Department of Industrial Engineering and Management

Implementation of RFID Tracking across the Entire Supply Chain

Ville Hinkka

Aalto University

DOCTORAL DISSERTATIONS

Aalto University publication series
DOCTORAL DISSERTATIONS 135/2013

Implementation of RFID Tracking across the Entire Supply Chain

Ville Hinkka

A doctoral dissertation completed for the degree of Doctor of Science (Technology) to be defended, with the permission of the Aalto University School of Science, at a public examination held at the lecture hall AS1 of the school on the 11th October 2013 at 12 o'clock.

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Aalto University publication series
DOCTORAL DISSERTATIONS 135/2013

ISBN 978-952-60-5310-3 (printed)
ISBN 978-952-60-5311-0 (pdf)
ISSN-L 1799-4934
ISSN 1799-4934 (printed)
ISSN 1799-4942 (pdf)
http://urn.fi/URN:ISBN:978-952-60-5311-0

Unigrafia Oy
Helsinki 2013

Finland

441 697
Printed matter

Aalto University

Abstract

Aalto University, P.O. Box 11000, FI-00076 Aalto www.aalto.fi

Author
Ville Hinkka

Name of the doctoral dissertation
Implementation of RFID Tracking across the Entire Supply Chain

Publisher School of Science

Unit Department of Industrial Engineering and Management

Series Aalto University publication series DOCTORAL DISSERTATIONS 135/2013

Field of research Logistics

Manuscript submitted 15 May 2013 **Date of the defence** 11 October 2013

Permission to publish granted (date) 16 August 2013 **Language** English

☐ **Monograph** ☒ **Article dissertation (summary + original articles)**

Abstract

The use of RFID (Radio Frequency Identification) tracking to improve the supply chain management (SCM) of today's complex and geographically dispersed supply networks has been highlighted in the past 10 years. Even if the use of RFID technology to smooth certain supply chain operations has grown rapidly, the number of supply chain-wide tracking systems, which would be highly integrated with the operations across the whole supply chain, has remained low.

The aim of this thesis is threefold. First, it aims to study the context in which companies operate to thus understand their tracking needs in ever-changing operational environments. Second, the thesis develops the means to define the most suitable coverage for the tracking system for particular supply chains, and third, the thesis proposes three different mechanisms to implement supply chain-wide RFID tracking systems.

The material for this dissertation was obtained by six different case studies, all which analysed RFID tracking implementation in certain supply networks. The analysis focused on considering different supply chain actors' viewpoints for common RFID tracking system adoptions to align the incentives of different actors. Mixed methods research, by combining quantitative analysis to multiple, different qualitative data collection methods, was used to research this complex and dynamic SCM phenomenon.

The results of this thesis indicate that improved tracking would help companies develop their SCMs to better respond to the requirements of their operational environments. SCM concepts of postponement and speculation could be used to evaluate the trade-offs between the resources needed to implement wide-spanning tracking with benefits that the wider coverage would offer. Finally, this thesis proposes three different mechanisms to realise supply chain-wide RFID tracking: "retailer as an initiator", "wholesaler as an initiator", and "tracking provided by a logistics service provider company". The characteristics of the supply chain greatly inform the selection of the most suitable mechanism.

Keywords Tracking, supply chain management (SCM), supply chain integration, inter-organisational information systems (IOIS), design science, Radio Frequency Identification (RFID)

ISBN (printed) 978-952-60-5310-3 **ISBN (pdf)** 978-952-60-5311-0

ISSN-L 1799-4934 **ISSN (printed)** 1799-4934 **ISSN (pdf)** 1799-4942

Location of publisher Helsinki **Location of printing** Helsinki **Year** 2013

Pages 200 **urn** http://urn.fi/URN:ISBN:978-952-60-5311-0

Aalto-yliopisto

Tiivistelmä

Aalto-yliopisto, PL 11000, 00076 Aalto www.aalto.fi

Tekijä
Ville Hinkka

Väitöskirjan nimi
Toimitusketjun laajuisen RFID-seurannan käyttöönotto

Julkaisija Perustieteiden korkeakoulu

Yksikkö Tuotantotalouden laitos

Sarja Aalto University publication series DOCTORAL DISSERTATIONS 135/2013

Tutkimusala Logistiikka

Käsikirjoituksen pvm 15.05.2013 **Väitöspäivä** 11.10.2013

Julkaisuluvan myöntämispäivä 16.08.2013 **Kieli** Englanti

☐ **Monografia** ☒ **Yhdistelmäväitöskirja (yhteenveto-osa + erillisartikkelit)**

Tiivistelmä

Radiotaajuuksiin eli RFID-teknologiaan perustuvan seurannan käyttöä on ehdotettu tehostamaan nykyisiä yhä monimutkaisempia ja maantieteellisesti hajaantuneempien toimitusketjujen hallintaa jo viimeiset 10 vuotta. Vaikka RFID-teknologian käyttö yksittäisten toimitusketjun toimintojen sujuvoittamisessa on viime vuosina kasvanut voimakkaasti, laajemmat usean toimitusketjun osapuolen ja heidän toimintonsa yhdistävät järjestelmät ovat kuitenkin edelleen harvinaisia.

Tämän väitöskirjan tavoite on kolmiosainen. Ensinnäkin se pyrkii tutkimaan yritysten liiketoiminnan ympäristöä määritelläkseen yritysten seurantasovellusten käyttötarvetta jatkuvasti muuttuvassa maailmassa. Toiseksi väitöskirjassa esitellään keinot määritellä sopivin seurantajärjestelmän kattavuus tietyssä toimitusketjussa ja kolmanneksi väitöskirjassa esitetään kolme eri mekanismia toimitusketjun laajuisen RFID-seurantajärjestelmän käyttöönottamiseksi.

