use in traditional aluminium based RFID tags (RAND Europe, 2012).

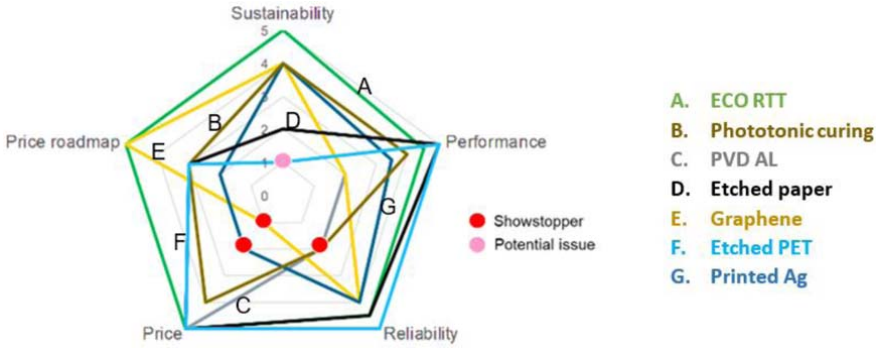

Figure 7 . Comparison of alternative RFID technologies (Stora Enso, 2018).

4.1 Tag level environmental benefits

Alternative comparison made between the printed environmental RFID tag and traditional polyester tag highlights the impact of the substrate during production and post-use, and energy consumption at the production machinery level. Table 1 summarises the results found in an LCA (lifecycle assessment), a study focusing on three sustainability emissions between an environmental and traditional polyester tag (Stora Enso, 2020).

The use of paper substrate in an environmental RFID tag process and lower energy consumption in manufacturing exerts a significant CO_2 emission impact compared to the traditional polyester substrate. Elimination of water usage and effluent treatment in the antenna manufacturing process has a significant eutrophication and acidification impact.

4.2 Fashion industry context

While the global RFID market was, in 2019, 18 billion tags in total, the fashion and apparel industry applied 12 billion units in garments to track the inventories. According to one taxonomy, a large company consumes over 800 million RFID tags, a mid-sized company uses 350–800 million tags, and small companies are below 350 million tags. The boutique fashion companies typically vary from larger production of some millions of garments to very small tailor shops with some hundreds of clothing items a year. The use of this taxonomy allows the evaluation of the impact of environmental RFID on a corporate level. In Table 2, the sustainability impact is looking at an average company, where the volume of tagged items is 350 million units.

It is estimated that 12 billion pieces of fashion apparel items were tagged in 2019. If the above environmental impact analysis is extrapolated to worldwide volumes in the fashion industry, green tags could have reduced 50k tons of total waste reductions in RFID tags alone. By 2029, the number of apparel estimated to be tagged with RFID should grow to 55–60 billion units per year. Total waste reduction with environmental RFID tags will then be 275k tons in the fashion industry alone.

Table 1. Comparison between sustainable and legacy tag in three areas (Stora Enso, 2020).

Impact vs. tag technology	Greenhouse gas g CO_2-eq/tag	Eutrophication 10^{-3}g PO_4-eq/tag	Acidification 10^{-3}g SO_2-eq/tag
Polyester tag	3.5	0.0036	0.019
Environmental ECO tag	1.4	0.0021	0.012
Difference (measure)	2.1	0.0015	0.007
Decrease (%)	60%	41.67%	36.84%

4.3 Brand-owner perspective

With increased consumer activism and awareness of the sustainability impact of the way companies operate, there is a growing demand for companies to respond to these concerns (see, for instance, McKinsey, 2020). The three selected case companies from the fashion and apparel industry have set ambitious sustainability goals and have become high volume RFID users during the past few years. With each of them, the number of RFID tagged items is expected to be one billion items, which is representative of their true volumes. The following examination outlines the sustainability goals each company has set in identifying areas that connect with environmental RFID, and therefore has validity as a source for improved sustainability performance (Tables 3 and 4).

The previous companies, in a similar manner to the leading global fashion and apparel brands in general, are translating sustainability into four pillars, which

Table 2. Impact on an average company with a tag volume of 350M units.

Environmental impact indicator	Environmental ECO RFID tag	Polyester RFID tag	Difference per tag	Annual Impact when 350M pieces tagged
GHG (CO_2 g/tag)	1.4	3.5	2.1 (61%)	735,000 kg of CO_2 reduced
EP (10^{-3}g PO_4/tag) + AP (10^{-3}g SO_2/tag)	13.8	22.7	8.9 (39%)	3115 kg of PO_4 and SO_2 reduced
Plastic (mg/tag)	0	290.7	290.7 (100%)	1,017,450 kg of plastic reduced
Total	1755 tons of reduction impact			

are focusing on greenhouse gas emissions, sustainable packaging related to sustainable raw-material use, human rights, and the circular economy. Sustainable tag technology responds to three areas out of four, and hence has a significance on a tag level to sustainability goals. In this paper, we understand that sustainable packaging entity refers to green manufacturing methods in order to avoid double accounting of plastic, which is part of the circular economy objective. Green manufacturing in sustainable tags means avoiding water consumption, pollution, and production waste.

5. Conclusions and discussion

This research paper addressed the environmental contribution of so-called green tags, which the literature review revealed to be an under-covered topic in academia, despite the increasing interest among fashion business practitioners. As the fashion industry was seen to move on to sustainable practices, it was seen as important to evaluate whether the environmental tag would be relevant for the companies and brand-owners in understanding the goals they have set.

Table 3. Environmental RFID contribution to the company specific goals (Companies' sustainability reports, see references on Decathlon, 2020; H&M, 2020; Inditex 2020a, 2020b).

Company and goal	Validity	Theme	Proof-points
Decathlon (Environmental RFID contribution rate 3/5)			
Decathlon is the largest global sporting goods retailer, headquartered in France and present in 52 countries worldwide. The purpose of Decathlon is 'to sustainably make the pleasure and benefits or sport accessible to the many'. The key sustainability focus areas for Decathlon include:			
Eco-design (making sure that the production of goods meets the needs of users while creating the lowest possible impact on the environment and society)	Yes	General benefits	5014 tons of reduced impact
CO_2 emission reduction (they have committed to a 75% reduction in CO_2 emissions by 2026)	Yes	CO_2	Reduction of CO_2: 1B tags x 2.1 g/tag = 2.1M kg
Supplier compliance around working conditions and water, soil, air pollution impact	No	Company-specific	
Sustainable packaging strategy (100% of packaging to come from sustainable sources)	Yes	Recyclability	Reduction of plastic waste at landfill: 1B tags x 290.7 = 2,907,000 kg
Incorporating circular economy in the value chain including promotion of repair/re-sale/re-use	No	Links to all RFID	
H&M (Environmental RFID contribution rate 4/6)			
Hennes & Mauritz AB is a Swedish multinational fast-fashion clothing retail company. It operates in 62 countries and is the second-largest clothing retailer after Inditex. H&M's sustainability vision is: 'with the help of technology and innovation, lead the change towards circular and renewable fashion while being a fair and equal company'.			
Reduce waste by aligning supply to demand and use of efficient distribution operations	No	Links to all RFID	
Improved transparency about sourcing through improved visibility on Tier-1/Tier-2 suppliers they source from, as well as sharing product sustainability information online for consumers	No	Links to all RFID	
Circular product design and sale including dedicated store formats to sell unused overstock as well as ability to recycle unsold stock for new products	Yes	Recyclability	Reduction of plastic waste at landfill: 1B tags x 290.7 = 2,907,000 kg
Sustainable packaging strategy focus including eliminating unnecessary plastic packaging and moving from single-use model to reusing models by 2025	Yes	Plastic	
The aggressive target of being a climate positive value chain by 2040, including focus on leadership in energy efficiency	Yes	CO_2, Energy efficiency	Reduction of CO_2: 1B tags x 2.1 g/tag = 2.1M kg
Chemical management through the use of safe and toxic-free products in their supply chain through establishing a hazard-based scoring system for substances being used in their supply chain	Yes	Green production, chemical etching	41.67% lower eutrophication and 36.84% acidification
Inditex (Environmental RFID contribution rate 3/5)			
Inditex is globally one of the biggest fashion groups headquartered in Spain. It operates in 93 markets worldwide with various brands: Zara, Pull&Bear, Massimo Dutti, Uterque, Bershka, Oysho, Stradivarius and Zara Home. In 2002, Inditex launched a Strategic Environmental Plan, and currently the company is running Sustainability Plans that are integrated into all product life cycle stages and supply chain stages.			
Design and sustainable raw materials	Yes	Plastics	Reduction of plastic waste at landfill: 1B tags x 290.7 = 2,907,000 kg
Environment, health & safety issues in manufacturing	Yes	Green production, chemical etching	41.67% lower eutrophication and 36.84% acidification
Green to pack & warehouse management	No		
Eco-efficient stores and sustainable packaging	Yes	CO_2	Reduction of CO_2: 1B tags x 2.1 g/tag = 2.1M kg
Human rights in the supply chain	No	Company-specific	

Table 4 . Sustainability pillars among fashion retailers.

Sustainability Focus Area	Global sustainability initiatives	Impact of using Environmental RFID tags vs. legacy RFID tags
Greenhouse gas emission reduction (CO_2)	CDP/UNFCCC	High
Sustainable packaging and reduction of single-use plastics and waste	FSC/PEFC	High
Human rights and supply chain transparency	UNGP	Low (Not much difference between environmental and legacy RFID tags)
Circular economy	EM Initiative	High (due to higher biomass of environmental RFID tags, 80% can be recycled)

Although this paper used only one specific environmental RFID tag technology to evaluate the sustainability performance against legacy tags, it provides a reference to the impact that green tags are in general able to provide. The key contributions of sustainable tags are related to avoiding single-use plastics (100%), significantly reducing greenhouse gas emissions (up to 61%), and a manufacturing method that especially minimises chemical waste (up to 39% in this paper).

At the large corporate level, where volumes are one billion tags a year, the environmental RFID brings concrete reduction of an environmental load derived from RFID tags, which in everyday language is the equivalent of 300 football fields of plastic and over 500 households' annual emission of greenhouse gases. Furthermore, as the technology evaluated is based on the printed electronics concept, it is likely to further increase the environmental impact by decreased logistics if the printing is located near the place where source tagging is made. Global supply chains typically contain greenhouse gas emissions that are rooted in the shipping of production supplies such as RFID tags. Traditional RFID tags are manufactured in large entities that do not allow flexible placement of production, in similar manner to new-generation sustainable tag manufacturing.

The underlying research question of the relevance of the environmental tag concept is not univocal. The research reveals that the RFID specific contribution at a fashion company level is limited, and hence does not significantly solve the sustainability challenge of a brand. However, two points suggest that the concept continues to have relevance despite this: first, turning the fashion business to an environmentally friendly direction may require consistent decisions favouring green alternatives in all areas if companies aim to shift manufacturing and operations to be sustainable: there is unlikely to be one silver bullet that changes everything. Second, for consumers, small signs (such as plastic straws in the fast-food business as a benchmark), are typically meaningful indications of the company's values and attitude that communicate taking sustainability seriously. For these reasons, fashion companies are likely unable to compromise in labelling, which is often used to indicate size and price but also to talk about the product and brand consumers are considering to buy. By this token, the researchers come to the conclusion that the environmental tag contributes significantly to tag level waste and emissions, and pose relevance to fashion brand-owners.

As RFID is used to create a digital representation of an item for supply chain analytics and make rationalisations throughout the chain, it already provides opportunities for sustainable improvement as a concept. One of the future questions is if the same can be done without adding an RFID tag. Today, the alternatives have been based on optical recognition, which so far has not been a viable route on most occasions due to several reasons, e.g. their inability to read without a reference point.

The research paper was meant to open discussion of the environmental RFID tags, and as such it was exploratory by nature. The case study setting allowed describing the key structures of what enforces environmental goals on a tag level and to consider what kind of results it might lead to in a wider context. However, the approach taken leaves much room for further discussion, research and validation.

Future studies are recommended in the LCA approach, which is a topic that needs wider debate on the right measuring model. Standardised measuring model would provide a commonly accepted criterion for green tags and would foster the use of it. The validation of impact will be carried out through another research, which should not look at one product technology only, but broadly at environmental tags and reports using a quantified method as to how the green tags perform in practice; and if there are practical new observations of deviations compared to traditional tags made on plastic and not on paper. Since this study looked only at the environmental perspective, it would be interesting to see research that aims to resolve sustainability topics more widely via RFID. From the consumer perspective, it would also be important to create and test concepts that would simplify the communication of the 'sustainability grade' of a fashion product at the time of purchase. It is currently difficult to understand, as a consumer, if a product is sustainably produced. From the market dynamics standpoint, any data or research that is able to report how the landscape changes in the RFID market by developing new end-use categories (such as the food sector) and new

technologies (such as environmental tags) is valuable. At the moment, all this is left to private institutions, which does not provide the neutral and open discussion forum that academia does.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Publication III

Voipio, V., Elfvengren, K., Korpela, J., and Vilko, J.

Driving competitiveness with RFID-enabled digital twin: case study from a global manufacturing firm's supply chain

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Driving competitiveness with RFID-enabled digital twin: case study from a global manufacturing firm's supply chain

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Abstract

Purpose – *The digital twin (DT) has become a heated topic among supply chain and information technology practitioners. While many papers in this area focus on technical tactics and learnings, this research paper aims to evaluate its business implications. According to literature, it has also been a weakly covered topic.*

Design/methodology/approach – *The research was conducted as a single case study, in which the impact of radio-frequency identification–enabled DT was quantified from the business benefits perspective. The evaluation was carried out using a framework model developed for the assessment identifying key contribution areas and the dynamics explaining how the benefits are expected to land on a business level.*

Findings – *Implementation of the DT was calculated to provide a significant supply chain performance improvement. The main contributor in the immediate benefits was the reduction in supply chain costs, in person-hours. However, the product availability improvement was conservatively considered in the evaluation, and thus, this paper estimates that it, together with higher cognition tools, constitutes the main financial return in the long run showing in the topline improvement. This paper suggests that the shift to DT can be generally limited by the cost savings perspective.*

Originality/value – *To the best of the authors' knowledge, this is one of the first studies released on the business impact of the cutting-edge technical solution area of the DT in supply chain management. In practice, businesses require an understanding of the business implications to decide on the investments in this area; thus, it is a critical part of the discussion.*

Keywords *Digital twin, Supply chain, Manufacturing, Radio-frequency identification, RFID, Industry 4.0, Business value*

Paper type *Research paper*

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1. Introduction

Industry 4.0 (4IR) was introduced by Professor Klaus Schwab from World Economic Forum in 2016. The idea of the concept was to repair the industrial production that had been practically worked as a push model over the years holding a lot of complex inefficiencies on a practical level. The 4IR concept aimed to use data, connectedness and new smart hardware and software technologies, e.g. sensors and artificial intelligence to improve leading and managing the whole value chain from raw materials to production and finally the delivery to customer's hands. This was content for the fourth industrial revolution – the internet and renewable energy – after previous phases centred around the use of coal in 1765, gas in 1870 and electronics and nuclear in 1969 (Schwab, 2017).

Obviously, 4IR became quickly a powerful vision of the next chapter needed to lift the industrial production to the new era, which many of the companies are currently pursuing. However, the practical solutions and knowledge related to, e.g. concrete technologies, sub-concepts and investments are critical in getting started with the development roadmap

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among practitioners. Despite the vivid academic debate, according to some commercial studies, less than a third of large companies in the USA, Europe and Asia report having started with 4IR practices (IoT Analytics Research, 2020). In academia, the discussion has been widely technical and related to data creation and handling methods, structuring the ecosystem into smaller focus areas and so on. However, the companies in practice need clear investment calculations to implement new initiatives as expensive exploration at the heart of the company – in production – can be fatal for the performance and even to the company's existence. This is the problem area where this research paper is positioned to contribute.

The purpose of this study is to help manufacturing companies invest in digital twin (DT) technologies. The research objective is to *provide a DT value quantification model for a global manufacturing business when radio-frequency identification (RFID) technology is used as the pairing method*. The main research question was split into the following three sub-questions:

RQ1. How is the supply chain function managing the data aspect?

RQ2. What is a DT and how does it create value?

RQ3. How is the immediate value of DT quantified in supply chain management (SCM), and what kind of value it can provide as a benchmark?

The theoretical perspective is tied to SCM, which has the primary responsibility of product-related data management throughout the company's internal value chain. The research used a case study method with mixed data as a basis for analysis. As shown in research questions, the key limitations were as follows:

- focus on the benefits and not consider investments or costs related; and
- focus on the immediate value that comes directly with the DT and leave out to another evaluation the benefits that would require more complex and specialised tools such as machine learning or artificial intelligence.

The rest of the paper is organised as follows: Section 2 introduces literature review, which focuses on SCM, data and related value aspects. Section 3 introduces the research strategy, methods, case company and data collection and analyses approaches used. Section 4 summarises results and findings. Finally, Section 5 includes discussions and conclusions.

2. Literature review

SCM represents one of the primary processes in a manufacturing company where all actions from raw material sourcing to manufacturing, warehousing, logistics and returns are integrated into a connected chain of actions. Companies run many functions as primary processes, such as sales and marketing, which in a similar way integrate to further defined sub-processes. Primary processes with support activities describe how a specific company is designed and operated on a top level (Porter, 1985).