Väitöskirjan materiaali on kerätty kuudesta eri tapaustutkimuksesta, joissa kussakin analysoidaan RFID-seurantajärjestelmän käyttöönottoa tietyssä tilaus-toimitusverkostossa. Analyysi keskittyi eri toimitusketjujen osapuolien RFID-seurantajärjestelmän käyttöönottamiseen liittyviin vaikuttimiin, jotta olisi mahdollista yhtenäistää eri osapuolien näkemykset ja tavoitteet. Tämän monimutkaisen ja muuttuvan ilmiön tutkimusmenetelmänä on käytetty yhdistelmätutkimusta, jossa kvantitatiivinen analyysi on yhdistetty moniin laadullisen tutkimuksen menetelmiin.

Väitöskirjan tulokset osoittavat, että parempi seuranta auttaisi yrityksiä kehittämään toimitusketjunsa hallintaa vastaamaan paremmin heidän liiketoimintaympäristönsä muuttuvia vaatimuksia. Toimitusketjun hallinnan käsitteitä viivästyttäminen ja aikaistaminen on käytetty vertaamaan valintoja toimitusketjun laajuisen järjestelmän käyttöönoton vaatimien resurssien ja laajan seurannan tuomien hyötyjen välillä. Lopuksi väitöskirjassa ehdotetaan kolmea eri mekanismia toimitusketjun laajuisen RFID-seurannan toteuttamiseksi: ”Vähittäiskaupan aloite”, ”tukkuliikkeen aloite” ja ”logistiikan palveluntarjoajan toteuttama seurantapalvelu”. Sopivan mekanismin valinnassa toimitusketjun luonteella on merkittävä vaikutus.

Avainsanat Seuranta, toimitusketjun hallinta, toimitusketjun integraatio, organisaatioiden väliset tietojärjestelmät, design science, radiotaajuuksiin perustuva tunnistus(RFID)

ISBN (painettu) 978-952-60-5310-3 **ISBN (pdf)** 978-952-60-5311-0

ISSN-L 1799-4934 **ISSN (painettu)** 1799-4934 **ISSN (pdf)** 1799-4942

Julkaisupaikka Helsinki **Painopaikka** Helsinki **Vuosi** 2013

Sivumäärä 200 **urn** http://urn.fi/URN:ISBN:978-952-60-5311-0

Acknowledgements

This thesis is a result of long and eventful series of research work. When thinking about the completion of this thesis afterwards, I would say the start was the most difficult phase. Therefore, I would like to express my sincere gratitude to Dr. Mikko Punakivi, currently at Helsinki Business and Science Park, Mr. Jarkko Lehtinen from VTT and Dr. Jouko Karjalainen from Aalto University. They believed in me and gave me an opportunity to develop my research skills in their projects and acquire essential experience needed to grow into a capable doctoral student.

I am deeply grateful to Prof. Jan Holmström, who patiently taught me how to write academic papers. His enthusiasm inspired me to gain higher achievements. I offer my thanks to Prof. Kary Främling for involving me interesting projects and for interesting discussions concerning scientific issues as well as life in general. I give my special thanks to Mr. Jaakko Tätilä who helped me a lot in the Technical Trade case study and related articles, as well as Ms. Maiju Häkkinen, whose work formed a ground for the Clothes case study.

I am thankful for Associate Prof. Daniel Hellström at Lund University and Prof. Klaus-Dieter Thoben at University of Bremen for their encouraging feedback and prompt service as preliminary examiners for this work. I express my gratitude to Prof. Gunnar Stefansson at Chalmers University and Professor Thoben for kindly agreeing to act as the opponents of this dissertation.

I want to thank for peer support of the Logistics Research Group members, especially Dr. Jouni Kauremaa, Dr. Bela Patkai, Juha Ahokas, Pekka Helkiö, Max Finne, Mikael Öhman, Dr. Riikka Kaipia, Prof. Antti Tenhiälä, Docent Jussi Heikkilä, and Dr. Saara Brax. I further thank my former colleagues in Value Network Research Group, especially Tero Haahtela, Maija Koskela, and Dr. Frank Bescherer for creating nice working atmosphere.

The empirical research needs collaboration and support of representatives of multiple organisations. I want to highlight the support of RFID Lab Finland Ry, especially Anne-Mari Pohjanlehto and Petteri Koivu.

Research is not possible without funding. Thank you to the EU FP6 for funding TraSer project, TEKES for funding several research projects, and Academy of Finland for funding IBSOM-project. These projects enabled me conducting tracking research. Also, I thank to the Finnish Foundation for Technology Promotion for the grant. In addition, I want to cordially acknowledge Prof. Kari Tanskanen for arranging me financial opportunities to concentrate on finalizing articles and writing compendium part of this thesis.

Finally and most importantly, a long-term project like a doctoral dissertation would be difficult realise without a support from family and friends. Consequently, I would like to thank my parents Katariina and Reijo and my sister Noora for always believing in me. I would, of course, like to thank my beloved wife, Tiina, for supporting my research work, as well as our son Elias for balancing my life.

Espoo, September 1, 2013

Ville Hinkka

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PUBLICATIONS

The dissertation consists of a summary and the following six papers:

(I) Punakivi, Mikko & Hinkka, Ville:

”Selection criteria of transportation mode - case study in 4 Finnish industry sectors”,

Transport Reviews, Vol. 26, No. 2. 2006. pp. 207-219.

(II) Hinkka, Ville:

“Challenges for building RFID tracking systems across the whole supply chain”,

International Journal for RF Technologies: Research and Applications, Vol. 3, No 3. 2012. Pp. 201-218.

(III) Hinkka, Ville; Holmström, Jan & Främling, Kary:

“RFID tracking in the book supply chain: The transition from postponed to speculative tagging”,

International Journal of Logistics: Research and Applications. Vol. 15, No 3. 2012. Pp. 194-214.

(IV) Hinkka, Ville; Häkkinen, Maiju; Holmström, Jan & Främling, Kary:

“Typology of configurable RFID tracking for fashion logistics”,

Under review in International Journal of Logistics Management.

(V) Hinkka, Ville & Tätilä, Jaakko:

“RFID tracking implementation model for the technical trade and construction supply chains”,

Accepted in Automation in Construction.

(VI) Hinkka, Ville; Främling Kary & Tätilä, Jaakko:

“Supply chain tracking: aligning buyer and supplier incentives”,

Will be published in Industrial Management & Data Systems. Vol. 113, No 8. 2013.

LIST OF USED ABBREVIATIONS

CIMO	Context, intervention, mechanisms, outcome
DC	Distribution centre
ICT	Information and communication technology
IOIS	Inter-organisational information systems
LSP	Logistics service provider
RFID	Radio frequency identification
SCM	Supply chain management
TAM	Technology Acceptance Model

1 Introduction

1.1 Background and motivation

In order to work effectively, supply chain companies need to integrate their key business processes to aim for the same goal (Monczka and Morgan, 1997; Christopher, 1998; Lummus and Vokurka, 1999). In supply chain management (SCM) literature, the integration of key business processes is typically considered to lead to better supply chain performance (Cooper et al., 1997a; Pagell, 2004). A major part of this process integration can be achieved when the companies' information systems can communicate and use the same information and communication technology (ICT) solutions (Power, 2005; Prajogo and Olhager, 2012).

Rapid ICT development has enabled the realisation of effective item-level tracking systems, which could cover multiple echelons of the supply chain (Visich et al., 2009). Tracking offers material flow transparency, which can be used to better control the movements of materials in the supply chain by automating operations to make them more reliable and faster and by responding to the varying demands more effectively (Delen et al., 2007; Sarac et al., 2010). The adoption of the Radio Frequency Identification (RFID) technology for tracking purposes has proved to offer quantifiable benefits for SCM (Visich et al., 2009), and these benefits are bigger than using any other available tracking technologies (Johansson and Pålsson, 2009).

Even though the adoption of RFID tracking has been accentuated for more than a decade and the technology would offer companies the means by which to integrate their supply chains and thus improve the effectiveness of the supply chain operations, adoption of the technology has been relatively slow (Sarac et al, 2010; Thiesse et al., 2011). In addition, most of the current RFID tracking systems are designed for single companies, usually retailers, which overlook the biggest benefits of the technology for SCM by focusing on only one or a few companies or operations (Visich et al., 2009). Even if these focused RFID tracking solutions solve certain problems in logistics, they might be suboptimal solutions, which would increase the costs of SCM more than the capitalised savings obtained by solving that single problem (Kros et al., 2011). Therefore, the aim of building tracking systems is to cover the whole supply chain (Wyld, 2006; Zhou, 2009), which is in line with the idea of the utility of supply chain integration.

However, some recent studies challenge the positive relationship between supply chain integration and supply chain performance (Fabbe-Costes and Jahre, 2007), and propose that high supply chain integration will be positively related to performance only if supply complexity is high (Das et al., 2006; Germain et al., 2008; Gimenez et al., 2012). In this viewpoint, the aim of building supply chain-wide RFID tracking systems that could integrate the supply chains can be challenged to be too vague to be applicable in every kind of supply chain. Therefore, the resources needed for building supply chain-wide RFID tracking should be compared more carefully with the nature of the specific supply chain, which partially defines the possible benefits that improved tracking may offer. In addition, different supply chain actors' roles diverge in various supply chains, affecting which supply chain echelons gain

most of the increased integration, and which echelon has the biggest influence over other supply chain actors. For these reasons, the benefits of tracking varies for different supply chain actors, and consequently the aim of building supply chain-wide RFID tracking systems should be considered more critically.

1.2 Overall aim of this thesis and research questions

In general, current tracking literature focuses on building supply chain-wide RFID tracking systems, while in reality, companies tend to build tracking systems to cover only certain operations or companies in the supply chain (Wyld, 2006; Zhou, 2009). As building RFID tracking systems requires a considerable amount of resources and the benefits of the system vary depending on the nature of the supply chain and the company's position in that chain, the aim of building item-level supply chain-wide RFID tracking systems for every type of supply chain should be regarded more critically. Otherwise, tracking would only cover some echelons of the supply chain, at least in the first phase. Therefore, this thesis uses postponement–speculation strategy concepts (Bucklin, 1965; Pagh and Cooper, 1998) to compare alternative supply chain echelons to start tracking, and in that way determines the means to define the best possible coverage of the tracking system.

As the use of tracking technologies spreads, the cost profile of tracking implementation changes, while the implementation costs of the technology decreases as more indirect benefits of tracking become available (Bunduchi et al., 2011). Therefore, the threshold to adopt tracking decreases gradually, and the aim of building supply chain-wide tracking becomes more realistic in more and more supply chains. As some supply chain actors will gain more if tracking is applied (depending on their position in the supply chain and the nature of the chain), this thesis proposes three different mechanisms to adopt supply chain-wide RFID tracking. These mechanisms start by tracking initiatives of the companies in a certain supply chain echelon. Then, the mechanisms include the proposed guidelines to enlarge tracking to cover the other actors of the supply chain.

In summary, the aim of this thesis is to explore reasons for the scarcity of supply chain-wide tracking systems and propose solutions for supply chain actors to adopt common tracking systems. While this thesis is based on case studies using RFID technology for tracking, research questions are also noted to include RFID as the technology, which realises the tracking.

One issue in technology diffusion is whether the offered solutions are perceived as useful among the potential user companies (Davis, 1989). Therefore, it is necessary to understand the context in which the companies operate and determine which kinds of tracking needs companies currently have and especially in the near future. This knowledge of tracking enables the design of suitable tracking systems to support user companies' process development in their operational environments. This therefore leads to the first research question:

(1) What are the tracking needs of companies in changing operational environments?