Enterprise resource planning (ERP) software has become a solution for companies to hold information together and coordinate companies' activities throughout the functions and processes. A typical problem with ERP is related to poor data quality, which leads to running business and operations with inaccurate information (Marmolejo-Saucedo, 2020). According to some commercial studies, over 30% of the data in ERP systems is faulty (Salmon, 2016), which suggests that the problem is not marginal but has significance for the business. The notion of supply chain data inaccuracy has been backed up by several academic studies over the years (see, for instance, Hardgrave, 2009). According to Oghazi *et al.* (2018), RFID-empowered ERP enhances SCM by facilitating the effective and efficient flow of products, finances and information, maximising profit for the entire network of

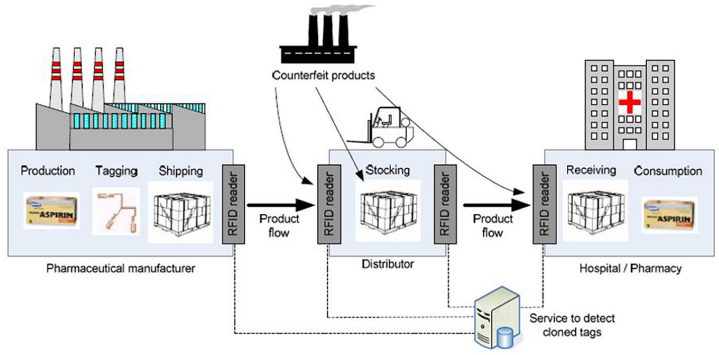
suppliers, manufacturers, distributors and customers (Oghazi *et al.*, 2018). RFID utilisation also improves supply chain information sharing, which drives its financial performance (Kim *et al.*, 2016).

Musa and Dabo (2016) present a literature review of over 1,180 papers that were published in academic journals on the applications of RFID in SCM between 2000 and 2015. Their review yields insights into how RFID can reduce costs and add value along the supply chain, particularly in relation to process optimisation, inventory management and logistics and physical distribution management. Despite the likely benefits of RFID, high investment costs deter especially small- and medium-sized companies from integrating RFID into business processes (Musa and Dabo, 2016). In 2018, Büyüközkan and Göçer published a profound literature review (over 100 papers) where the reader can understand the current state of the digital supply chain concept in academic and industrial studies, as well as what the future developments look like and how the existing importance of digitalisation can be integrated into the supply chain. Their literature review includes only a few RFID-related articles, although they mentioned that RFID technologies play an important role in the digital supply chain when the aim is to get the right item, at the right time, in the right place, in the right quantity, in the right condition and at low cost. Ilic *et al.* (2008) present a simplified example of how RFID works in a health-care supply chain when collecting the data from each location into a single database (Figure 1).

Internet-of-things technologies were researched to deliver value throughout the supply chain. Aside of the ordinary supply chain domains (e.g. logistics and warehouse), it was studied to improve on-shelf availability (Correa *et al.*, 2020). Similar observations were confirmed by Jin *et al.* (2017), who rooted the supply chain value drivers to availability, customer service, market planning and supply chain excellence. Their analysis listed three main pillars as performance domains in the supply chain:

1. customer experience related (e.g. ability to serve new markets and customers, outperform the customers);
2. Supply chain costs (e.g. reduce five the cost of goods sold, improve speed and productivity); and
3. Cost of capital (e.g. reduce working capital, use assets efficiently).

Figure 1 Simplified view of an RFID-enabled (pharmaceutical) supply chain



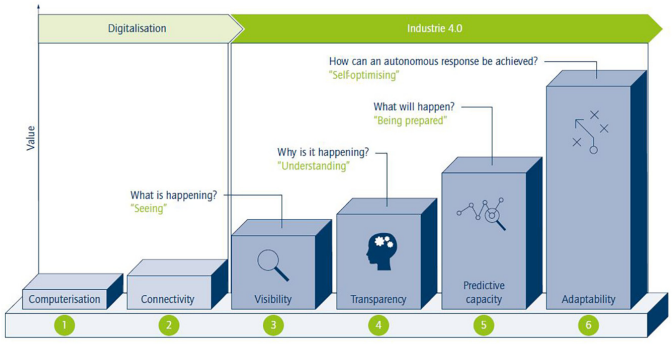
Source: Ilic *et al.* (2008)

According to He and Bai (2021), real-time data of a manufacturing system (e.g. inventories and production flows) is a challenge that the DT has been able to solve. A DT is a virtual replica of a living or non-living physical entity, which enables the use of analytics to drive business performance (General Electric, 2021). The concept of DT was discovered by NASA and applied in the Apollo project in 1969. In 2021, DT was researched by academia and in 2015 it was adopted to commercial use by some leading global technology firms e.g. GE, Siemens and Dassault. DT contains application subsystems, where resource and process optimisation represent traditional supply chain role within a company (Zhang and Zhu, 2019). Implementing a DT establishes a model of the physical process to a virtual level using sensors at a shop floor (Tan *et al.*, 2019). Qi and Tao (2018) note that the DT has an emphasis on data acquisition, while big data focuses on data processing using a wide set of data sources. Schuh (2017) clarifies the relationship between digitalisation and 4IR. They suggest that computerisation and connectivity belong to a digitalisation agenda, while the 4IR theme focuses on visibility, transparency and higher cognition capabilities, i.e. predictive analytics and business adaptability. Interestingly, connectivity and visibility are at the intersection of digitalisation and 4IR and the topic that the DT focuses on. Figure 2 illustrates the structure of the relationship between digitalisation and 4IR. Similar structuring was presented by Yao *et al.* (2017), adding that present development lies at real-time visibility and the future shall bring the predictive and proactive strategies with big data and artificial intelligence.

In the current fast-paced world, the use of DTs can create a competitive advantage through an operating system responding faster to customers' desires than the market in general. Agrawal and Narain (2018) specified that key elements of the competitive advantage are rooted in improvements in transparency and visibility, inventory levels, decentralised warehousing, delivery times, understanding of customer's requirements, sales and profit margins, supply chain flexibility and decision-making processes. This outcome (as well as the review from Büyüközkan and Göçer, 2018) underlined that DT influences both costs and revenues in financial evaluations, while a more traditional perspective stresses the cost elimination perspective in the supply chain digitalisation projects (see, for instance, Ustundag and Tanyas, 2009).

Another example of using DTs to drive growth and competitiveness comes from feeding real-time impulses to product lifecycle data. With real-time data, the product management

Figure 2 Maturity levels in digitalisation process



Source: Schuh (2017)

function can locate six patterns, such as challenges in service utilisation, and implement changes that improve the product and offer appeal in the marketplace (Tao *et al.*, 2018). Competitiveness improvement can also happen by reducing supply chain costs when the supply chain risks and resilience are better handled through the use of DT. Ivanov and Dolgui (2020) presented a holistic view of data sources and DT capabilities enabling improved planning model (Figure 3).

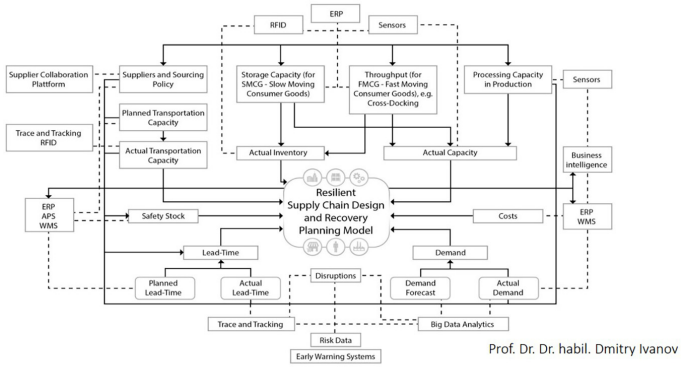
A practical offspring of a DT is the ability to take into use machine learning tools in SCM. One of the famous commercial solutions in this space has been 09Solutions, which has been evaluated to be one of the most visionary solutions for supply chain planning (Salley *et al.*, 2021) with its Digital Brain platform. It supports traditional supply chain processes, e.g. demand planning, sales and operations planning and revenue growth management by connecting enriched SCM data to specialised reasoning software that is able to build tailored correlations and manage probabilities (09 Solutions, 2021).

Despite the obvious benefits of DTs and digitised production in the manufacturing business, companies also foresee several financial uncertainties when deciding about implementations. Lee and Lee (2010) present the Supply Chain RFID Investment Evaluation Model to support retailers in investment decisions on supply chain technology. The model supports investment decision-making once a company has quantified the benefits. They note that academia lacks sufficient information on the return-on-investment related to RFID technologies. This is supported by the research from Horváth and Szabó (2019), who list drivers and barriers on 4IR. They note that, aside from other things, the uncertainty of return and profitability are hindering the financial support for 4IR and, by extension, DTs.

3. Methods and material

A case study is one of the most powerful research methods in operations management (Voss *et al.*, 2002). It supports theory-building research by identifying variables, linkages and dynamics in a selected research area. In theory building, case research benefits from having a predefined conceptual framework that explains the main things to be studied (Miles and Huberman, 1994).

Figure 3 Digital supply chain twins to improve resilience



Source: Ivanov and dolgui (2020)

In this paper, the researchers used secondary literature sources first to connect DT, SCM and value creation in the manufacturing context and then to form a framework model for value quantification and as a representation of the dynamics. Finally, the benefits were quantified in the empirical part according to the framework model considering the specific data acquisition method (RFID), which sets practical constraints and levers to the final quantification; i.e. how the value is created. According to Yin (1994), the "how" and "why" questions fit well with the case study approach, which is an exploratory research method by nature. Figure 4 illustrates the research strategy as a process.

The research used mixed data in the empirical part, where qualitative approach was used to understand the context, key use-cases and related parameters, while the quantitative approaches were used to measure the parameters and analyse the expected impacts on a business profit level. Finally, the qualitative group discussion was used to validate the outcome. Figure 5 describes the use of mixed methods.

3.1 REDO framework

The paper suggests a framework that was formed for quantifying the benefits of supply chain DT. As the benefits are intertwined with the technology used, the model presented is specific to the use of RFID as the technology that provides item level virtualisation.

Figure 6 illustrates the RFID-Enabled Digital Twin in Operations (REDO) model, which introduces common supply chain cost and revenue areas that are influenced by DT. The model claims that DT offers a means to drive cost decreases by minimising manual work, errors and stocks and, on the other hand, drives growth by improving availability and customer experience. In the framework, the primary assessment focuses on the direct impact derived from bottom and topline improvements, but the model also takes into consideration the medium-term perspective, which is reflected on the left side as an indirect impact. As the reduced cost level improves price competitiveness, it drives market

Figure 4 Research strategy

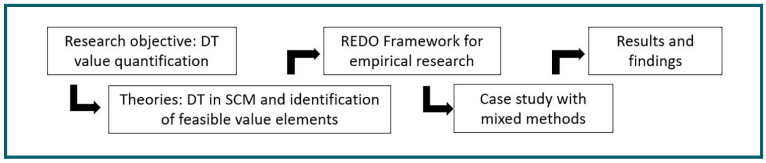


Figure 5 Use of mixed methods

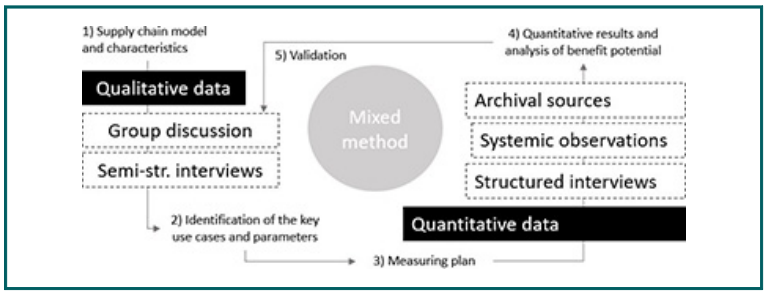
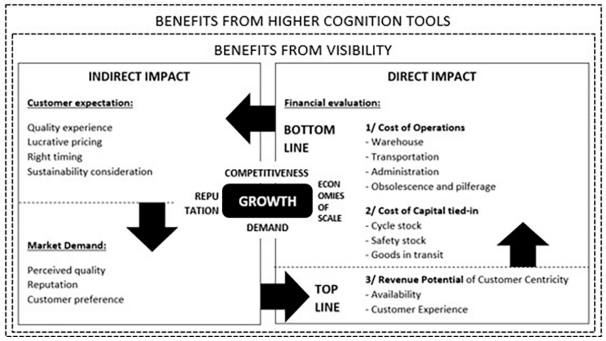


Figure 6 REDO (RFID-enabled DT in operations) model



reputation due to higher customer value and eventually accelerates demand and finally higher economies of scale that are enabled by increased sales volumes.

Although the immediate benefits calculation is the primary objective of this study, the model describes the dynamics, where efficiency gain found in the supply chain drives improvement in customer satisfaction thus leading to higher demand and again, consequently higher performance in direct measures of revenue and overall business competitiveness.

In the model, the core of the value assessment is set on relevant supply chain cost and revenue measures (Jin *et al.*, 2017) and through the indirect impact on customer and market reactions. It also suggests that improvements take place in two levels: firstly, through visibility – availability of real-time and accurate data that DT provides; secondly, through benefits that higher cognition tools provide when, e.g. artificial intelligence is configured in use to further optimise and improve the performance of core measures. The logic presented as levels follows the research from Schuh (2017).

3.2 Case company introduction

The case company works in the global industrial manufacturing business, where it represents a well-known and traditional high-quality company with long-standing customer relationships. The case study focused on its spare parts unit, which operates the high volume of critical shipments and is, therefore, an ideal application area for digitalisation.

In the case evaluation, the supply chain cost and revenue areas listed in Figure 6 were carefully studied to understand how the operations were managed and how the DT with specific use cases would improve the financial performance.

3.3 Data collection and analysis

The research used three main data collection methods for triangulation, which is recommended for improving research reliability and validity (Voss *et al.*, 2002) and to reduce the risk of personal bias in qualitative study.

On quantitative studies, the main errors are rooted to random, systematic and gross errors. Random error could be, for instance, a port strike that would temporarily reduce the incoming goods and create a false measuring result of excess working hours in the

warehouse. Systematic error would be, for instance, measuring systematically product returns as shipment errors. Quantitative errors were mitigated with triangulation and combined use of qualitative research. In this project, the quantitative results were verified in a group discussion by going through the results and indication to confirm that the results were logical to key stakeholders who would be able to identify and point out any unusual result. Table 1 clarifies the data sources and collection methods.

The interviews aimed to collect information from the supply chain and its key performance measures to get a comprehensive understanding of the supply chain model, its characteristics and opportunities with DT. As the respondent represented different functions and perspectives, the questioning was tailored to each area to form a holistic view of the business altogether. E.g. supply chain controller was requested precise financial information, while the sales manager was asked about customer desires and processes to understand the key measures that could be influenced with DT. Table 2 outlines the interviews carried out (Tables 2 and 3).

On quantitative data analysis, the statistical methods were used for analysing the supply chain parameters that were extracted from structured interview questionnaires, archival resources and systemic observation techniques (e.g. structured observation and review of archival sources) at the site (Evertson and Green, 1986). The aim for quantitative parts was to get a precise understanding of the potential benefits, when the measurements were extrapolated to the size of business at hand. The topics analysed included, e.g. costs related to shipment errors (average number of errors per month and average costs associated) and rush orders; man-hours related to inventory counting, shipment

Table 1 Data sources and collection methods

Source	*Goal*	*Data and method*	*Description*
Group discussions	Create, confirm and validate data collection	Qualitative: thematic discussions	Three group discussions were held to first get an understanding of the SC, then to validate the measurement plan and finally the established results
Interviews	Create an understanding of the key measurement points to implement the REDO framework	Mixed: structured and semi-structured questionnaires, data archives	Master data set was compiled through questionnaires that investigated six key areas in the supply chain Interviews were carried out to eight key managers in the company across the key functions
Observations	Value quantification through measures at on-site due diligence	Mixed: archival sources, systemic observation	Two days in two locations focusing on six key areas in the supply chain

Table 2 Interviews used at validation

Function	*Title*	*Themes*
Management	Head of SC development	SC setup, differentiation, customer requirements, principles, goals
Management	Head of the supply chain	Pain points, future development plans
Warehouse	Warehouse manager	WH practices, structure, pain points, practical challenges
Order management	Customer service manager	Service performance, customer requests, unmet needs, errors in customer orders
SC planning team	SC planner	Inventory levels, shipping accuracy
IT	IT manager	Technology landscape, IT and SW infrastructure, development roadmaps
Sales team	Sales director	Delivery perception by customers, ordering patterns, sales strategies used
Customer	Buyer	Shipment handling, delivery quality, receiving practices, availability, unmet needs

Note: IT - information technology

Table 3 Investigated supply chain parameters

Area	*Parameters*	*Value contributor*	*Data source*
Warehouse	Inbound and storing	Person-hours	Observations
	Picking and outbound	Person-hours	Observations
	Quality control	Person-hours	Observations
	Inventory value	Capital tied-in	Observations
	Real estate	Capital tied-in	Observations
	Cycle-counts	Person-hours	Questionnaire
	Inventory efficiency	Capital tied-in	Questionnaire
Transport	Express shipments	Shipping costs	Questionnaire
Management	Overhead	Person-hours	Observations
	Order management	Person-hours	Observations
Shrinkage	Obsolescence	No. of lost sales	Questionnaire
	Pilferage	No. of lost sales	Questionnaire
Sales	Lost order lines	No. of lost sales	Questionnaire
	Returns due to SC issues	No. of lost sales	Questionnaire
	Out-of-stock	No. of lost sales	Questionnaire

verifications, returns handling (number of hours spent on repetitive mechanical work and the average hourly cost associated); and counting missed sales derived to availability challenges at customer site (number of monthly orders missed due to availability shortage) (Woodley, 2004).

4. Results

4.1 Qualitative findings

At the time of evaluation, the case company's supply chain was still manually handled on a large scale. The manufacturing unit received components and raw materials from ten units, with 60% coming from its own units while the other 40% came from external vendors. The visibility to external partners' operations was low, making it challenging to optimise the full supply chain. The total inventory in the own manufacturing units was limited: only 2%–3% of the total inventory value. A DT allows for decreasing inventories, which is why the inventories held at various warehouse locations became one of the focus points for quantification evaluation.

The company-run warehouses operate in three levels to serve the market: global, regional and local. Approximately, 35% of the full inventory was stored at the regional warehouses, while the global and local warehouses carried together another 35%. The remaining 30% was stored in the customer sites on manually handled consignment stocks. The inventories were then seen to be balanced in all three levels, and it would provide an area for further analysis outside the DT project to evaluate what kind of distribution of inventories would best serve this specific supply chain.

In warehouses, it was observed that a large part of the operations was run manually with paper and pen, and the items in the warehouse were often manually identified without proper product marking or serialised coding. All the work areas (receiving, storing, picking, packaging, dispatching and verifications) in the warehouse benefited from the semi-automation (digital support) or automation. The company ran integrated ERP software, but all the data was manually entered into the software. As a backup system, supply chain operators also kept printed paper files. In the site survey, time spent was recorded on various supply chain tasks to estimate the benefits that automation would provide. For instance, just in the dispatch area alone, searching and identifying items constituted 30% of the time allocated from full-time employees.

Key customers were served through local warehouses and consignment stocks (over 30% of the inventories), which provided low or no visibility to operations leading to costly overproduction and significant size of safety stock, which was built to avoid stock-outs and bad customer experience. The data received from these two areas were often outdated. In addition, theft and piracy were a challenge in certain parts of the geographic market, which influenced demand and relationships negatively.

Table 4 explains the supply chain structure and the use cases that were identified as being applicable for the case company. The table outlines the common use cases and shows how they connect supply chain domains to each other. For instance, automated inventory management was designed to automatically keep inventories updated in the ERP system using the RFID reading concept in all units from manufacturing to local warehouses. RFID and data analytics can handle many of the straightforward use cases with low-code applications, while more demanding analysis and correlation findings will need artificial intelligence (marked as with "AI" in the table) capabilities. The line between the two (analytics vs AI) is shallow.

The functionalities required for the use cases were scoped with known tools and concepts and confirmed feasible using experienced RF engineers on-site to validate technology use. However, in the evaluation of the benefits that the paper was aiming to deliver, the application development costs and such were not considered. The underlying thought was that the actual sourcing process would be a program of its own and should not be confused with upside evaluation.

4.2 Quantitative results

The financial impact in use cases was estimated based on the cost decrease or revenue increase potential that each use case held. The evaluation was based on the data collection, detailed calculations and understanding of the underlying functionalities. Table 5

Table 4 Use cases in the case company for RFID-enabled DT

Manufacturing units (total of ten; own and partner)	*Global warehouses (3 pcs)*	*Regional warehouses (20 pcs)*	*Local warehouses (90 pcs)*	*Consignment stocks (>300)*	*Customers*
1: Automated inventory management Automated inbound scanning, automated out-bound scanning, supported cycle count. *AI-supported automated reordering and stock optimisation				7: Intelligent consignment stock Providing RFID-tagged items on a modular read space, which automatically - keeps track of items available to the customer - triggers re-orders - triggers invoices	
2: Stock location management Using RFID-tagged shelf spaces to pair data with truck readers on shelf spaces and individual items. *AI-supported truck navigator					
3: Dispatch navigation Supporting dispatch area workers with a Pick and Pack application, where the handheld device guides manual work. *AI-assistance to guide transportation loading to increase safety and shipping errors					
4: Shipment validation Using RFID to validate that shipments and shipment orders match each other to avoid costly shipment errors. *AI-assistance to consider missing attachments and supportive supplies					
5: Brand protection Use of tamper-proofed RFID tags to verify the originality of goods throughout the supply chain					
6: Returns management Supporting item-level identification of returning items with RFID tag code and fastening the inspection, refund and re-use of goods					

Table 5 Benefits quantification according to the redo model

Investment area (cost/ revenue item)	*Description of benefits*	*Calculated impact*
Section 1: Cost of operations – total reduction of 5.5% to supply chain operating costs		
Warehouse cost	Productivity increases from decreasing manual work in distribution centres and customer-held stocks	Average 7% reduction in man-hours
Transport cost	Improved management of shipments: avoiding rush orders and rationalising routing with data handling	Average 3% reduction potential in transportation costs
Admin cost	Reduction of manual work related to shipment errors, data collection and re-ordering	Average 10% reduction in man-hours
Obsolescence and pilferage	Reduced costs due to higher visibility, lower stock levels and higher control	Average 10% reduction in shrinkage
Section 2: Cost of capital – total reduction of 8% to working capital employed		
Cycle stock	(No changes)	–
Safety stock	Reduced safety stock by improved forecasting accuracy and quality of data	Safety stock reduction of 50% impacting lower tied-in capital
Goods in transit	(No changes)	–
Section 3: Revenue potential – total increase of 1.5% to sales		
Availability	Reduction in missed sales due to stock-outs	1% increased sales
Customer experience	Ability to negotiate the price increases due to higher preference and service level	0.5% on top of annual price increases

summarises the financial analysis made on the impact of the uses for the company's profitability. On the high level, it structures benefits into three areas: direct cost savings, savings related to cost of capital and finally at the new revenue potential, when the operations are supported with DT. The translation from percentage to monetary values was done by using the total cost of the given area and counting reductions and increases from the base value. The percentage values were received by tracking time consumptions of various duties and then removing the time consumption on the areas, where the technology at hand would provide automation thus creating time savings. The same logic applied to transportation costs, availability and customer experience.

The results do not reflect the time component but include benefits achievable over time. In the case company, the improvements were expected to materialise fastest to the supply chain cost side (6–12 months), within one year to capital tied in and slowest to the increased revenue from current customers (1–1.5 years).

Table 6 summarises the profit reflection for improvements when the company's revenue is scaled to the €100m revenue level. Although direct cost savings composed the largest part of the calculated benefits (total €6.3m), the indirect benefits were also significant (ca. 15% of the total) when using a conservative estimation. In reflecting the improvements at profitability, it was noted that cost savings directly improved the bottom-line performance,

Table 6 Conversion of benefits to earnings

Financial component	*Estimated benefit in the case company*	*Reflection to EBITA*	*Increased profits at revenue of €100m/yr*
Section 1: Cost of supply chain	5.5% reduction	5.5%	€5.5m
S2: Cost of capital employed	8.0% reduction	0.8% (WACC 10%)	€0.8m
S3: Return on service level	1.5% increase	0.6%	€0.1m
Total		€6.4m/year	

while the two other areas (capital cost and revenue increase) were calculated separately to reflect the impact on profits. The revenue increase was based on the service-level improvement when DT provided more accurate data on availability and was able to improve the stock-outs at the customer interface. The additional benefits, such as customer experience improvements and advanced analytics, were not considered in this evaluation, as the focus was on immediate quantifiable benefits.

5. Discussion and conclusions

The main objective for the paper was to provide a benefits' quantification model for supply chain DT, which responds to the need set by academia. The study focused on the RFID technology as a method to produce DT and approached the research goal by forming a framework that was formed from literature review and tested in a single case study setting.

5.1 Managerial findings

In this case, the cost reduction was the highest contribution area for a DT. Although the study did not make a specific sensitivity analysis of the three core areas presented in the REDO model, the authors noticed that the topline impact was conservatively evaluated assuming a 1% increase by availability improvement. Simple calculations revealed that if the sales increased by 3%–4%, it would surpass the cost level benefits and become the highest contribution area of DT. This could come true through a couple of ways:

1. a broader use of profitable consignment stocks, which are now becoming better managed by DT; and
2. integrating SC directly to customers' ERP systems, where selling and purchasing are automated and frictionless but which do require DT and virtualisation technologies.

For this reason, the conservative approach taken in evaluating the topline impact gives a slightly modest image of the technology and further strengthens the already prevailing way of building technological capabilities to cut costs – this underlying ethos of cost reduction benefit can be misleading.

5.2 Scientific findings

The results confirm that the use of DT has an immediate link to business profitability by providing visibility that enables rationalisation (e.g. reducing stock levels) and automation (e.g. reduction of shipment errors and cycle counts) that reduces supply chain costs. The findings encourage further use of DTs and establish a commonly validated model on how to account for the benefits. As a scientific conversation, quantification would establish a rich platform for debate and provide much-needed feedback for other functions enabling continuous technical and financial improvement and increased understanding of the best practices.

On limitations and risks, it should be noted that this research used a single case study method, which can as an exploration provide reasoning but not generalisable data on DT benefits. The study focused on the evaluation of the benefits only and did not consider investment costs that would be needed for a proper business case evaluation. On the other hand, the focus was as well on the immediate benefits only, and thus, the more advanced application of advanced analytics was not evaluated. Risks in the study were related to the qualitative process, which is vulnerable to researchers' personal bias and faulty interpretations (Onwuegbuzie and Leech, 2007).

For future research, authors suggest investigations of the REDO models on indirect benefit areas, which would bring further understanding on otherwise abstract areas related to market dynamics. Connecting academic discussion of customer value and reputation into this model would complete the picture and give a more holistic view of the DT. Further

validation is also needed on the quantification of the benefits, which would allow the theme to emerge as a robust research area with solid information on how to apply accounting models, how the benefits vary in different kinds of supply chain contexts and, e.g. how the new higher cognition tools contribute to the benefits calculation. One interesting area to learn more about would be to understand the topline contribution areas, where proper sensitivity analysis and investigations on the topline growth areas would complete the picture of the DT in the non-cost saving areas. Finally, the presented approach only weakly considers the impact of the DT in sustainability measures. As sustainability is becoming a part of any company's performance evaluation, the inclusion of sustainability in the REDO model's benefit quantification would be useful.

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Further reading

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Publication IV

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Solving the Employee Shortage in a Food Service Business with an Intelligent Cabinet Solution: a Design Science Approach

Submitted.

Solving the Employee Shortage in a Food Service Business with an Intelligent Cabinet Solution: a Design Science Approach

Abstract

Since covid-19 several service businesses have struggled with workforce availability. The roots of the employment shortages have been reported to arise from an ageing population in industrialized economies, and many have proposed that advanced technology could provide relief by automating manual tasks, and hence, build fewer service workers requiring business models. This research paper looks into the food service business and applies a design science research approach in a single case study testing an intelligent cabinet solution to drive self-service capability for fresh food serving. The study takes a managerial perspective in assessing the test, and thus, the retail technology selection theory is used as a reflection of the managerial aspect and further developed to describe the managerial agenda, when a firm shifts to self-servicing. The results show that intelligent self-service is feasible with fresh food serving and is able to reduce workforce needs in point-of-sale, but requires new skillsets in operating the digitized framework.

Keywords: self-service, design science, food service, technology selection, digital transformation

1 INTRODUCTION

Digitalization has driven growth within businesses and society in the 21st century. The business value from digitalization has derived from higher productivity of the workforce and from the new level of flexibility, when location, time, and connectivity are no longer constraints for doing work, running processes, and trading goods and services. (Wilenius, 2017; Goasduff, 2021)

Industry experts have seen digitalization progress in three waves, where the first wave in the 1990s focused on digital products, the second wave on digital distribution in the 2000s, and finally, the third wave focused on the shift in business models in the 2010s. (Berman & Bell, 2011) Business model-level shifts mean a deeper and more holistic transformation of what the company sells, how the profit is being made, and what kind of resources and processes the company manages (Christensen et al, 2016). In the 2020s, digitalization progresses through the virtualization of physical life. In academia, the conversations go under the themes of internet-of-things, the digital twin, and Industry 4.0. The common focus in the fourth wave is to explore and verify how the distance between digital and physical life is being closed by specific technologies understanding their impact on the supply chain system and profitability. (Schwab, 2016)

In the hospitality businesses, new technologies have entered the market to e.g., automate customer handling, which reliefs the scarcity of the low-cost workforce availability and is supported by customers' desires for e-commerce like self-service. (Ivanov et al, 2017) One of the interesting topics in food service automation

concerns the use of modern second-generation vending machinery in lunch cafés and workplaces, which provide a flexible and always-open supply of fresh food. These so-called intelligent cabinets (as exemplified in Figure 1) are placed next to coffee machines and sell salads, fresh-made microwavable food, deserts, healthy juices, and snacks such as fruits and yogurts. Second-generation vending or intelligent self-service technology (ISS) differs from traditional vending by its convenient user experience, higher data resolution of the inventory including for instance expiry date management functionalities, and the ability to sell all shapes and kinds of products. With the technology using a mix of artificial intelligence, machine vision, weight sensors, and radio-frequency identification, the fridge automatically manages its inventory and charges the customer purchases through a commonly used modern mobile and card payment framework. The user experience of the fridge is set to simulate as closely as possible an event where one is picking food from a home refrigerator. Just in this case the operation is not handled by the parents but by the food service provider, who defines offering, manages replenishment, and processes automated payments.

FIGURE 1: EXAMPLE OF INTELLIGENT CABINET USE CASE (BYTE FOODS, 2022)

In academia, the studies on the self-serving link to research interests in digital transformation, service marketing, and retailing. The Journal of Retailing introduced a special issue on technology in March 2021 due to today's technology-based era that lifts the importance of dialogue between academia and practitioners (Gauri and Grewal, 2021). According to them (ibid.), consumers are wanting to save not only money but also time, and ask for more digital tools and apps to manage their lives. It pushes businesses to rethink their service concepts and technology stacks in order to respond to consumers' desires. At the same time, some reputable scholars have stressed that service as an object needs to be elevated in research to restore the credibility and relevance of marketing to companies (Grönroos, 2020). Cham et al (2021) remind in another special issue on technology and marketing strategy that technology has ever since the beginning renewed paradigms, and thus, the research should be increased in areas, where the status quo in markets is being challenged by new technology. However, it has remained unclear how offline retail, digitalization, and service creation should be understood from the managerial perspective, which is the gap this research contributes to in the theoretical dimension.

The introduction of a self-service technology represents an attempt to package the above-mentioned gap in a practical concept and the paper focuses on testing it in a single case study method. The research question is, what is the feasibility of the intelligent cabinet concept with workplace food services, which is further divided into subquestions of (i) what is an intelligent cabinet technology concept, (ii) what are the emerging needs in food service businesses, and finally, (iii) how the technology performs in the context. The research is exploratory and intends to provide an understanding of the challenges and drivers in parallel with evaluating the fit.

The case study is built on the design science approach and is based on mixed-method data collection and analysis. The quantitative data was derived from the sales and investment data, while the qualitative data was captured from interviews with customers, personnel, and the managerial team combined with systematic observations during the test period. The qualitative research measured attitudes, drivers, and barriers as insights from the audience, while quantitative data helped to understand the performance perspective. The design science approach applied in the paper is illustrated in Figure 2: While the food service context establishes the environment for the test, the theoretical foundations are tapped into retail technology discussions.

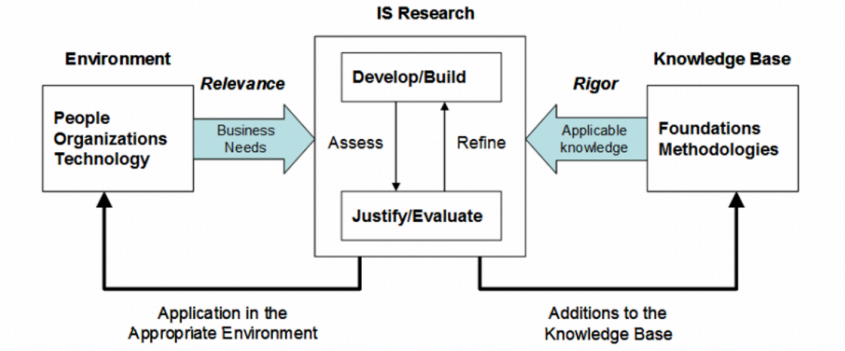

FIGURE 2: DESIGN SCIENCE IN INFORMATION SYSTEMS RESEARCH (HEVNER ET AL., 2004)

The rest of the paper is organized as follows: the paper continues in Section 2 with a literature review summarizing earlier research findings and perspectives related to retail technologies. Section 3 introduces the methods and material including information on the research design and the case company involved. Section 4 reviews the results, after which Section 5 discusses the conclusions and future research needs.