As the recent SCM literature proposes that supply chain integration does not always improve the performance of the whole supply chain (Fabbe-Costes and

Jahre, 2007; Gimenez et al., 2012), the logical conclusion would be that supply chain-wide tracking which requires the integration of information systems of different supply chain actors does not always improve the effectiveness of the whole supply chain enough relative to the resources needed to realise integration. Therefore, the current tracking literature, which proposes supply chain-wide tracking as an aim for tracking system design, is challenged by the second research question:

(2) How do we define the most suitable tracking coverage for different kinds of supply chains?

Even if the second question challenges the justification of building RFID tracking systems, at least in certain premises, multi-organisational RFID tracking system implementation probably still remains a reasonable aim for different types of supply chains. However, the current literature lacks guidelines for achieving supply chain-wide RFID tracking. In addition, the answer for the second research question likely indicates that the supply chain-wide RFID tracking system is not a realistic goal, at least in early phases of the adoption, although it might be realistic as a long-term goal. Therefore, the tracking systems probably need to be built gradually, on a step-by-step basis. To discover how supply chain-wide RFID tracking systems could be achieved, the third research question arises:

(3) What types of mechanisms would enable the adoption of supply chain-wide RFID tracking systems?

1.3 Structure of the thesis

This doctoral thesis consists of separate publications and this summarizing compendium. The thesis proceeds as follows: After this introduction chapter, the second chapter works as theoretical background content as related to the topic of the thesis, and it is completed by presenting the shortcomings of the current literature. The third chapter presents the methodology for conducting the studies of this thesis. This chapter begins by presenting the research design, followed by an explanation of the data collection methods and finally proceeds to present how design propositions of design science (Denyer et al., 2008) are used to synthesize the results of this thesis. The fourth chapter addresses appended papers and their contribution to the thesis. The fifth chapter presents the results by using CIMO-logic (Denyer et al., 2008) as defined in the methodology chapter. The sixth chapter discusses the result, and finally, the seventh chapter concludes the thesis and presents the limitations and outlines for future research. The separate publications included in this thesis are located at the end.

The relationship between appended papers and the research questions is as follows: In general, Paper I responds to research question number 1, Paper II responds to research question number 2, and the remaining four papers offer three different mechanisms as solutions to research question number 3. However, in practice, each paper is larger in its entirety and therefore most contribute to other research questions besides the principal research question mentioned above. Figure 1 presents the relationship between the research questions (RQs) and the papers.

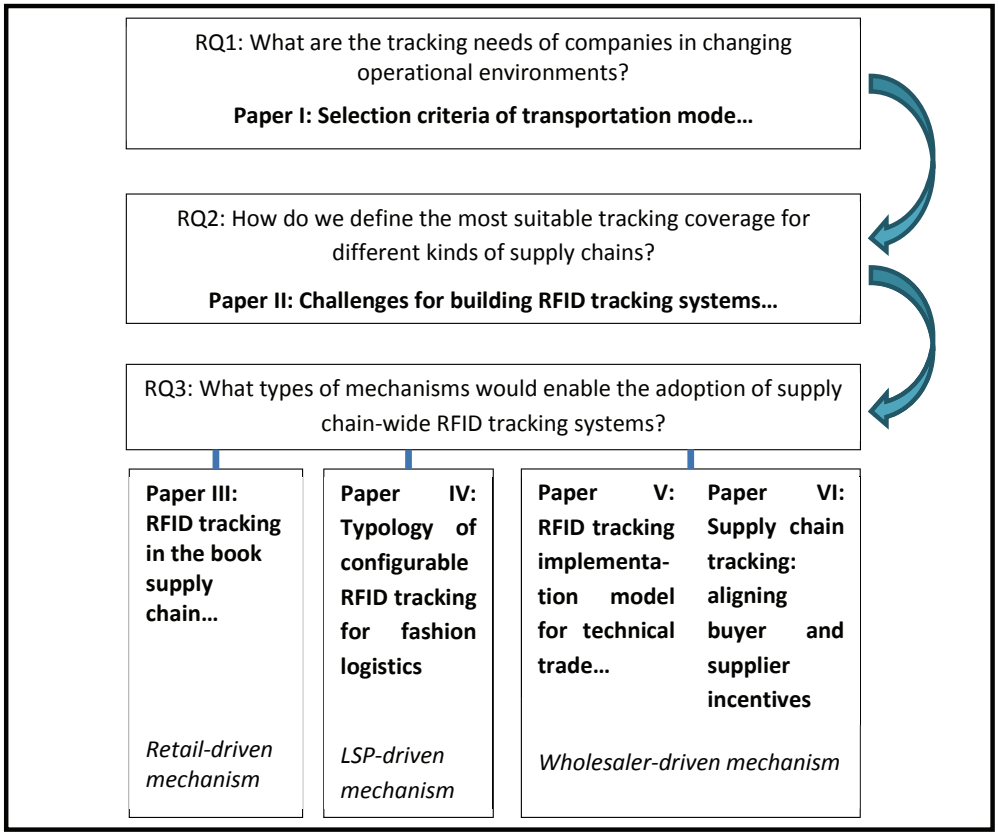

Figure 1. Appended papers and their relationships with research questions (RQs) of the thesis.

2 Theoretical background

Next, the relevant previous literature to this dissertation is presented. Section 2.1 describes how supply chain integration and especially integration of information systems is an essential part of supply chain management (SCM). Section 2.2 presents the adoption of ICT systems for SCM purposes. Then, section 2.3 presents an example of an inter-organisational information system solution – tracking. Later, section 2.4 discusses how widely used SCM concepts postponement and speculation could be used in tracking system design. The following section 2.5 presents how actors approach and technological frames is currently used in information systems and SCM research. Finally, section 2.6 concludes the Theoretical background chapter and presents shortcomings of the current literature.

2.1 Supply Chain Management (SCM) and integration

The role of logistics is to provide the boundary-spanning, demand and supply coordinating capabilities the firm needs to create customer value to satisfy customers (Mentzer et al., 2004). Logistics is an intrinsic part of a larger concept of supply chain management (SCM), which integrates all the key business processes across the supply chain (Cooper et al., 1997a; Lummus et al., 2001; Tan, 2001; Frankel et al., 2008). Supply chains consist of several autonomous organisations participating in input-output transformational processes around a good or a service, including material and information flows, and eventually leading to the delivery of an end-product or service to a customer or other end-user (Cooper et al., 1997b; Stock and Boyer, 2009). While the purpose of logistics management is to create customer value from the viewpoint of a single firm, the perspective in SCM is the whole supply chain. Therefore, SCM is based on the collaboration between supply chain members and the notion of competition between supply chains, not supply chain members (Monczka and Morgan, 1997; Christopher, 1998; Lummus and Vokurka, 1999).

Supply chain collaboration can be classified by several levels between dyadic relationships, in which the supply chain companies focus on the other supply chain actors where they have immediate contact, to an almost vertical integration of the companies in the supply chain (Cooper et al., 1997b; Kampstra et al., 2006; Daugherty, 2011). In general, supply chain collaboration can result in significant benefits to an organisation (McLaren et al., 2002). If the supply chain has a dominating organisation that sees the benefits of supply chain collaboration and forces the rest of the supply chain to comply, this supply chain dynamic simplifies the coordination of supply chain activities (Arshinder et al., 2008).

The definition of the concept “supply chain management” includes integration of the key processes (Cooper et al., 1997a), and the theory behind integration states that increased integration leads to higher performance (Pagell, 2004), even if some authors require more justification for this statement (Fabbe-Costes and Jahre, 2007). The literature also points out that a broad span of integration offers better performance for companies than a narrow span integration with direct upstream or downstream companies (Kannan and Tan, 2010). However, recent studies indicate that high supply chain integration will be positively related to performance only if supply complexity is high (Das et al., 2006;

Germain et al., 2008; Gimenez et al., 2012). Therefore, supply chain integration should not be considered as a self-purposeful aim for all supply chains, even if SCM in general strives for more integral collaboration. Gimenez et al. (2012) proposes that integration is most beneficial with those customers that (1) demand high variety in products, (2) require make-to-order production in small batches, or (3) have high expectations with regard to flexibility and quality.

Supply chains are separated in two distinct substructures: (1) physical, which deals with the flow and storage of goods; and (2) information, which deals with information associated with those goods (Power, 2005; Prajogo and Olhager, 2012). The rapid development of ICT systems has enabled companies to develop new techniques to improve information-related supply chain integration by advancing inter-organisational information systems (IOIS) and related applications such as e-business technologies (Sanders, 2007; Rajaguru and Matanda, 2009). Therefore, IOIS have become an essential tool to achieve supply chain integration.

2.2 Adoption of ICT systems in SCM

The aim for use of information technology in SCM is to enhance the service level, improve operational efficiency and information quality, and enable agile supply chain operating models (Auramo et al., 2005). In practice, ICT is expected to influence the following supply chain performance measures: (1) Cost, (2) Delivery, (3) Quality, (4) Flexibility, (5) Inventory, (6) Process improvement, (7) Innovation, and (8) Sales and financial (Zhang et al., 2011). However, building IOIS systems alone does not improve the efficiency or reduce the transaction costs of the supply chain (Müller and Seuring, 2007). ICT integration alone cannot act as a substitute for other efforts at supply chain integration (Pagell, 2004; Gunasekaran and Ngai, 2004).

Several factors affect organisations' willingness to implement new technology and how ICT applications diffuse. Davis (1989) created the well-known Technology Acceptance Model (TAM) for new technology implementation. According to two approaches of TAM, the new technology needs to be considered useful, and its implementation and use cannot be too difficult. However, some authors (e.g., Hossain and Quaddus, 2011) argue that individual level ICT adoption and implementation models, such as TAM, are not applicable on the organisational level. Shin and Edington (2007) raise seven contextual factor categories which affect IT implementation: (1) Path dependencies, which include, for example, the form of current systems and the experiences of previous implementation of systems; (2) Project management, which includes managing expectations, dedicated resources, communications and end-user participation; (3) Organisational management structure, which includes the role of the CEO (chief executive officer), the commitment level and corporate project leader; (4) IT competency, which includes the CIO's (chief information officer) competency, the firm's past IT experience, the business line managers' IT competencies and the project team's IT skills; (5) Techno-political culture, which includes the political environment, social order, interdepartmental cooperation and mutual understanding; (6) Complementary investments, which includes change management, business process and work flow redesign, and training; and (7) End user, which includes satisfaction, willingness to change and stakeholders (Shin and Edington, 2007).

Venkatraman (1994) suggests five different levels to explain how IT transforms an organisation's business in ascending order of importance: (1) Localized Exploitation, (2) Internal Integration, (3) Business Process Redesign, (4) Business Network Redesign, and (5) Business Scope Redefinition. In this classification, the higher the transformation level and the effect of IT on operations, the larger the potential benefits (Venkatraman, 1994). Similar classification is presented by Vijngaert et al. (2008) in a form of the Business/IT-alignment framework for logistics. Their framework is a representation of five maturity phases of the firm in the logistics domain: 1) Pre-supply chain, 2) Functional orientation, 3) Internally integrated, 4) Externally integrated, and 5) Value chain integrated (Vijngaert et al., 2008).

Several articles that discuss ICT solutions in SCM conclude that at least business process redesign is needed to get enough benefits to justify new technology implementation (e.g., Auramo et al., 2005; Lee et al., 2011). Also, if the companies are able to integrate their information systems successfully, their operational performance will increase (Rajaguru and Matanda, 2009), while only congruent ICT systems between supply chain actors do not maximize supply chain profits (Rajaguru and Matanda, 2013). Therefore, high-level integration, which includes the exchange of relevant real-time information about processes between companies, offers the biggest benefits of ICT system usage.