2 LITERATURE REVIEW

The retail industry is undergoing modernization, and new ideas are being generated from a variety of motivations. This is prompting the emergence of high-technology and staffless 'unmanned stores' materializing in cities. The investments made in new retail concepts have mostly been temporary pilot projects, which yet have not progressed to scaling, regardless of the resources put in to construct them. (Lung, 2020). Unmanned shops can differ depending on the type (for example, grocery store, convenience store, fashion store), model (unmanned vending machine store, physical store, mobile store on wheels), and the technologies used. Unmanned stores are also called 'connected stores' or 'smart stores', but overall, the term refers to an unstaffed retail store that has advanced technology to enable self-service shopping for customers. (Shuai et al, 2019)

A recent study provides a systematic review of the literature on the role of vending channels in marketing. The analysis identifies areas of vending wherein research is lacking, notably: marketing trends regarding smart vending machines; consumer responses to vending experiences; and safety issues. (Stoyanov, 2021) The fast development of e-commerce and technologies related to cloud computing, mobile payments, internet-of-things, and artificial intelligence have also caused advances in unmanned retail markets. There is an ongoing transformation of traditional retail into unmanned retail by utilizing the abovementioned advanced technologies (Zhang et al., 2020).

Experts report that automation in retail offers several advantages. Cost savings have been attributed as an advantage of automated store operations and faster fulfillment of click-and-collect orders (Mkansi & Nskanda, 2019; Capgemini, 2018; Rust and Huang, 2014). Labor costs are reduced significantly in unmanned stores, and rental costs are lowered because these kinds of stores are usually smaller (Fung Business Intelligence, 2017). In addition, researchers found that unmanned store technologies help to facilitate customer visits more easily, thus improving customer satisfaction and enhancing the overall in-store experience (Lo and Wang, 2019). Similar findings were reported earlier by another study, which concluded that in the hotel segment the key preference from consumers to use technology over human interaction was motivated by faster service processes (Kattan and El-Said, 2014). Significant interest is also set in data and the use of smartphones, which are key cornerstones of new advanced technology-enabled retail and something that is acknowledged to gear the profitability and stickiness of retailers (Grewal et al, 2017).

Research on smart fridges underlined the opportunity of the technology to drive healthier living for users through its ability to serve fresh food and handle nutritious data (Luo et al, 2009). Other studies have shown that one of the caveats of traditional vending machines is their focus on mostly unhealthy food (Byrd-Bredbenner et al., 2012; Raposo et al., 2016; Park&Papadaki, 2016). According to a recent survey among university students, healthy food and drink are preferred over traditional vending food offerings. The study concludes that the inactive lifestyle together with unhealthy food at vending machines had resulted in weight

gain among university students. The common use of vending machines was rooted in the lack of time and disability to prepare food. (Hayder et al, 2021)

A study made on frontline service technologies identified a typology with eight archetypes that illustrate how companies approach technology roles in the customer service areas (Keyser et al, 2019). In their typology, technology-assisted retail represents an archetype where manual service is replaced with automation or technology. According to some researchers, it has been expected to intensify in the coming years (Huang and Rust, 2018). Dedicated research on frontline customer service envisions that automating the work with technology is only the first step, after which there need to be new technologies to enable thinking and feeling in the frontline at the digitized encounter (Rafaeli et al, 2017). Feelings and emotions are central in the customer interface as it has been shown by studies to correlate with customer satisfaction and loyalty, thus having a business-critical role for the companies (Mattila&Enz, 2002).

From a service creation and renewal perspective, Parasuraman et al (1991) have researched how new services fail and succeed. They noted that a successful customer experience can be either acceptable or desired, and in many cases, an acceptable experience is enough to win in the marketplace. Same researchers had earlier (ibid, 1985) come up with a Service Quality (ServQual) theory, which identified five potential gaps in implementing a new service concept: The gap can be in (1) management's ability to understand its customers, (2) the management's ability to translate the understanding to a service intention, (3) the organization's ability to provide the intended service, (4) the organization's ability to match the service with the mission-critical external factors, or (5) the organization's ability to manage expectations correctly. Grönroos (1984) has researched perceived service quality that similarly identifies gaps between expected and perceived value. Grönroos (2020) also points out that service context is scientifically a versatile and unique area that requires fresh holistic approaches to support scientific development and practitioners' work.

In the marketing community, a stream of work has been released on technology-rich customer engagements. Some scholars have requested research that outlines when, why, and how AR (Augmented Reality) outperforms face-to-face service encounters (Heller et al, 2021). Inman et al. (2017) suggest a Shopper-Focused Decision Calculus providing a holistic view of decision-making when considering retail technology. As the model's name says, the researchers underline the connection of a business owner's benefits with the consumers' perception of change. Their point is that even a good technological solution can fail if consequently, consumers lose trust in the business owner's goals and fairness. (ibid.)

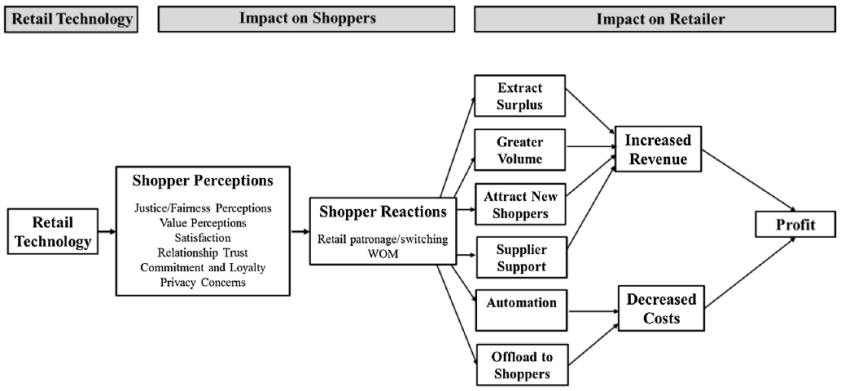

FIGURE 3: SHOPPER FOCUSED DECISION CALCULUS (INMAN ET AL., 2017)

From the consumer perspective, it has been earlier also noticed that the value perceived (why to use) and feasibility (how to use, usability) are central in consumers' decision-making of whether to accept technology in buying or not (Baskin et al., 2014; Lu et al., 2013). Consumer value in self-service technologies has been connected to functional ("this is handy"), emotional ("I can find the best deal"), and social rewards ("I am seen as progressive since I use new technology"), in which the functional values has been reported to be the most important value domain (Curran and Meuter, 2007; Ho and Ko, 2008). This anyhow can be seen to be more of a sign of the immaturity of the industry rather than the final stage, as the researcher of the frontline customer service theme has noticed that feelings, in general, are an important part of the customer engagement that shall not be undermined (Rafaeli et al, 2017).

Regarding customer segment feasibility, it has been reported that consumers with limited time horizons (referring to elders) are negatively responding to new self-services, which require efforts to learn, unlike the younger and more future-oriented audiences (Jungkun et al, 2021). According to some other experts, innovations with less complexity and higher relative advantages are more likely to be adopted than complex ones regardless of the value and uncertainties related, thus the characteristics of the new technology also matter essentially in the adoption (Arts et al, 2011).

Finally, regarding both customer and segment perspectives, it is essential to understand the time aspect related to the willingness and readiness to engage with technology (Meuter et al, 2005). The more society and common processes are being digitized, the higher the readiness to start trialing and take into habitual use the technology in everyday practices. Time aspect matters also to companies: Colli et al. (2022) noted that companies' time perspective in digital transformation projects correlated with the results they achieved. In their research, companies with a short-term focus were geared to problem-solving, while companies with a long-term focus reached innovations and higher business value.

3 METHODS AND MATERIAL

3.1 Research Design

Moghadam et al. (2021) note that case studies are a commonly used research method in operations management (investigating product, technology, and organizational interactions) and in new product development. On data sources, their research underlines the use of interviews, observations, questionnaires, and archival sources in the research. Voss et al. (2002) point out that generalization is the weak link in a single case study setting, although it can provide the most intimate view of the research phenomena at hand. According to them, why, what, and how questions are well covered with case research. Marshall and Rossman (1989) define a case study as a compliant strategy with explanatory research, which aims to understand a little-understood phenomenon with salient themes.

The objective of the research was to test an intelligent cabinet in a food service context. The literature review was done to understand the multi-disciplinary background of the phenomena, which formed the basis for the case study construct using a framework model that guided the data collection and analysis. The empirical part followed the convergent mixed method approach that allowed iterative use of data to understand, interpret, and confirm the observations (Creswell, 1999). The research process is introduced in figure 4.

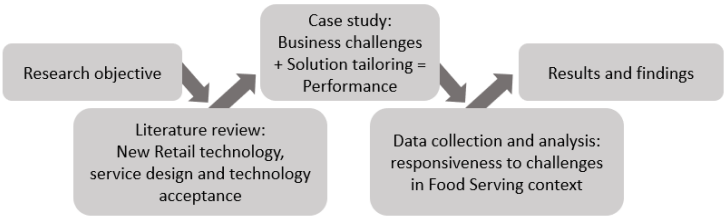

FIGURE 4: RESEARCH PROCESS

Research reliability means the ability to reach stable and consistent results. E.g. in qualitative research, the researchers' beliefs easily influence the interpretations leading to faulty results. Research validity means the ability to accurately reach results on topics that were intended to be measured. In this research, reliability and validity were taken into consideration by using triangulation in data gathering. As the goal was to understand how an intelligent cabinet solution performed in a food service context, the use of multiple sources provided a rich and holistic understanding of the phenomenon. However, it should be noted that the research setting provides only limited generalizability.

3.2 Data Sources, Collection, and Analysis

Data were collected before, during, and after the live test project. *In the pre-test phase*, the analysis aimed to further detail the challenges that the test was set to overcome. From a business perspective, the main goal was to increase sales. From the customer value perspective, the extension of the service beyond the open hours was seen as an additional service aside from revenue generation. *During the test*, the data collection and analysis were used to improve the set-up and gather data for the final evaluation taking place, when the test period was closed. *In the post-test phase*, the key data sources were round-table discussion and thematic interviews, which were carried out to gather company perspective, further understanding of the experience, and validate the analysis that was made from the data gathered during the test. Table 1 details further the data sources used in the case study implementation.

TABLE 1: DATA COLLECTION IN THE CASE STUDY

DATA	METHODS	NUMBER OF SOURCES	PURPOSE	WHEN & WHY
Qualitative	**Thematic interviews and round-table discussion** incl. the current situation, sales distribution, business model, development needs and experiences.	12 interviews before and after the test start among the staff incl. café service employees (2), an IT development manager, regional manager, marketing manager, and IT implementation manager.	To get the practitioners' expertise for the project before and after the test.	- PRE-TEST: to support solution design and setup prior the test start. - POST-TEST: to support evaluation and explain the results achieved.
	Observations	Notes from 12-week project including open feedback canvas for spontaneous experience sharing and change requests.		- TEST: to support solution refinement during the test.
	Structured interviews mapping customer experience and evaluation of the new service.	16 end-customer interviews one week after the test had started.	To understand end-customer experiences and attitudes.	- TEST: to support evaluation and explain the results achieved.
Quantitative	**Archival sources**	Sales, product, and customer interaction data from the cabinet software from the 12 weeks of running time.	To measure sales performance and provide data for analysis and optimisation	- TEST: to support the evaluation and quantify the test's impact on the business.

Thematic interviews and a roundtable discussion were carried out with 12 people from the organization to form a broad enough understanding of the starting point and confirm the context. The use of themes allowed the respondents to elaborate more on the areas they were familiar with in their daily work, for instance, café employees had extensive information on the sales distribution while the IT development manager had more of a managerial view of the needed development steps underneath.

Observations were collected with an open canvas method, where a notebook was left visible by the cabinet and introduced especially to staff to leave feedback in terms of spontaneous comments from the end-consumer user and their own experiences from daily use. The feedback was reviewed two times a week to initiate immediate corrections in the running test as well as record the commentary for later review.

End-customer interviews were conducted in person at the cabinet a week after the test had started. Respondents were spontaneously picked in random order and asked to participate in a short interview on the new vending service at the café. The questioning tracked whether the respondent had used the intelligent cabinet. The rest of the interview was organized according to the respondent's answers on the usage: those who had used it were asked about the experience, while those who had not used it were asked about the reasons they had not tried it and what their desire for it such a service was. The overall purpose was to understand the experience, motivations, and attitudes according to the model. The analysis conducted on the structured interviews included simple statistical ratios on the drivers, barriers, and open questions to better understand the respondents' feelings and experiences. The number of respondents was low (16) and each of the respondents was interviewed for 10-15 minutes, thus the results were intended to provide insights.

Archival sources included several data sets that the cabinet provided from the usage, including information on purchase times, purchased products, and repeat purchases. The data analysis was descriptive and provided numeric evidence of the performance and the end-user behavior. According to the convergent mixed-method approach, the numeric analysis was kept iterative allowing interaction between qualitative and quantitative data sets.

In the end, the theoretical framework (mSFDC) was used to integrate the qualitative and quantitative data in a summarizing table indicating the acceptance and business profitability aspects.

3.3 Evaluation Model and Use of Modified Framework

The nature of the case study was to evaluate how well the given technology fitted the context. For this reason, the empirical part collected information on the business challenges, which were combined with the learnings from the literature review of the new technology acceptance in retailing. The evaluation model compared how well the challenges were responded to through the use of the technology.

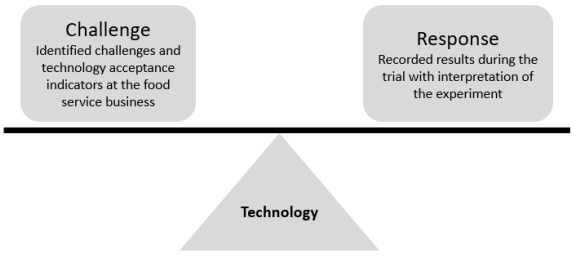

FIGURE 5: EVALUATION MODEL

Parasuraman notes that the discussion on technology at the frontlines should be dealt with from a broader and more conceptual perspective, which fosters theory building and allows academia and practitioners to better learn and discuss the development (Rafaeli et al, 2017). For this reason, the paper selected the SFDC framework as a basis to reflect the managerial agenda and loop the learnings into theoretical discussions. As a part of the preparation for the test, the researchers modified the SFDC framework model to fit the purpose of the study by changing (1) the scope to people, and (2) by lifting the technology to take on a central role in connecting people and business results. The final modifications were made during the pre-test information-gathering phase after it became clear that a succeeding test requires acceptance from not only consumers but also the staff.

The role of technology was on many occasions broadly discussed as a key topic. How the technology was intended to be used, seemed to greatly influence the attitudes the stakeholders adopted and the business benefits that were collected. For this reason, it was decided that the use of technology should be one of the key elements in the approach and something that lives between attitudes and numeric benefits.

Figure 6 explains the modifications that were adopted during the test for the framework model. While the original model had a strong sense of direction (from technology decisions to attitudes, results, and benefits), the improved model states the connectedness and claims the key elements have an interactive relationship.

Retail technology decision influences attitudes (internal and external to the company) already as a starting point when the decision is being announced. Later when the technology is being applied, the attitudes influence how it is taken into use (internally and externally), thus resulting in benefits. However, it is not one-directional. The intended use of technology also influences attitudes and impacts retail technology decision-making. Companies could for instance decide to modify the decision with small amendments or totally re-decide to change the technology decision to something else based on the strong opposition from staff and customers. Once the technology is taken into use, the attitudes can change and be more positive (“it was helpful”) or negative (“it just makes things worse”) and hence lead to a re-evaluation of connected emotions.

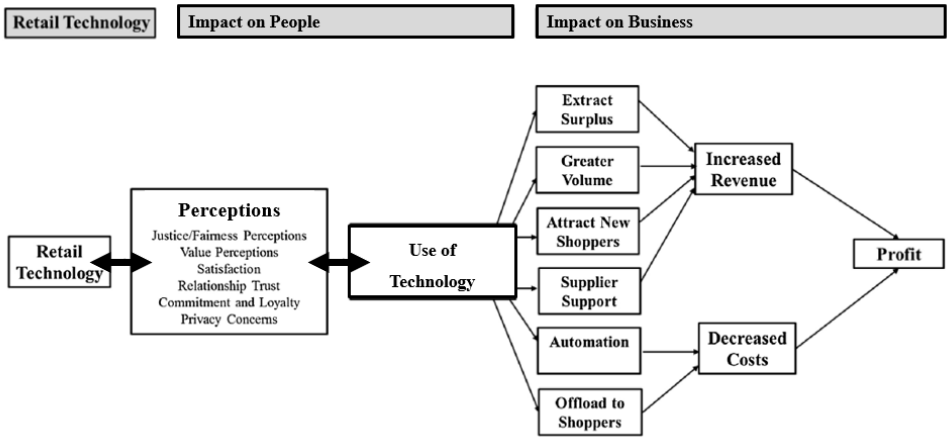

FIGURE 6: MODIFIED SFDC (mSFDC) FRAMEWORK

3.4 Case Company: Food Service Unit in an Office Building

In this research, the empirical test of the intelligent cabinet concept took place for three months on a food service unit at a single office hotel location, where the case company operates a lunch restaurant and café for ca 600 people working on five floors. Typical workers in the building have a background in engineering and administration. The lunch restaurant is open daily for two hours, from 11 to 1 pm, while the café is open during typical office hours from 9 am to 4 pm. The café personnel also manage the reception, where visitors sign in to make business visits. The lunch restaurant is run by the same company, but a different team.