However, there are certain problems in the adoption of IOIS. The SCM literature clearly highlights that the whole supply chain should be seen as a single entity. In most cases, supply chain integration increases performance of the supply chain, and therefore, integration of information flows by using IOIS increases the competiveness of the whole supply chain. However, each company decides whether it will join IOIS, as diverse or dissimilar companies may see the objectives of IOIS differently. For example, Samaddar et al. (2006) propose that downstream companies are more likely to engage in strategic IOIS, while upstream companies are more likely to engage in operational IOIS. A big share of the ICT literature in the field of SCM considers internal integration (Pagell, 2004; Barki and Pinsonneault, 2005), which indicates that ICT implementation raises challenges even within one organisation. Companies also tend to see ICT adoption in their own perspectives, which can be different from other supply chain partners' perspectives or what is the best solution for the whole supply chain (Rajaguru and Matanda, 2013). Still, those companies that first build positive relationships with other supply chain companies and show commitment to each other and then adopt new ICT technology will gain more benefits of that technology (Hazen and Byrd, 2012; Rampersad et al., 2012). However, supply chain integration by adopting IOIS may also change the dynamics of the supply chain, which may decrease some supply chain actors' intentions to implement IOIS (Huang et al., 2002; Boonstra and de Vries, 2008).

When companies are considering IOIS adoption, they compare the benefits and disadvantages of the adoption. Different authors have described different factors under consideration in this situation. TAM compares the usefulness of the technology with the ease of implementation (Davis, 1989). Richey et al. (2009) see this situation as a choice between internal and external drivers, such as a desire to improve, and environmental pressures with barriers such as internal planning failure and external monitoring failure. In the last resort, the

question is about the price of the IOIS adoption versus expected redeemable benefits of the system.

2.3 Tracking and RFID technology

Tracking is one IOIS solution, which helps integrate the supply chain (Kärkkäinen et al., 2003; Wamba, 2012). Tracking systems, in general, send a message to the tracking database when a tracked item arrives at a predefined checkpoint in the distribution network. The literature has identified four main reasons for conducting tracking and building tracking systems: 1) The real-time coordination of material flows and individually tracked items, such as merge-in-transit; 2) the generation of exception notices based on tracking information; 3) the use of tracking in increasing the efficiency of administrative processes such as improved inventory count and goods receipt transactions; 4) the use of tracking information in developing and improving logistics management metrics and analyses (Stefansson and Tilanus, 2001, Ala-Risku et al., 2003, Kärkkäinen and Holmström, 2002; Kärkkäinen et al., 2004). In the SCM perspective, the clear potential that tracking brings is the visibility between supply chain actors and operations, which enables operations to spread in wider geographical areas and increases the number of organisations involved in operations. It also helps to react to changes in demand, thus avoiding the bullwhip effect and improving the responsiveness of the supply chain (Holmström and Främling, 2005; Lehtonen et al., 2005, Moon and Ngai, 2008; Bottani et al., 2010; Sarac et al., 2010; Zhu et al., 2012).

A tracking system consists of three primary components – identifiers, readers and tracking databases (Van Dorp, 2001). Currently, the two most common technologies used in tracking are barcode and Radio Frequency Identification (RFID). A barcode is an optical machine-readable representation of data relating to the object to which it is attached. RFID is the use of a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object. RFID technology has the following two advantages over barcode: (1) RFID does not require a line of sight to be read, and therefore dirt, ice or dust on an RFID tag does not prohibit or make reading difficult; and (2) it is possible to read multiple RFID tags simultaneously, while barcodes need to be read individually (Wyld, 2006; Rundh, 2008). In addition, the RFID literature frequently mentions two additional benefits for RFID tracking: an RFID tag can hold a greater amount of information than a barcode, and the electronic information of an RFID tag can be overwritten (e.g. Wyld, 2006). However, these latter two benefits are questionable, because it is possible to increase the amount of information in barcodes by extending barcodes or using 2-D barcodes. Also, in typical SCM applications there is no need to rewrite RFID tags, because in tracking systems, it is more useful to keep the identifier the same and change the content related to that identifier in the database (Thiesse and Michahelles, 2006). Besides, the price of a basic, individual tag is so cheap that re-using it is not economically sensible. Still, the first two mentioned benefits are so fundamental that the use of RFID technology improves the logistics performance of the company more than other automatic identification technologies, particularly when the barcode is used (Johansson and Pålsson, 2009).

Based on the advantages of RFID over other technologies, the literature proposes multiple benefits for using RFID for tracking purposes. Mehrjerdi (2011) presents the most comprehensive list, proposing 79 different possible

benefits of RFID technology. However, the obtainable benefits of RFID tracking depend on the usage level of the technology: on the lower usage level, RFID tracking can automate numerous individual operational processes, for example, by decreasing costs and increasing speed and quality, but RFID tracking can also be used on the higher level by improving managerial processes, for example, by using tracking data for management decisions concerning the whole supply chain (Visich et al., 2009).

To classify different usage levels of RFID tracking, Wamba and Chatfield (2009) developed the idea of Venkatraman's (1994) "How IT transforms organization's business" to be applicable in RFID tracking solutions. They created a four-level contingency model for effective RFID tracking integration across a supply chain: (1) *Slap & Ship*, where the supplier attaches RFID tags to shipments to a focal company, which uses these tags in its own operations, especially in receiving, but the supplier does not get any value out of these tags in its operations; (2) *Intra-organisational*, where RFID infrastructure is integrated as a part of a company's intra-organisational information systems, and RFID tracking is used in several intra-company operations to improve operations or even enable the transformation of business processes inside the company; (3) *Inter-organisational*, where inter-organisational electronic integration through RFID technology is achieved typically in a dyadic buyer-supplier or logistics service provider – focal firm relationship and where RFID tracking is used to improve internal and intra-company processes; and (4) *Network-organisational*, where RFID tracking is integrated as part of larger supply network's IOIS with common standards, and where RFID tracking has been used to transform the whole supply network's business processes. According to their model, a higher integration level requires bigger investments, but respectively offers higher benefits. However, even if the need for higher-level integration in RFID tracking implementation is recognized, only a few organisations and supply chains that implement RFID tracking have reached those higher levels (Chuang and Shaw, 2007; Visich et al., 2009; Wamba and Chatfield, 2009). To fully obtain the benefits of RFID tracking in SCM, the replacement of old technologies such as barcodes is not enough – the processes should be re-designed to optimise the effective use of RFID technology (Kamoun, 2008; Sarac et al., 2010).

Hellström (2009) proposes a six-stage model for the RFID implementation process based on a model of the IT implementation process by Cooper and Zmud (1990) and on the grounded data from IKEA and Arla Foods' actual RFID trials and implementation experiences of tracking returnable transport items:

(1) In the Initiation phase, the problem is identified and the objective is defined. Based on the identified problem, different concepts to solve the problem are developed, and different system designs are planned.
(2) In Adoption, a cost-benefits analysis is made to define and compare benefits and costs, and an RFID trial is executed to test and verify technology performance.
(3) In the Adaptation phase, a system integrator is selected, and technology is modified and installed.
(4) In the Acceptance phase, employees and other users are educated and trained in the system, and all involved organisations are informed about the use and implications of the system.

(5) In the Routinisation phase, improvements are made based on users' experiences, and the system is gradually used in improving decision-making with the help of the collected and processed tracking data.
(6) During Infusion, implementation is expanded to cover other applications that had previously been too expensive for tracking implementation.

RFID tracking is implemented for many different purposes and identification levels to improve SCM (Holmström et al., 2009a). The best-known RFID implementation was initiated by U.S.-based retailer Wal-Mart. In January 2003, Wal-Mart mandated its top 100 suppliers to attach RFID tags to all pallets and parcels until January 2005. In 2005, the mandate involved more than 600 Wal-Mart suppliers. By using a mandate, Wal-Mart utilized its market power over suppliers to accelerate the adoption of RFID technology in the company's supply network by forcing the suppliers to attach RFID tags to the shipments directed to Wal-Mart. Wal-Mart's initial aim was that the whole supply network would benefit from tracking. Still, in January 2005, the top 100 suppliers attached RFID tags only for shipments to Wal-Mart, and only because they were obliged to do so. Very few suppliers even considered system integration with Wal-Mart's RFID tracking or saw major benefits of tracking for their operations. Wal-Mart also started to use pallet-level tagging and then moved to parcel-level tagging, but the initial aim of item-level tracking has not yet been realised. (Vijayaraman and Osyk, 2006; Yang et al., 2008; Fries et al., 2010; Keating et al., 2010).

The biggest item-level RFID tracking implementations are initiated by retailer companies, such as the grocery, apparel and book industries (Kroon et al., 2007; Soon and Gutiérrez, 2008; Napolitano, 2012). The largest existing item-level RFID tracking solutions are in the apparel and fashion industry, and currently, the largest is Mark & Spencer (M&S). M&S started a large-scale roll-out after a successful trial of the use of RFID tracking in selected stores in 2006 (Hadfield, 2007). Later, the RFID tracking solution was scaled up to cover 150 factories, 120 stores, and 13 clothing departments in 20 countries. Annually, M&S purchases approximately 100 to 150 million RFID tags for its suppliers to tag clothes to be delivered to M&S. (RFID Journal, 2008; Roberti, 2010). Wal-Mart also decided to focus more in the apparel industry by announcing in 2010 its new start with RFID tracking, and at this time Wal-Mart promised to take a cooperative approach with its suppliers regarding certain types of garments and aimed to adopt item-level RFID tagging directly, which would made this implementation become the largest existing item-level RFID application in the world (Roberti, 2010).

2.4 Postponement and speculation in SCM

SCM aims to create value for a customer by reducing uncertainty and the cost of delivering the product or service while at the same time satisfying customer needs as well as possible (Heikkilä, 2002; Kopczak and Johnson, 2003). One organisational concept to consider the effectiveness of the supply chain is postponement (Bucklin, 1965; van Hoek, 2001; Yang et al., 2004a; Yang et al., 2004b; Boone et al., 2007). In postponement, the idea is to delay, or "postpone" actions that would, for example, differentiate the product from generic types during supply chain operations. The logic behind postponement is that risk and uncertainty costs are tied to the differentiation (form, place and time) of goods that occurs during manufacturing and other supply chain operations (Pagh and

Cooper, 1998). Yang et al. (2004a) divide postponement as purchasing postponement, product development postponement, logistics postponement, and production postponement. Currently, the majority of the articles based on postponement approach are written on a company level (Yeung et al., 2007), but the concept also applies at the supply chain level.

The opposite concept of postponement is speculation (Bucklin, 1965). Speculation enables to gain economies of scale in manufacturing and logistics operations, and limits the number of stock outs (Pagh and Cooper, 1998). Pagh and Cooper's (1998) article presents four different SCM strategies in a 2x2 matrix: 1) The full speculation, 2) The logistics postponement, 3) The manufacturing postponement, and 4) The full postponement. Since the Pagh and Cooper article (1998), postponement literature has rarely considered speculation as an eligible SCM strategy or even mentioned the term. Therefore, it seems that the current postponement literature aims to research the use and possibilities for postponement, but to not discuss when the speculation could be considered as an SCM strategy or reachable aim.

The echelon of RFID tagging in the supply chain can be viewed through postponement–speculation concepts. In this context, speculative RFID tagging would mean that an RFID tag would be attached at the earliest possible time – for example, when the product or its key component is manufactured or assembled, in order to reduce the handling and control costs in the later echelons of the supply chain, and to gain economies of scale in tagging. In this context, speculative tagging would also mean that all tagging would be done before the supply chain actors know how large a share – if any – of the tagged products will end up in those parts of the downstream supply chain, which would be able to use and gain benefits from these tags. Therefore, postponed tagging would mean that only those products known to end up with RFID-using customers would be tagged to restrict the amount of money spent for RFID tags.