3.4.1 Business Challenges

A food service business like the one at hand has several locations under the same brand name and concept. Every unit is organized independently, while the administration, sales, and sourcing are integrated to drive efficiency. Over the years, the business has expanded from providing a lunch service to also offering value-added services such as café and reception services, which were also present in the care setting. Value-added services aim to get more value from the local contracts, as the margins in the lunch service are typically thin: if the lunch cost is high, customers bring their packed lunches, and hence to retain the business the customer value must be solid.

During the project configuration, the following business challenges were identified as addressable for the intelligent cabinet solution at hand:

1. *Resource availability*: in industrialized countries, the younger generations have been educated for high-end professions such as engineering, narrowing resource availability for low-cost service work. The

resource shortage is not eased by the aging population, which in the coming years is expected to increase resource shortage and lead to wage increases.

2. *Customer experience*: only happy customers buy more. Customers in office buildings today work more flexibly during the day; some from early hours and others till late in the evening. How can you provide and sell more to these off-hour workers and not miss the revenue opportunity? Key customer experience components were identified to be: (A) the availability, referring to extended opening hours, (B) the offering, referring to healthier alternatives such as fruit, juices, and salads over the coffee and donuts typically provided by café, and (C) the speed of purchase, meaning a fast and easy purchase.
3. *Operational efficiency*: as explained, the margins are thin in the service business due to head-count costs that typically comprise a major part of the costs. To keep the business profitable, value-added services are often built on top of other duties that the personnel handle, which leads to service quality problems and hence lower customer satisfaction and loyalty. For instance, when the same person runs the reception and café, in peak times it often leads to an unmanned café while the service person is at the reception signing in customers and handling meeting rooms that are part of the receptionist's duties. On the other hand, adding to the headcount would ruin the profitability and hence not be applicable.
4. *Sales volume:* how can the share of sales be increased in a single location. As resources and offerings are limited and the food service companies strive for additional sales, the question is, can automated retail provide a complementary way to drive growth by extending the sales to off-hours?

3.4.2 Solution Design

In the project, the researchers used an intelligent cabinet solution to provide an unmanned retailing service for the lunch café. The solution follows a modern digitalization approach with an emphasis on frictionless experience and the use of intelligent internet of things (IoT) technologies such as radio-frequency (RFID) identification, remote cloud services, and the use of smartphones at the consumers' end. The technical solution was fitted against the business challenges found in the pre-test phase and installed at the café to sell fresh food and snacks during peak times and off-hours. The café is located so that everyone visiting the daily lunch service would pass the cabinet and hence notice the new service concept.

The cabinet itself looked like a modern fridge with a glass door and a screen placed on the top panel. Customers could access the locked fridge via a smartphone payment app commonly used in the country. The top panel displayed the QR code connecting to the payment application and specified the sellable items, prices, and promotions. In the cabinet, all the sellable items were attached with tamper-proof RFID tags, which the cabinet was equipped to read with integrated RFID readers. The inventory information was kept updated in the cloud, which also handled information transfer to the replenishment service used by the café personnel and to the payment application that handled monetary transactions from the consumer to the café.

The replenishment operations were handled by the café personnel during the slower periods of the day. To do that, the café personnel were provided with an encoding station. In the replenishment process, the café

personnel collected the refillable items together, attached an RFID tag to the pre-defined places, and used the station to encode the RFID to match the items they represented. Using the replenishment application, the café personnel were able to set the cabinet to its replenishment state, unlock the door, and fill the cabinet with new sellable items.

At the time that the test started the café personnel was trained to manage the cabinet, the software was integrated to handle the payments, and the cabinet was branded as a 'quick-snack' kiosk to give it a face. The cabinet was located as illustrated in Figure 7 in an office hotel on the ground floor next to the manned café, which was run by the reception service team aside from their daily work. When the test started, a promotional campaign introduced the cabinet to consumers explaining how to use it. Two weeks after the start, customer interviews were conducted for two days at the cabinet both to give first-hand introductions to the cabinet and to interview customers to understand their experiences and attitudes, and to hear concerns and ideas that the audience might have.

The offerings made available in the cabinet included fresh porridge, smoothies, fruits, sandwiches, soda, nutritious coffee, chocolate, candy, and healthy curd. Prices were matched to the ordinary café prices. During the project, the pricing strategies were not studied.

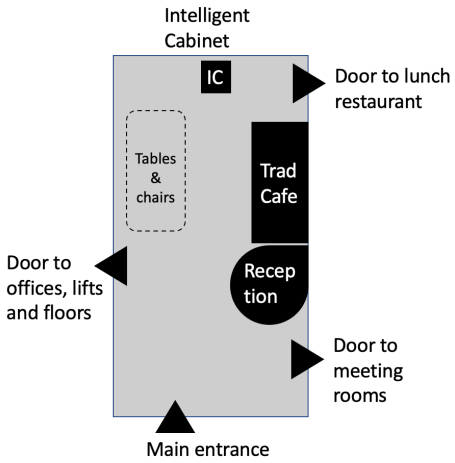

FIGURE 7: FLOOR PLAN AND INTELLIGENT CABINET LOCATION IN THE TEST PROJECT

4 RESULTS

The test ran for three months at the location. During this period, the solution was evaluated through quantitative and qualitative measures. The evaluation aimed to understand how the solution solved the challenges as defined in the evaluation setup.

4.1 Purchase Patterns

In the test, the monthly sales from the cabinet remained low. In a typical week, the cabinet produced on average 31 purchases within a range of 15-60 pieces, where 41% of the purchases occurred outside office hours. On average, there were six purchases a day with an average purchase of 2 euros, where item prices varied between 1-4 euros. According to an ROI analysis made for the case, the cabinet would have broken even after one year if the average price had been 8 euros with 50% gross profit.

Typically, convenience sales are made from habitual purchases and as consumers learn to use new technology it can provide increasing purchase patterns and hence higher profitability. On the other hand, one can claim that a new installation can be initially successful due to early enthusiasm that later erodes leaving "new gimmicks" redundant after a while; or that technology can cannibalize the traditional sales channel creating just additional costs, but no "true new sales".

In the quantitative analysis, the trends were two-fold: the number of purchases conducted within a week decreased supporting the eroding enthusiasm hypothesis, but the average basket size grew. Thus, it suggests the cabinet found loyal users who started to buy from it, while the "trial buyers" disappeared after a while.

4.2 Attitudes and Experiences

Interviews with customers and service personnel in the structured interviews and open answers combined with weekly systematic observations of the trial highlighted four key topics that came through repeatedly:

1. *The general attitude towards new self-service technology was positive.* The consumers who had used the cabinet reported had recommended it to their peers. In addition, the ones who had not used the cabinet felt it provided them with some new flexibility and saw it positively as something they could foresee using in the future. The service personnel felt it was easy to understand and use and did not report an added workload due to managing the cabinet, which was one carefully followed topic. Two other findings were also found: it came through in interviews and discussions that technology could potentially cut jobs, which was a sensitive topic and something that potentially influenced the staff motivations. Also, from the consumer standpoint, the customer value was questioned as the cabinet was placed next to a manned café with the same but narrower offering than the café – why use the cabinet when there is a familiar friendly face as an alternative?
2. *Need for driving trial.* Consumers reported that they needed a reason for trying out the cabinet for the first time to become familiar with the solution, after which the usage became more natural and enabled habitual purchases to occur. In the interviews, the service personnel mentioned the same observation that consumers needed support in using the cabinet for the first time.
3. *Coaching the personnel.* During the first days of the test, technical support closely helped the service personnel, which the customer's managerial team emphasized later as a good practice that enabled the local staff to buy into the concept. In the same post-test interviews, it was also stressed that intelligent

cabinet execution was much more than a technical implementation. Traditional retail tactics highlighting the location, visual appearance, taste communication, price promotions, habit creation, and so on play a big role in making unmanned retail a success. The underlying point is how the implementation team is encouraged to take the consumer perspective into. For instance, if the cabinet had been placed on each floor, and not next to the manned café, it would have provided a value-added benefit by being close to the customers.

4. *Use of data.* The last point that came up from the implementation team was to emphasize the possibilities of data in ramping up the experience and usage. In this test, data was only used to manage replenishment and evaluate the test's success, although it would offer wide opportunities to find the right offering for the cabinet, optimize pricing, and maximize sales at the key moments during the day with the right messaging and promotions. The cabinet is just a starting point for commercializing a micro-market, where the cabinet conducts the sales, but the responsiveness to local desires defines the success. When data is available, it should be used intelligently to tailor the experience and try to avoid the standard approach which is typical for old-fashioned vending machines. For instance, in composing the offering, one question is what kind of product combinations sell best as one of the features of intelligent cabinets is to be able to sell several products seamlessly at the same time.

4.3 Technology Responsiveness to Business Challenges

The research project identified four business challenges (BC1: customer experience, BC2: efficiency, BC3: resource availability, and BC4 sales volume) in the case company. The solution was tailored for use at the site and measured during the project to match the solution with the challenges.

Table 2 summarizes the results, which are organized according to the modified SFDC framework that was used to structure the test. The top part of the table shows the measuring points for the business performance and business challenges 2-4, while the lower part of the table shows how the people (customers, staff, and management) perceived the technology (matching with the business challenge 1).

TABLE 2: CHALLENGE-RESPONSE MATRIX

GOAL	DATA POINT	RESULT	REMARKS
QUANTITATIVE RESULTS FOR BUSINESS (BC2-4)			
PROFIT: Return on investment	Break-even	14 months	The case anticipated break-even to be reached in 8 months, while the data suggested it would take 14 months if no changes were made.
INCREASED REVENUE: attract new customers (BC4)	Off-hours sale	41% of the sales in off-hours	This indicates that 41% of the time customers could not have bought from the café without the intelligent cabinet.
INCREASED REVENUE: Sales volume increase (BC4)	Basket size	Positive	The hypothesis was that if the solution found its customers, after small trials a growing basket size would be observed, which also materialized.
DECREASED COSTS: work offload to shoppers (BC2 & BC3)	On-hours sales	59% of the sales in 'open-hours'	Most of the purchases happened during hours, and as they were trial buys, they potentially increased the workload by needing assistance from staff. This would change in longer run.
QUALITATIVE RESULTS FOR PEOPLE (BC1)			
FAIRNESS	Staff	Neutral	The fairness topic was mostly discussed related to staff, as unmanned sales in a manned location is directly seen as a threat. Employer reputation influenced the neutral outcome.
VALUE	Shoppers	Negative-Neutral	In customer interviews, the new unmanned technology was seen positively by extending the purchasing opportunities for the customers. On the other hand, the concluded sales did not support positive perceived value as implemented in the project.
SATISFACTION	Management, staff and shoppers	Neutral	The satisfaction was measured via the interviews with the management, staff, and customers. It came across that all the stakeholders were curious, but not yet certain how the everyday practice would turn out.
TRUST	Shoppers	Neutral-Positive	Using a credit card and using new technologies was seen to require trust, and in the café context, it proved to be no issue for the customers, as they felt that they were dealing with a known company. On the other hand, there were some indications that customers had mixed feelings of using the technology when it could potentially remove the personal service in the site in case it became a success.
LOYALTY	Shoppers	Positive	Shopper basket growth was a positive sign of developing loyalty from the shoppers.
PRIVACY	Shoppers	Positive	This proved to be no issue as referred to in the trust measure.

5 DISCUSSION, CONCLUSIONS, AND FUTURE RESEARCH

The research adopted a design science approach to understanding the feasibility of the intelligent cabinet solution in a food service business. The RQ1 about the intelligent cabinet technology concept was responded to by a literature review, which provided the key theoretical framework for the empirical part and understanding of the managerial agenda that a company faces in making technology decisions in a retailing context. Literature also provided an understanding of the foundations of the food service industry (RQ2), which is traditionally dominated by service creation and management perspectives. The empirical part provided further insights into the food service business in a specific setting, and finally, tested an intelligent cabinet technology as a solution for the identified specific challenges (RQ3).

The results show that the overall responsiveness of the intelligent cabinet concept to food service was positive, although challenges related to new technology adoption were present as well. A modern lifestyle influenced by online behavior and remote work has lifted a desire among consumers for a new level of freedom from location and operating hours. Start-ups have emerged in this area (e.g. in food delivery), which challenge traditional food and lunch service providers. The use of new technologies among traditional service providers was seen to support the businesses with contemporary customer desires, but the test showed that the technology itself easily grasps much the attention from the management leaving less focus on how to apply the technology properly matching specific needs of the audience by the way it is configured and introduced (choosing a location, designing right kind of offering, branding it rightly to position the service correctly, and deciding pricing so that it captures the new value and drives profitability). These issues require service concept-specific understanding as pointed out by Grönroos (2020). Section 4.2 summarizes experiences from interviews, which underlines that the value should be thought of from the staff perspective as well. Hence, the outcome of the pilot is not flat ‘yes’ or ‘no’ but rather an outcome that reports insights that identify a number of variables that have an influence on the performance. At the end of the paper, these variables are added to the used framework as main themes to propose a more holistic view of the decision-making agenda.

The research was one of the first studies published testing intelligent cabinet solutions in the food service industry. It provides an understanding of how a traditional food servicing industry could see a digital transformation path to comply with modern lifestyles and working environments. As a case study, it is limited in generalization and represents a single event in a quickly developing area. For this reason, it was important to conceptualize the situation to provide longer-lasting output from the research. As another limitation, the framework model adopted dominated the evaluation, which left some central perspectives such as risk assessment in a new technology decision outside of scope.

5.1 Managerial Findings

The research results indicate that the Intelligent cabinet concept is an interesting and promising concept for food service digitalization, but it also underlines that making a shift in a traditional business context requires

more profound efforts than setting up a digital point-of-sale. Section 4.2 summarized findings that were made by the organization requiring attention when planning and implementing an Intelligent cabinet solution. Additionally, the technology acceptance perspective was adopted from the literature to form a more exhaustive understanding of what must be taken into account.

One of the obvious managerial questions is the competence gap, which came up in the empirical project and sets questions if the current staff in food services can be trained for the digital landscape or whether it needs new talent. Overall, the people perspective came up as an important area to consider early on when doing technological shifts and is not limited only to internal competence. E.g. understanding consumers' needs, desires, and openness at a local level influences what, how, and when to implement in regards to sales automation.

5.2 Scientific Findings

The paper adopted the SFDC model from retail theories to illustrate a situation, where a business owner seeks a fit for new digital technology that can deliver improved business results with the acceptance of its key audiences. The paper further developed the framework and used the mSFDC framework to illustrate a new technology decision situation for a business owner, and it contained increased attention on people in general (and not customers only), and related to it, the role that technology was set to carry. People's perspective, which was already mentioned in the managerial findings, has wings also in the scientific area where it translates into questions about the future of work in customer service in the food serving industry.

One of the findings in this research paper was that implementing a digitized service in a traditional context is a multi-faceted area, where one needs to apply several sub-expertise areas to form a well-working concept including digital marketing, product management, operations, etc. However, these aspects were narrowly integrated into the frameworks proposed by scholars for retail technology selection and digitalization.

After analyzing the results from the empirical part, the paper continues proposing changes to the model and presents Service Focused Decision Calculus (SeFDC), which is illustrated in figure 8 and it intends to demonstrate and request a more complete view of the decision-making agenda faced by a business owner when redesigning a physical retail concept with digital technologies. The selection of retail technology is connected to an idea of new value that a company wants to acquire. It has a reflection of the perception that people as stakeholders make in their minds on psychological factors, but also how they perceive the wider landscape where the company operates in connection to brand image, ecosystem, career opportunities, and cultural development. The use of technology is closely linked to the perception, but also a central part of the wider service concept that defines locations unmanned service is provided, pricing strategy being followed, offering in terms of products sold as well as integrations to other supporting systems (e.g. payment and apps), promotions made that introduce and trigger trials and operational model that runs the replenishment. Finally, the benefits are related to short-term profit, but also more interesting long-term assets such as

customer loyalty, growth opportunities, and operational competitiveness. In the test it became clear that the concept must succeed on two levels: Companies wish to invest in practical technical advances that become profitable short-term. On the other hand, to drive business agenda, it should ideally drive long-term strategic assets. This aspect is integrated into the proposed SeFDC framework.

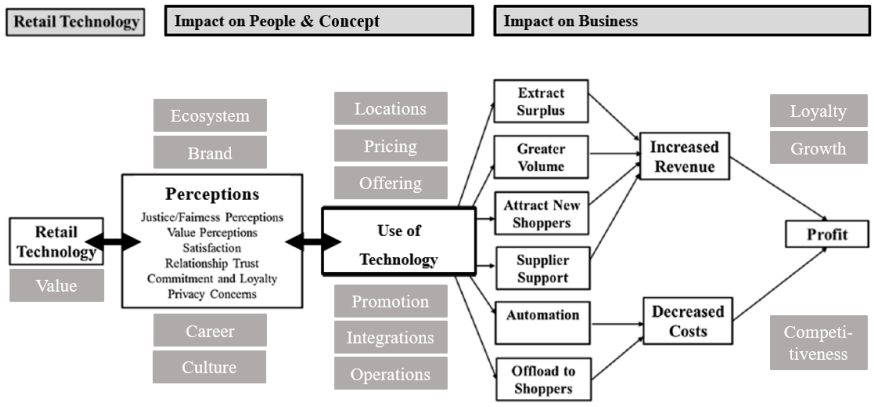

FIGURE 8: SERVICE-FOCUSED DECISION CALCULUS (SeFDC)

5.3 Future Research

The current technology era requires close collaboration between academia and practitioners. Further research on technologies employed to automate customer service interfaces would be needed to recognize broader patterns and understand how digitalization materializes in this area.

From this research, the framework model enriches the retail technology selection context by pointing out areas to consider when re-designing the service concept. Further studies that can elaborate on the context and provide empirical data on pointed key elements would be needed to establish best practices and success factors in renewing the service concepts.

Furthermore, understanding how the end-customer value changes when moving to the modern self-service era could provide a more structured and clearer view of the market change and the customer perspective. Several related technologies are seen as a rich research area that can help the adoption and drive the end-customer value of new retail technologies. For instance, connecting machine learning to intelligent cabinet implementation could help to optimize price points and the offering used on a cabinet level, and thus create an understanding of the hyper-local market desires and landscape. Understanding the thinking and feel of the digital encounter is also currently unclear.

Additionally, when moving on to a higher level, operations research could shed a light on what kind of network models could guide companies who are interested in ramping up new service models with Intelligent cabinet technology. Finally, by reflecting on self-serving through the research agenda of the platform economy researchers could provide an interesting view of the business model of such a hybrid platform.

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RESEARCH ARTICLE

The future of work: skills and knowledge perspective on service automation in the foodservice industry

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ABSTRACT

Academia has requested more research on the 'digitalization of the food environment', which has been recently reviewed as an important but weakly covered research area. The paper probes service automation in the foodservice industry using intelligent self-service (ISS) technology. The main research question is how the skills and knowledge (S&K) requirements change with ISS. In the study, a framework was developed to provide a view of competencies in service management. A single case study with a mixed method focused on an ISS pilot at a lunch cafeteria, during which the S&K requirements were evaluated. Empirical data enabled analyzing the S&K needs before and after the technology implementation. Findings underline that ISS reminds typical platform orchestration, where the S&K requirements include e.g. digital marketing, data analytics, and lean operations. Hospitality workers have been reported to be weakly covered in hard skills and digital problem-solving, which sets a challenge to human resource management. Other studies have pointed out that the gig economy could solve resource challenges in digitizing industries. This is one of the first papers released on the human resource impact of ISS. It contributes to discussions on the foodservice industry as well as to the digital transformation of a business.

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1. Introduction

Digitalization has driven growth within businesses and society in the twenty-first century. The business value from digitalization has derived from higher productivity of the workforce and from the new level of flexibility, when location, time, and connectivity are no longer constraints for doing work, running processes, and trading goods and services (Wilenius 2017; Goasduff 2021).

Industry experts have seen digitalization progressing in three waves, where the first wave in the 1990s focused on digital products, the second wave on digital distribution in the 2000s, and finally, the third wave focused on the shift in business models in the 2010s (Berman and Bell 2011). Business model-level shifts mean a deeper and more holistic transformation of what the company sells, how the profit is being made, and what kind of resources and processes the company manages (Christensen, Bartman, and van Bever 2016). In the 2020s, digitalization progresses through the virtualisation of physical life. In academia, the conversations go under the themes of internet-of-things, digital twin, and Industry 4.0. The common focus in the fourth wave is to explore and verify how the distance between digital and physical life is being closed by specific technologies understanding their impact on the supply chain system and profitability (Schwab 2016).

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In the hospitality businesses, new technologies have entered the market to e.g. automate customer handling, which reliefs the scarcity of the low-cost workforce availability and is supported by customers' desires for e-commerce like self-service (Ivanov, Webster, and Berezina 2017). One of the interesting topics in FS automation concerns the use of modern second-generation vending machinery in lunch cafés and workplaces, which provide a flexible and always-open supply of fresh food. These so-called smart fridges (as exemplified in Figure 1) are placed next to coffee machines and sell salads, fresh-made microwavable food, deserts, healthy juices, and snacks such as fruits and yogurts. Second-generation vending, or intelligent self-service technology (ISS) as called in this paper, differs from traditional vending by its convenient user experience, higher data resolution of the inventory including for instance expiry date management functionalities, and the ability to sell all shapes and kinds of products. These features allow sales automation to expand from snacking category to lunch serving. With the technology using a mix of artificial intelligence, machine vision, weight sensors, and radio-frequency identification, the fridge automatically manages its inventory and charges the customer purchases through a commonly used modern mobile and card payment framework. The user experience of the fridge is set to simulate as closely as possible an event where one is picking food from a home refrigerator. Just in this case the operation is not handled by the parents but by the FS provider, who defines offering, manages replenishment, and processes automated payments.

As the technology needed for modern digitized food serving already exists in the market, the recent observation has been that companies struggle with having the right skills and mindset to run the business. One claim has been that FS companies have been growing talent from kitchens, where the best cooks and most hard-working waiters and waitresses are promoted and pulled to make a career in the FS industry.

In a recent pilot project that the authors of the paper participated in, the team testing an ISS solution concluded that the challenge for the project was not the technology that worked perfectly, but the lack of management skills to set it up perfectly. In the pilot, an intelligent fridge was set to run next to a manned café without a clear strategy on how to design a classic marketing mix of location, offering, promotion, and pricing (as defined by Borden 1964) to best deliver the customer value. The result was that consumers responded in interviews that new technology is always exciting, but why buy a chocolate bar from a fridge, when you can just pay for the candy or sandwich to the friendly cashier whom you have come to know over the years? Would that be said if the solution was implemented from a customer value perspective and placed next to one's work desk saving a walk to the café on the first floor?

Figure 1. Smart fridge (BYTE FOODS 2022).

It came clear that in this case there was little attention paid to the consumer perspective: what kind of use of the technology would further increase customers' satisfaction, loyalty, and spending on the food services, and address potential weaknesses of the traditional business model? After the start, the technology would also need to provide several new opportunities for value creation in supply chain management through higher cognition tools such as advanced analytics, big data, and machine learning (Schuh 2017) to continue improving the offering and handling at a hyper-local context understanding the supply side parameters, profitability aspect, and seasonal changes. However, capturing the full potential of the new technologies would likely require different skills than traditionally found in the workplace cafés as the pilot project showed.

The purpose of this research is to explore *how the competence requirements change in the food-service (FS) business when intelligent self-service (ISS) is taken into use*. The research questions are as follows:

1. What is the current state of skills and competence in the FS industry?
2. What are the work areas involved in creating and delivering an FS concept?
3. How does the work change when the concept is digitized with ISS?

The research focus is on the competencies in the FS industry, and service management as a phenomenon. As technology, automation, customer value and operational concept per se are broad topics, they were not included in the research focus of this paper. In terminology, some synonymic uses of terms are being used to avoid repetition and improve readability. As a hierarchy, 'service automation' is the term used for the category, in which 'intelligent self-service' (ISS) represents one technological solution to automate service delivery. In the paper, it is also referred to as 'second-generation vending', 'smart fridge', 'intelligent cabinet', and 'unmanned kiosk'.

2. Theoretical foundations

Literature was reviewed to form an understanding of competencies in the FS industry and service management. Both areas are equally important as the purpose is to understand the effect on the competence requirements when the service management changes.

2.1. Skills and competencies in a foodservice industry

Several studies have observed the recent labour market changes that have occurred due to the Covid-19 restrictions, which have hit especially the hospitality market (FS, travel, and tourism). According to Huang et al. (2021a), the hospitality businesses that have pivoted new concepts (e.g. takeout only) and adopted new technologies (e.g. contactless payment) are primed for long-term survival. Authors propose that training in new transferable skills can be an effective way to avoid job market disruptions by establishing new cross-industrial skillsets and thus building more resilient businesses. One of the supporting observations has been that technological unemployment is not expected to be a permanent problem in the digital economy (Pulkka 2019), although contradicting evidence also exists reporting job destruction that occurs when Industry 4.0 drives a new level of efficiency through automation technology (Denny 2019).

Some other researchers have pointed out that workforce management is likely to need – among others – new arrangements such as the common use of external workers not only in information technology (IT) but in other departments too, where the work is highly specialised and pragmatic. They go as far as suggesting a workforce ecosystem approach for companies to holistically manage resources in the middle of technical, social, and economic changes (Altman et al. 2021). Some other researchers see the future for the digitizing industries in the gig economy, where platform specialists work independently through flexible arrangements and specialise in technical tasks needed to run a system (Santana and Cobo 2020).

The skills and knowledge (S&K) requirements change towards technology and broader skillsets have been recognized to be needed by hospitality researchers (Cetin, Demirciftci, and Bilgihan 2016). Compared to other industries, hospitality workers in general enjoy low wages and score low in mastering hard skills, among which technical expertise was discovered to be one of the weakest competence areas (Huang et al. 2021b; Bergson-Shilcock 2017). The low skillset as a starting point can be challenging for employers to consider reskilling and upskilling the workforce, especially when the job requirements include digital problem solving and not just conducting the duties mechanically.

The S&K profile change has been rapid, as the digital aspect of skillset requirements was absent still some years ago (Alhelalat 2015; Adeyinka-Ojo 2018). Today the influence of the digital economy can be seen in the recent hospitality industry research (see e.g. Choi, Mehraliyev, and Kim 2020) and has been accelerated by the Covid-19 influence in the markets (Gavrila and de Lucas Ancillo 2021). According to Granheim et al. (2021), the digitalization of food is a little-known area, which requires academic attention. In their systematic literature review, the 'availability of food' research area focused on digitized food distribution, which was revealed to be underdeveloped. At the same time, the food cluster is a globally significant industry, which cannot be ignored.

2.2. Service management

From a technology perspective, Shopper Focused Decision Calculus (Inman and Nikolova 2017) was suggested as a framework for retailers to consider for connecting technology decisions with attainable business benefits (Figure 2). The researchers argue that shoppers' perceptions correlate with the success of the new technology deployment. If consumers trust the company and feel that the technology gives them new value and convenience without compromising other values such as fairness, they are likely to react positively and drive positive word-of-mouth to support the shift. Negative perceptions lead symmetrically to switch to other providers and abandon the earlier service provider if solid alternatives exist. The research demonstrated how consumer businesses are continuously evaluated by their audiences. Even smart technologies cannot help, if the target audience has negative reservations about the changes and decides to ignore the new services provided (Inman and Nikolova 2017).

Shopper-focused decision calculus (SFDC) extended the Service Quality (ServQual) theory, which had earlier revealed the challenges when inconsistencies exist between a customer and a company in value creation (Parasuraman, Berry, and Zeithaml 1991). Figure 3 illustrates the common pitfalls that the researchers identified as 'gaps' when companies deliver value to consumers. The model

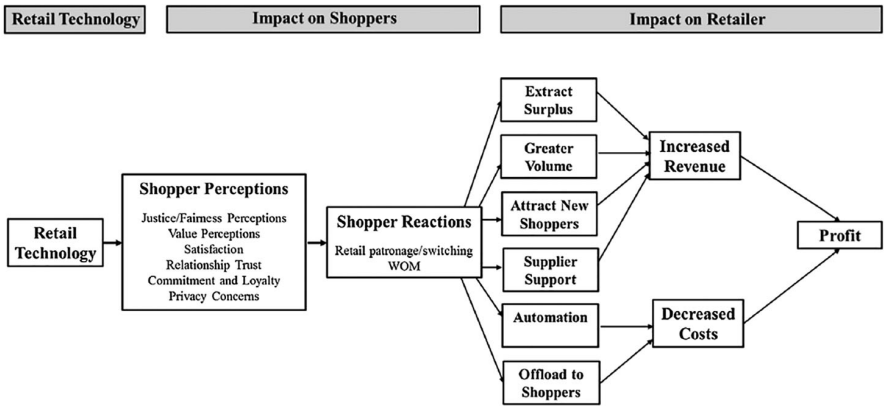

Figure 2. Shopper focused decision calculus (Inman and Nikolova 2017).

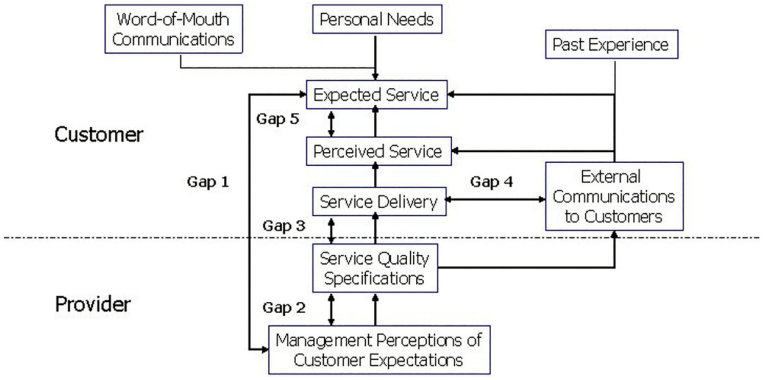

Figure 3. Service quality theory (Parasuraman, Berry, and Zeithaml 1991).

presents the inconsistencies as follows: (1) Management does not understand properly the customers' service expectations, (2) Management translates wrongly the expected service into service requirements, (3) Delivered service does not meet the intended service, (4) Miscommunication about the service raises false expectations, (5) Perceived service does not reach the expected service (Parasuraman, Berry, and Zeithaml 1991).

ServQual has been widely discussed by academia and it demonstrates a process view on creating and delivering customer value in a service context. However, in SFDC the customer value is just one property defining customers' acceptance of a new service, while ServQual fully focuses on defining the chain of actions and hence focuses more on the managerial perspective in service creation not limited to the technology adaptation context. According to SFDC, the other properties outside the immediate customer value aspect – such as trust – have similar importance. Interestingly, some of the properties are pre-existing when a new technology decision is being made, while some other ones are only evaluated by customers when they face the new solution.

While SFDC and ServQual talk about the managerial process and consumer perspective of a new service, the service design (SD) discussion has been keen on debating how new experiences should be innovated understanding the design perspective in the event. Johnson et al. (2000) suggested simplification in their research stating the design shall go through four main phases starting from design (ideation, strategizing, and concepting) and analysis (business context, problem identification) to development (service design, testing, training, piloting) and delivery (full-scale launch). Although SD discussion also talks about business themes such as analysis and strategies, they primarily focus on the design perspective as a starting point as described by Yu (2017).

To elaborate on the managerial aspect in the digital era, success factors of digital transformation were studied by Osmundsen, Iden, and Bygstad (2018) through a systematic review of empirical papers published. Researchers noted that organizational aspects and change management had been generally narrowly covered, and underlined that digitalization entails reformed organization, new business models, and performance improvements. Their results on eight success factors include for instance culture, capabilities, and activities ensuring adequate engagement with managers and employees. As a key organizational matter, Whysall, Owtram, and Brittain (2019) noted that Industry 4.0 trend has put traditional human resources management in a challenging position when the business environment changes faster than the S&K within an organization. Researchers suggest that traditional ways to use lateral hiring and identifying performers from an organization should be replaced with identifying new roles and developing systematic ways to lead organizations' skills in the right direction. However, in a matter of getting new roles filled as claimed by Whysall, Owtram, and Brittain (2019), earlier studies show that companies work differently in large and small enterprises. In large firms, the work is more organized into systems, led through processes,

and invested in training, whereas at an employee level the work is specialised by nature. In small and medium-sized firms, businesses are more driven by the entrepreneur and his/her character and produce more creative approaches with the new services and ideas provided in the market (Ghobadian and Gallear 1997). This implies that when looking at new self-serving technology used in hospitality, it can be expected to occur first by innovative SME firms, and then in large companies that hold a solid innovation culture and mindset, but which often move slower than smaller entities.

3. Methods and material

3.1. Research strategy

The research objective was to understand how the competence requirements change when taking IIS into use in the FS industry. As there was a limited amount of previous research on the topic, an explorative mixed-method case study research design was considered appropriate (as proposed by Yin 2003). According to Flyvbjerg (2011), a case study allows for maximising the utility of information, while some other scholars (Creswell & Plano, 2018) underline the mixed-method usefulness in case studies that include comparisons. Information-oriented data selection was seen to support the research objective and thus used in the project.

3.2. Research process and data

After defining the research objective, a literature review was conducted to understand the research phenomena more thoroughly. Literature also allowed the development of the 'Lenses framework', which formed a filter for the case study, in which empirical data was collected and analyzed to understand competence requirement changes before and after the technology use. Figure 4 illustrates how the research process was designed.

The empirical project provided both qualitative and quantitative data. The qualitative data consisted of pre-and post-pilot phases when the requirement needs were addressed both in interviews with individual company managers and in a group discussion. Group discussions allowed broader brainstorming with the stakeholders about the change from the manual sales process to automation. During the project, systematic observations and consumer interviews were carried out to give a broader and richer view of the end-customer needs and to understand how the solution was seen by its users. Although the case study used primarily qualitative data sources, quantitative data was also used to observe how the ISS performed in terms of sales and how the usage of the intelligent cabinet evolved over time. Hence, the data types had different roles in the study: one was used to measure success, while the other was to explain and create an understanding of the change.

Data analysis in the qualitative part followed a thematic research method, where the process evolved from understanding patterns, themes, and explanations for them (Aronson 1995). The quantitative part used statistical methods seeking descriptive, comparative, trend, and relationship information from the sales data (as framed by Woodley 2004). For instance, the team wanted to know

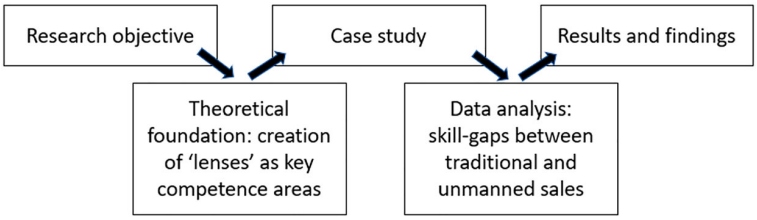

Figure 4. Research process followed.

how the sales developed over time, at which times the ISS was used, how it compared with traditional café peak hours, what the variance of the users was, etc. Table 1 outlines the data sources, methods, and objectives used in the study.

In creating an understanding of the change, the skill-gap model was utilised. In qualitative data collection, the participants were not only asked to explain the performance but also to reflect on the differences between the old and new operational concepts including practices, and S&K. Especially in the post-project phase, the comparison perspective was present to form an understanding of the differences: what are the existing S&K and profiles employed, what should be the desired skills and vision of the profiles in order to manage the ISS successfully.

The method follows the commonly used skill-gap framework, as presented in Figure 5, where the organization estimates future skills and compares that to currently measured skills. The aim of the model is to create an understanding of the gap between current versus needed skills and knowledge as a basis for further development (see more on the approach e.g. Shanthi and Sharma 2018).

In this research, reliability, and validity were taken into consideration by using triangulation in qualitative data gathering. As the goal was to understand how the skill set requirements change aside from the use of ISS, the use of multiple sources provided a more holistic understanding of the phenomenon. However, as the research still uses a single-case method, the results should be understood as an exploration of one situation in a specific context with limited generalisations.

3.3. Framework model

From the literature, authors developed the 'Lenses framework', which synthesises the theoretical approaches into a single model describing the service management construct. As it illustrates, the

Table 1. Data sources in the empirical part.

DATA	METHODS	NUMBER OF SOURCES	PURPOSE	INFORMATION USE
Qualitative	**Thematic interviews** incl. the current situation, sales distribution, business model, development needs and experiences.	12 interviews before and after the pilot start among the staff incl. café service employees (2), an IT development manager, regional manager, marketing manager, and IT implementation manager.	To understand the current situation, desired state, and solution and staff responsiveness during the project.	– PRE-PILOT: to understand the current state of the S&K – POST-PILOT: to understand the desired state of the S&K
	Observations	Notes from a 12-week project including an open feedback canvas for spontaneous experience sharing and change requests.		– PILOT: to support evaluations.
	Group discussions	3 sessions with the full implementation team to understand and confirm the main themes for one-to-one interviews and foster joint understanding of the challenges and S&K aspects during the piloting project		– PRE, POST and DURING the pilot feedback sessions to support the evaluations
	Semi-structured interviews mapping customer experience and evaluation of the new service.	16 end-customer interviews one week after the pilot had started.	To understand the solution and staff responsiveness to customer needs	– POST-PILOT: to support evaluation and explain the results achieved.
Quantitative	**Archival sources**	Sales, product, and customer interaction data from the cabinet from the 12 weeks of running time.	To measure the sales performance of the ISS	– PILOT and POST-PILOT: to understand how the pilot success and support diagnosis

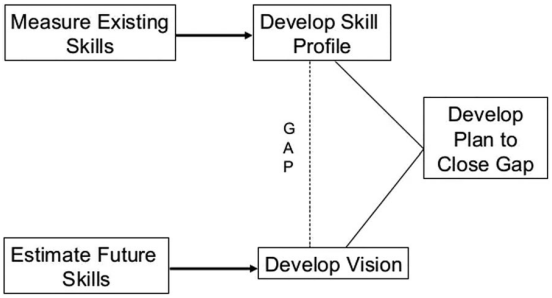

Figure 5. Skill-gap analysis model (as illustrated by TATA GROUP HR 2013).

management perspective (as described by Parasuraman, Berry, and Zeithaml 1991) looks at the service as a managerial process, where needs are translated into a business concept. Although Parasuraman, Berry, and Zeithaml (1991) discusses primarily value delivery, the notions made by Osmundsen, Iden, and Bygstad (2018) about the organization, people, and business model should be seen being part of the management perspective. The design perspective (as described by Johnson et al. 2000) sees the service event as a creative construct, where one needs to be able to design and provide desired experiences. And at the end, the customer perspective (as described by Inman and Nikolova, 2017) sees the service through the end-user angle, which evaluates the event free from structures and perceives its emotional and rational values that consumers either accept or reject.

The paper argues that establishing a new successful service requires success and connectedness in three areas simultaneously: 1. ability to translate customer perspective into actionable insights, 2. ability to design and build a service on top of the insight, and 3. connect the desired service to value creation and operational capabilities to run the business. The three areas follow and update Drucker's (1954) presentation of a successful business that combines customer, value, and revenue generation, which was later updated by Gassmann, Frankenberger, and Csik (2014) as a 'magic triangle' focusing more on the holistic value concept. The now suggested 'Lenses framework' turns service management into the spotlight. In many cases, casually discussed 'service update' by practitioners turns out to be a business renewal situation where a company renews the whole operating system more than taking a simple tool into use. Thus, it is a more central and deeper change process that typically requires a new S&K perspective for the whole team. When a change process is approached too lightly and without proper management attention, it simply fails to deliver business results (Figure 6).

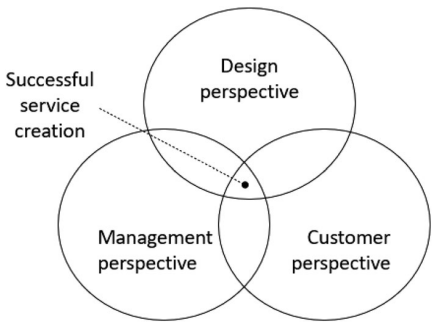

Figure 6. Lenses framework.

3.4. Case introduction

The case project was about an intelligent cabinet concept piloted in 2019 in an office hotel, where an FS company operated a reception, café, and daily lunch service. The FS company was one of the major firms in the country with hundreds of similar arrangements in offices and workplaces. In this location, the staff was a small and efficient team of fewer than 10 people, which operated a kitchen (4–5 people) and a customer service team (2–3 people) focusing on the café, reception, and during lunchtimes the cashier in the restaurant. In addition, there was a regional manager that managed the administration, financial management, and relationship with the office hotel property owner.

The goal for the pilot project (but not this study) was to see if the ISS kiosk would provide a financial return by its ability to sell to customers at off-hours and help co-selling the most requested products (sandwiches, juices, sweets) during the peak hours when a narrow customer service team was occupied with other duties either in reception or cashiers in the lunchroom. The project lasted for three months, and it was closely followed by the pilot project implementation team consisting of members from both the FS firm's IT, marketing, support, and regional management teams as well as the solution provider's technical, sales, and support teams. The research project reported in this paper ran aside the pilot project and had a goal to understand the S&K differences between the traditional and digitised ISS cafés. The research project used the same data sources and touchpoints as the pilot project but had a specific data collection and analysis for the S&K perspective reported.

The research project started with pre-design meetings to set goals and a project plan for the study, continued during the pilot phase analyzing the sales, performance, and needed changes, and finally met at post-evaluation workshops where results were analyzed, and learnings were listed. During the project, the team implemented consumer interviews of 16 pieces of 5–10 minutes to understand the user-experiences experience and perception of the new service and kept a shared diary of observations from the canteen staff and the project team to markdown relevant observations of positive, negatives and neutral but surprising events. After the project was closed, there were additional four one-to-one interviews of 15–30 minutes with the FS management team (country manager, site manager, marketing responsible, IT development manager) to understand individually their concerns, thoughts, and goals with ISS solution.

Although methods used both qualitative and quantitative data sources, the primary focus was on the qualitative part and the quantitative data was only used to assess the performance and support the qualitative data generation – i.e. to fuel interviews and group discussions. Thus, the quantitative part provided rather a thermometer of the business success, which was central in evaluating if the current S&K was efficient in setting up and managing the new service.

4. Results

In the pilot project, the monthly sales from the cabinet remained low. In a typical week, the cabinet produced on average 31 purchases within a range of 15–60 pieces, where 41% of the purchases occurred outside office hours. On average, there were six purchases a day with an average purchase of 2 euros, where item prices varied between 1 and 4 euros. According to an ROI analysis made for the case, the cabinet would have been able to break even after one year if the average price had been 8 euros with 50% gross profit. The sales trends found in a time series were two-fold: the number of weekly purchases decreased during the project supporting the eroding enthusiasm hypothesis, but on the other hand, the average basket size grew. Thus, it suggests the cabinet found loyal users who started to buy from it, while the 'trial buyers' disappeared after a while.

The quantitative results indicated that the ISS was under-performant for reasons that were not technical, and thus, it was seen that they would have been avoided with a better-skilled team that had more competence in developing and executing a marketing-mix including modern digital S&K to utilise data analytics and orchestrate the solution.

This led to further analyses of the S&K aspects, where the Lenses framework was utilised. The pre-pilot materials were used to understand the traditional service process and the competencies as a starting point, while the post-pilot data was used to evaluate the desired state. Table 2 summarises the results of the comparative evaluation, where the traditional café context represents the existing situation, and the new unmanned café / ISS context is presented as the desired state. The comparison shows that the implementation of the ISS concept requires broader S&K profiles in the desired state and clearly shows how the traditional S&K will have challenges in implementing ISS.

From the customer perspective, establishing a traditional café that sits nicely in context mostly requires a seasoned café worker, who understands the basics and how they typically operate in a location; while setting ISS needs much more understanding of the unmet needs and how a new technology with specific capabilities can play a role. Similarly, designing and decorating a new café on location can be conducted by an outsourced graphical or interior designer, while the ISS also requires an understanding of digital marketing knowing that the digital display can be interactive and programmatic, and an ISS unit is digitally connected and visible for the office workers from internet browser. Finally, the managing operation needs motivated and spirited customer service workers in the traditional concept, while the ISS needs talent that can manage replenishment,

Table 2 . Skillset comparison between traditional café and iss.

Competence area (Lenses model)	Dimension	Existing traditional café in an office hotel	New unmanned café / ISS in an office hotel
Customer perspective	Purpose	Ensure adequate understanding of the customers' needs and desires as a basis for profitable business	
	Context	Traditional café is a known and tested concept, which requires marginal changes to follow micro-local needs	Unmanned café is a new concept where the aim is to bridge technological capabilities to customer desires and value domains
	Desired skill profile	Seasoned café worker as a site leader, who knows from experience what works in practice	An enthusiastic researcher who can understand the unmet needs and desires of the audience, and requirements for technology implementation understanding the customers' skills and attitudes
Design perspective	Purpose	Define, create, and setup a concept for a café on a site	
	Context	– Café concept is tested and mature as such – The design focuses mostly on visuals and branding – The offering is mostly fixed and 'the usual' with sandwiches, sweets, juices, and warm drinks – Location is typically in the hub of the property, e.g. in the reception area – Marketing is about weekly promotions and service attitude of the personnel	– Unmanned café is a new and uncharted concept – The design work focuses on translating the customer perspective into new value sources that can be captured using technology – Conceptualization should understand the opportunities broadly from offer development and pricing to locations, processes, and introductions. – Visual design, branding, and promotions are just part of the broader concept – Mastering technology required to build truly data-driven solution and solve technical challenges
	Desired skill profile	Graphical designer – potentially outsourced to agency or freelancer as a project	A creative technology and business strategist, who can freshly package and redefine the purpose and concept of a worksite café to digital era
Managerial perspective	Purpose	Run the business with stability, growth, and profits	
	Context	The traditional café concept is typically profitable when operative costs are carefully managed	The unmanned café concept is a hybrid (physical and virtual) by nature requiring versatile skills from the team.
	Desired skill profiles	Customer service workers, and integrated management of administrative work for HR, accounting, and promotions	Multi-talented team with skills in IT, operations, digital marketing, and data management.

programmatic pricing, digital promotions, and IT from item-tagging and simple trouble-shooting perspectives in the process.

One essential difference in comparison is data, which enables process automation but also requires S&K from the staff that replaces customer dialogues with data analytics and related actions. The efficiency in the ISS model requires that the staff is multi-talented and customed to work through data and technology, while the traditional service workers have more emphasis on customer dialogue, empathy, and people skills in serving the audience. Obviously, setting up and operating a new versus mature concept has a difference too, but one cannot avoid the fact that serving customers through technology versus directly is different by nature.

Elaborating on the results in the introduced Lenses framework level, a traditional manned café is mostly run from the managerial perspective, where customer service skills support the customer perspective, but the concept lacks the design aspect that would make a future proof. The pilot project ran on ISS was built from a design perspective and powered by technical skills that supported solving managerial challenges of staff shortage and expanding sales to off-hours. It anyhow lacked adequate competencies on customer perspective in setting up the solution, and thus, it remained underperformant. Some of the recently endorsed 'high-technology & high-convenience' projects seen in the marketplace have been criticised for lacking adequate managerial S&K to be applicable for scaling (see e.g. reviews on Amazon GO from Ives, Cossick, and Adams 2019; Wong 2020). Figure 7 illustrates the interpretation of the results reflected by the Lenses framework.

5. Conclusion, discussion, and future research

The main goal of the paper was to understand the competence shift among the foodservice companies when ISS is taken into use. The literature review revealed that the starting point for a technological leap is not easy as the current workforce is commonly low-pay and low-skilled with modern technologies. To reflect the competencies needed in a modern service provision, the Lenses model was formed. The empirical part utilised the framework to compare traditional and unmanned cafés in terms of setting up and operating the business.

The results indicate that the service operations done through technology require different S&K, even on a local level. This is emphasised especially at the start of the technology era when new technology-led concepts are being developed and introduced. The literature review pointed out that new concepts are often introduced by visionary entrepreneurs prior to being adopted by the

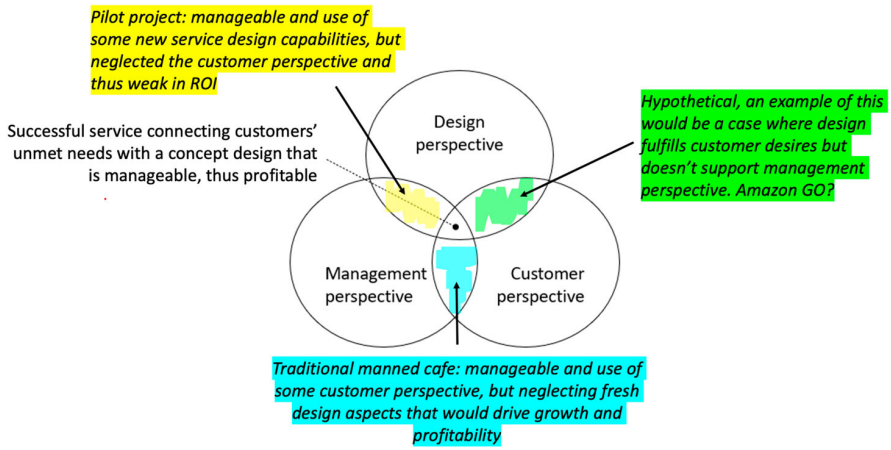

Figure 7. Interpretation of the results in the lenses framework.

major firms, which seek to streamline, productize, and scale the concepts. As the purpose of unmanned services is to reduce manning while improving flexibility and availability, efficiency should come from operating technology with staff that has versatile skills in orchestrating digital marketplaces. The idea of the gig economy was lifted in the literature review as a natural way to solve the S&K challenge ahead when traditional industries digitise. The new generations raised with modern technology are from the start more customed to using technology and data analytics than some of the older generations, whose competence is based on long experience in managing customer interactions in a traditional setting. The 'digital orchestration' reminds traditional management work, where product promotions, programmatic pricing techniques, offering decisions, and location are being optimised in parallel to replenishment and IT operations. Local café managers in such a context have just very different tools for delivering service and growing business, while the mechanical routine work is outsourced to intelligent machinery. While it can be seen creating technological unemployment, self-service technologies have become in many places a key strategy for surviving through employee shortages and changing lifestyles that favour mobility, 24/7 shopping, and e-commerce.

The research project was based on a mixed-method single case study, and thus it is limited in terms of generalisation. It does not consider the different ways of organizing the duties, which can change the work requirements of a specific role in a company significantly. One limitation of the study is the fact that different automation technologies may vary in terms of S&K, but the authors believe that from the helicopter view, the trend remains the same. Another aspect that was only partly discussed in this research, is the S&K perspective from the product life cycle or innovation context. It is obvious that new pioneering concepts at the start require different S&K from the team while maturing business models (such as trad café) are run with a different kind of team in terms of S&K. The reflection of results in the Lenses aspect touches this but leaves much to later studies.

5.1. Scientific implications

The research paper provides novel evidence from the digitalization taking place in an FS business. As explorative qualitative research, it provides insights for identifying variables to be tested in a quantitative approach that can further illuminate some of the changes taking place in FS and the hospitality industry across the world.

From the digitalization perspective, the paper continues the discussion started on Industry 4.0 (Schwab 2016) of the physical life merging with advanced technologies and provides evidence on the future of work in this context. The study implies that customer-facing technologies are currently in a testing phase and provides a clear indication of the changing work profiles needed in managing and orchestrating digitizing businesses.

Finally, the proposed Lenses Model facilitates the theoretical integration between business models, service management, and human resources. The case study implies that such integrative theories are needed to avoid siloed views of reality and to keep theoretical propositions valid and relevant.

5.2. Managerial implications

To managers, the study presents a sample of digitalization for traditional service industries and implies that digitalization changes the talent profile required to run a modern business using automation. It leads to re-skilling current employees and/or recruitment of new profiles that better comply with the tasks. Results exemplify what kind of duties were found in an unmanned café context.

Furthermore, for the practitioners, the implication is that the simple-sounding technological concept is likely to require broader acumen from the team to succeed in re-designing the service concept using automation. It can serve as a great inspiration and career accelerator for those traditional café workers, who can get excited about utilising the established customer and industry understanding in a changed context. Leaders should support narrating the work at hand, a

provide support with training on those parts that require totally new skills – typically related to digital dimensions. Change management, psychological safety, and trust are needed to get the team engaged and focused.

5.3. Future research

The research presented in the paper had limitations related to the case study setting and perspective adopted focusing on the competence areas. As future research, quantitative studies are needed to validate the observation of the S&K requirement changes reported. Also, other perspectives such as innovation maturity mentioned in the research limitations would be an interesting topic that could provide a broader understanding of the S&K requirement changes. Research that can further explore and provide evidence on how the change meets with the different segments of the FS industry, would be valuable. What are the patterns and typologies of change? (On innovation diffusion e.g. Moore 1991)

It was noted that service automation, in general, is a broad area that would benefit from further research of means, structure, and business models. This study used an intelligent cabinet solution as a representation of ISS, but it is evident that the FS and hospitality industry faces currently several different technological concepts that intend to automate and provide the self-service capability. Studies that support building technical typology of the alternatives would help theory building and bridging theories between service management and technology.

Finally, the paper suggests that the new technology sets more broadly business renewal challenges for traditional businesses. Studies that elaborate on the business renewal from technology (e.g. use of artificial intelligence) or management (e.g. re-skilling, upskilling vs new hires) perspectives would accelerate theory building and support practitioners.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Publication VI

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Dissemination of Supply Chain Visibility: Intra-Organization Perspective

Dissemination of Supply Chain Visibility: Intra-Organization Perspective

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***Abstract*— Information generation has been raised as a source for superior innovativeness and organizational performance by the Market Orientation (MO) research stream. Supply Chain Management research has in parallel shown a growing interest in Supply Chain Visibility (SCV), which focuses on real-time information about inventories and can be used to understand markets and customer needs. This theoretical paper that stems from the abductive theory-building approach proposes that the connection of SCV-MO has a strong grounding to practice and clear request by academia but has lacked solid theoretical formation. The paper contributes to the research gap by connecting the key theories and proposing an SCV-MO framework model with a research agenda.**

Keywords*— *supply chain visibility, innovativeness, digital transformation of supply chain

I. Introduction

Supply chain management (SCM) has grown from the fragmented management of activities emerging as a research field in the 1960s [2]. At the time, 'material handling' was seen as part of marketing responsible for selling and delivering goods to customers [18]. Eventually, logistics became a concept of handling purchasing, materials management, and distribution, and investigating how to efficiently manage product and service flows [9,2]. Today SCM researchers describe that in a globalizing competitive marketplace, the focus is on increasingly boundary-spanning collaborative practices, which in a virtual setting enable not only cost-saving but in an equal measure sales increase [2,22]. The sales contribution of SCM comes from its ability to drive customer value (e.g., cost competitiveness), support customer desires and experience (e.g., sustainability in sourcing, omnichannel fulfillment), and extract insights from the customer front.

This theoretical paper is interested in the accurate and nearly real-time information that SCM collects from the customer interface, which can give indications and insights about the customers. Supply Chain Visibility (SCV) has become an emerging research theme within SCM focusing on the data capture and sharing practices in its function. However, as the research interest has been within SCM function and related inter-firm relationships, the use of SCV data within a firm on a cross-functional use has not yet been fully discovered. This paper intends to understand how SCV can support market intelligence (MI) in its information generation that fosters the innovativeness of an organization and propose a related research agenda. The paper contributes to discussions taking place in SCV, MI, and the integration of SCM and marketing.

II. Literature Review

A. Market Orientation

The marketing concept is an organizational culture that puts the customer at the heart of its strategy and operations [8]. Understanding how customers perceive the market requires not just focusing on the customer but understanding the firm's competition as well, which reveals the alternatives that a customer has in fulfilling a need. This defines the essence of Market Orientation (MO) [16]. Competition, as a component of MO, has been earlier portrayed through the theory of Five Forces proposing that powers parties (rivals, suppliers, buyers, new entrants, and substitutes) hold in a marketplace eventually influence the competitive situation [25]. Researchers suggest that translating marketing philosophy into practice provides a competitive advantage for a firm and studies have verified that MO helps companies to win the competition, which is less market-oriented [5,15]. The challenging notion in MO for a firm that wants to become more market-oriented is its anchoring to a culture, which is known to be difficult to lead. Research on corporate cultures has suggested that cultures emerge from behaviors, but superior cultures leading to competitive advantage are not reached by managerial manipulation [1]. Researchers have pointed out that besides customers and competitors, a MO organization needs cross-functional coordination meaning behaviors and actions that a company jointly takes to provide superior value to customers over its competition [24].

Kohli and Jaworski [16] stressed in their research the importance of MI (defined as information generation, dissemination, and responsiveness) as a source of MO. However, "generating and using insight to shape marketing practice" has been pointed out by American Marketing Association in 2016 as one of the seven challenges faced by marketers today [14], which is confirmed by other researchers stating that academic empirical research on market intelligence practices is limited and lacks theoretical grounding [16]. Despite the generally accepted importance of MI, it is not clear in practice how intelligence is generated,

disseminated, and responded to across the organization [10]. Furthermore, they see that managers are unclear on how to use MI in decision-making raising concerns that information generation and dissemination may not be well planned, and the MI unit may, bluntly speaking, just operate as an internal news desk that generates and shares information for internal audiences that uses if they wish. However, scholars note that efficient information generation and end-use should be planned beforehand [23].

In a study focusing on the quality of market intelligence, the researchers defined that "information generation is the acquisition of data concerning the firm's markets from sources external to the firm" which can be understood to claim that an organization learns from markets only through external sources such as from marketing research [4]. However, Moorman [23] has proposed that information acquisition is a process of bringing information from the outside into the firm environment describing insight generation as a listening capacity. Heinrichs and Lim [11] suggest in their theoretical model of a strategic response capability that insight generation capabilities include adaptive capacity, learning curves, market sensing capability, organizational learning & memory, and knowledge management processes. The sources used in the model also stress the role of internal sources in insights generation.

Internal information sources are important from the competitive advantage perspective, as they are exclusively controlled by an organization itself. Maltz and Kohli [21] note that without unique (exclusive) information sources, information dissemination is the only source of competitive advantage in MI. Hunt and Morgan [13] propose in comparative advantage theory that the modern understanding of resources expands to information, and an organization, which has low-cost access to a high-value resource, has a comparative advantage leading to a competitive advantage position in the marketplace and thus, it has potential on a firm level to high financial performance.

B. Supply Chain Visibility

The definition of SCV has been unclear and debated, which has resulted in inconsistent use of the term [36, 29]. This paper borrows some of the definitions from Williams et al. [35] and perceives SCV as (i) a capability that (ii) provides "access to high-quality (accurate, timely, complete, and in useable forms) information that describes various factors of demand and supply." The key functionalities of SCV capability are data capturing and sharing [12]. This paper argues that SCV research started from product identification research in early 2000 [see e.g., 17], which became ten years later the SCV research stream that adopted the view of competition that was alliance-led (chain-to-chain) [22], and hence, resulting to intra-functional and cross-company context. The authors propose that the research needs to re-focus on the intra-firm aspect, where the data is utilized cross-functionally to form an integrated data-driven firm responsive to the speed and agility required by markets today. Figure 1 illustrates the proposed shift in SCV research orientation.

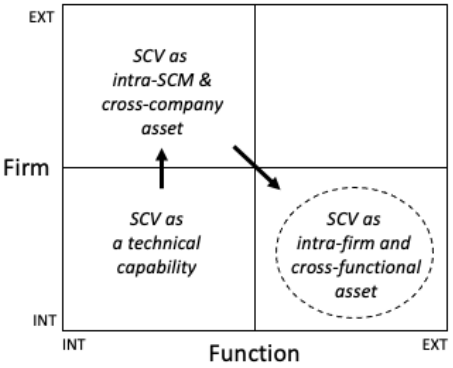

Figure 1: The proposed shift in SCV orientation

However, the aspect of internal-external chains is not fully absent in this era either as the control of SC matters to SCV. In an open-loop SC, the brand owner does not have end-to-end control of the chain but collaborates for instance with an external distributor that manages the reselling. Hence, a brand owner does not automatically have visibility and accurate data from stores, which could provide an ideal source of customer insights. Studies have reported that data sharing is sensitive with external partners [20], and for that reason, a closed-loop SC structure favors the SCV concept as it is viewed in this paper. Observations from companies (e.g., Inditex in the fast fashion business) also confirm first movers on SCV appear to be from closed-loop structures [see e.g., 31].

According to our view on research evolution, the interest in SCV stems from the observation that SC data found in enterprise resource platforms (ERP) is commonly inaccurate.

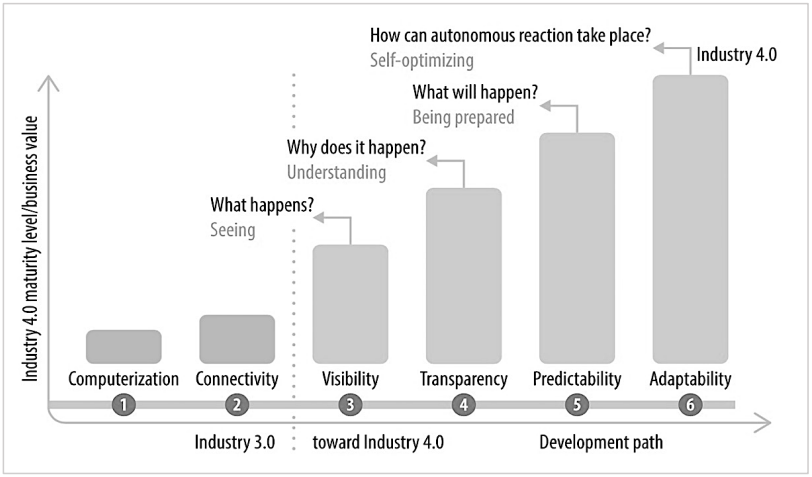

Figure 2: Visibility as a gateway to higher cognition (Schuh et al., 2017)

Depending on the industry, the inventory record inaccuracy (IRI) has been reported to be at a 30-80% level [32,7,27], which has led to several managerial challenges within SC (e.g., bullwhip and ripple effect) [3,37,19]. SCV provides a solution to IRI, which combined with SCM challenges (e.g., ever-shortening product lifecycles, quick constant changes, and increasing customer requirements) demand a new approach [12].

The technical approach to SCV can be provided through an automated product identification and tracking solution, which has three main elements in a typical system: (i) an ID (e.g., serial numbering, bar coding, radio-frequency identification), (ii) integration and reading infrastructure (e.g., antenna or camera with an artificial intelligence engine), and (iii) cloud solution generating, managing, and displaying data on inventories. Benefits for the SCM are obvious efficiency gains; global consultancy Kurt Salmon Associates reported in an RFID Retail study that automated product identification and tracking (i.e., SCV) provided 11-60% improvements in six performance indicators (customer satisfaction, inventory accuracy, stock-outs, shrinkage, profit margin, and markdowns) [32] among retailers reporting experiences from system implementation. In many cases, the design of the SCV system is also connected to solving company and industry-specific dilemmas, e.g., how to minimize food waste in the grocery retail industry. Although the number of core technologies is limited, studies have reported high versatility of adoption between industries [33, 38]. Some industries (e.g., fast fashion) have proven plug-and-play solutions for SCV implementation, while many others tend to be still working with manual serial numbering and tracking [33].

The emergence of SCV is also partly a consequence of new data-savvy technologies and the industry 4.0 (I40) research trend, which proposes a shift in business models when data is translated (with e.g., advanced analytics, machine learning, and artificial intelligence) to modern IT capabilities and customer experiences (Schwab, 2016). While the I40 is a common research interest in digital transformation studies, it provokes organizations to innovate new cross-functional connections that can improve and renew the traditional roles of functions and organizations among their peers. In an I40 framework describing the maturity and roadmap for digitalization, introduced in Figure 2, SCV is proposed to be a gateway for a firm to higher cognition tools as it can create a digital twin and provides data for advanced analytical data processing [39].

III. Conceptualisation of SCV-MO

The interest in SCV-MO connection comes from some of the leading firms in the textile and fast-fashion industry, who have been keenly studied by scholars to understand their supply chain strategy and operational model. The observations present that they use real-time and item-level data from the supply chain to understand the current inventories and market demand to optimize e.g., what kind of products customer desire and how to optimize the store-level stock replenishment to avoid excess inventory build [31]. Thus, these firms have built a strong SCV capability which is used cross-functionally in an intra-firm context.

This theory paper proposes a conceptual model in figure 3 that in practical terms illustrates how SCV can be used as a real-time sensor of the marketplace demand, which by connecting to MI function can drive the innovativeness of a firm as presented by Kirca et al. [15]. The model proposes that the assimilation of SCV data to cross-functional use should occur on two levels: on the operational level as an ongoing

information supply from markets to new product/service development (NP/SD), offering decisions, and marketing promotions (MP); and on a strategic level monitoring the long-term responsiveness of the business introducing improvements to the strategic business plan (BP).

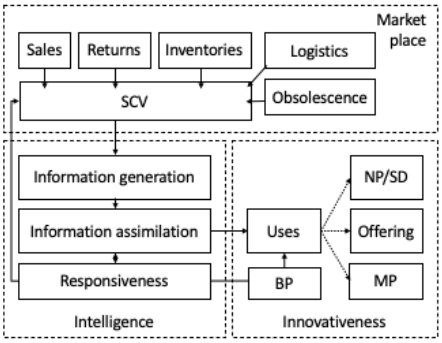

Figure 3: Conceptual framework

The conceptual framework is used in figure 4 to establish a relationship model that presents operational relationships between SCV-specific data sources (both from online and offline touchpoints) and their cross-functional operational uses marked as demand pulses (DP) in the figure. The relationship model exemplifies also the long-term strategic perspective to demand fluctuations that the responsiveness functionality monitors to identify trends needing attention from organizational design to stay competitive. The DP's (on the left) and trends (on the right) mentioned in the model is illustrative and meant to showcase how the relationship model can be used to research relationships and causalities.

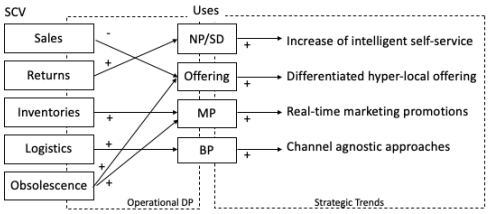

Figure 4: Relationship model

IV. Discussion and Research Agenda

The theoretical paper presented approaches to theory building from an abductive perspective [see e.g., 30] and draws attention to the data-driven practices demonstrated by some of the leading firms in the textile industry. It presents an interesting phenomenon that lacks theoretical backing, which is the gap filled in this paper by the formation of the SCV-MO conceptual model. It can be used to expose and research relationships between data sources and uses in a cross-functionally integrated organization to understand what kind of ties and methods support organizational performance, and further contribute to theory building in SCV, MI, and MO.

Although the paper draws from the example of the textile industry, the authors claim that the need for SCV-MO connection is universal and is more connected to speed, agility, and data-driven business models than to a specific context in a certain vertical.

As the research agenda, the authors propose studies that respond to some of the most striking research questions arising from the SCV-MO model:

- How can the implementation of the SCV-MO model support organizational performance? E.g., empirical studies illuminating new cross-functional data-sharing practices and their impact on key performance indicators followed in an organization.
- How SCV practices should be optimized to support cross-functional utilization? I.e., how the broader utilization of SCV data in an organization influences the data collection practices. For instance, if the customer desires are needed to understand, potentially understanding the purchase basket compositions is a critical data point needed in the offering development and marketing promotion although it would not have significance to supply chain management.
- What kind of cross-functional processes should support the value capturing of SCV-MO? This is a theme that is highly essential in the current business environment, where it has been unclear how to organize and restructure the organization to become more collaborative and cross-functional, and less functionally organized with clear boundaries in the roles and responsibilities. One example of such is the emergence of agile organizations, which aim to tear down internal fences.
- And, how the reverse utilization of the information flows should be applied, i.e., how SCM can further optimize their processes in procurement, capacity building, and preparations by understanding the conclusions made at the marketing units.
- Finally, as many of the previous questions are qualitative by nature and intended to explore the new research agenda, quantitative approaches are needed to explore and validate the cross-functional relationships observed in an SCV-MO setup as it is exemplified in Figure 4.

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