2.5 The use of the actors approach and technological frames in SCM and IOIS research

Arbnor and Bjerke (2009) formulated a theory of methods in their framework which includes three approaches to business studies: 1) The analytical approach, which is based on an assumption that there is an objective reality in which patterns and causal relations can be investigated and disclosed through research; 2) The systems approach, which is based on an assumption that the world needs to be understood in terms of mutually dependent "components", as a system with parts, links, goals and feedback mechanisms; and 3) The actors approach, which is completely different approach based on sociological meta-theories, where reality is seen as a construction, and knowledge creation depends on the researcher's interpretation of various social constructions. Their framework is based on the premise that the choice of the research methods should not only be influenced by the research question, but also by the researcher's view of reality (Arbnor and Bjerke, 2009).

Gammelgaard (2004) uses the framework of Arbnor and Bjerke (1997, 2009) by analysing the use of different methodological approaches in logistics literature. She states that the analytical approach is predominant, while almost all other articles in the field of logistics use the system approach. The difference between these two approaches is that while analytical approach seeks general, time and value-free explanations in SCM, the systems approach seeks to show concrete

systems as maps and models, because in this approach, logistics is considered to be too complex for deriving causal-effect relations (Gammelgaard, 2004). The actors approach instead seeks to show that terms such as SCM must be understood and implemented differently in different organisations, according to their individual context (Gammelgaard, 2004). Gammelgaard (2004) concludes her article by proposing that logistics research should adopt the actors approach, because humans govern the logistics systems and will exert an influence on the practice of the systems, and the actors approach will enable researchers to gain insight into the actual logistics management processes, providing a more accurate image of the nature of logistics and SCM.

In information systems and IOIS adoption literature, there are more examples about using the actor approach than in SCM literature. The majority of these articles are based on the actor-network theory (Callon, 1986; Latour, 1987), such as an article about IOIS implementation in the seaport of Barcelona, Spain, by Rodon et al. (2008), and the telecommunication network construction project in rural areas of Peru by Andrade and Urquhart (2010). Actor-network theory is based on an idea of identifying all the appropriate actors, whether they are e.g., humans, organisations or animals, aligning their interests with those of focal actor, and forwarding them through four translation steps to attain the objectives of each actor (Callon, 1986).

Gammelgaard (2004) did not find any exemplary cases of the actors approach in logistics research, but recently Mirzabeiki et al. (2012) used the actors approach to consider the various viewpoints and interests of different supply chain actors – rail-track owners, rail operators and LSP (logistics service provider) companies – towards design and implementation of rail-wagon tracking. Mirzabeiki et al. (2012) use technological frames by Orlikowski and Gash (1994) to align the organisational interest of different supply chain actors. Orlikowski and Gash (1994) use the term *technological frames* "to identify that subset of actors' organizational frames that concern the assumptions, expectations, and knowledge they use to understand technology in organizations". They amplify this by stating that "this includes not only the nature and the role of the technology itself, but the specific conditions, applications, and consequences of that technology in particular products" (Orlikowski and Gash, 1994). Orlikowski and Gash (1994) found three domains that characterize the interpretations that the participants made about the new technology: 1) Nature of Technology, 2) Technology Strategy, and 3) Technology in Use.

Technological frames have been used in various studies in published information systems literature to interpret processes related to IT adoption in organisations. Davidson (2006) found the following three frame domains to be widely applicable: 1) Frames related to information technology features and attributes, 2) Frames related to the organisational applications of IT, and 3) Frames related to incorporating IT into work practices. The frames evolve during the process as different actors get new information, or their representatives may change while actors discuss each other (Davidson, 2002; Ovaska et al., 2005; Davidson, 2006).

Usually, technological frames are used to frame different perspectives inside certain organisations (Davidson, 2006), but the frames have also been used to analyse several different geographically dispersed units inside a global organisation (Yoshioka et al., 2002) and also to analyse stakeholders from

different organisations (Barrett, 1999). Even if the article of Mirzabeiki et al. (2012) was the only article found where technological frames were used to consider various viewpoints of different supply chain actors, there is no reason to ignore the use of technological frames in the SCM context, because the supply chain can be seen as a single entity, such as large, dispersed organisation, and different supply chain actor organisations as different actor groups inside large organisations.

2.6 Conclusions of the theoretical background

The field of IOIS includes many different applications, and the barriers of adoption may differ depending on the application. This thesis focuses on supply chain-wide tracking solutions, which works as a case IOIS application. As RFID is currently the most effective technology to execute tracking, this thesis focuses on tracking applications based on this technology, although most of the handled issues are not dependent of the technology in use.

Effective tracking enables better SCM by offering possibilities to improve responsiveness and increase the operational performance of the whole supply chain. Supply chain-wide tracking requires collaboration between supply chain actors (Spekman and Sweeney, 2006), but also advanced and integrated information systems between organisations in order to share tracking information to gain the benefits of improved tracking (Johansson and Pålsson, 2009; Thiesse et al., 2011). The use of RFID technology for tracking purposes has increased in the past decade, but it is still mainly used in closed-loop operations in manufacturing, in streamlining processes in distribution centres, and in retailing (Attaran, 2007; Ngai et al., 2008; Sarac et al., 2010). Even if most of the current RFID tracking systems in use are designed to improve certain supply chain actor's operations or specific tasks, the aim of the RFID tracking system research has been to create an open standardised system, which could benefit the whole supply chain as most of the current barcode systems do today (Wyld, 2006; Zhou, 2009). However, even if RFID tracking is widely in use today, the number of supply chain-wide RFID tracking systems that are integrated in a higher level of companies' operations remains limited.

The aim of building supply chain-wide tracking networks that are integral part of the companies' operations is in line with the central theories behind SCM and supply chain integration (Cooper et al., 1997; Pagell, 2004). In this respect, most of the current RFID tracking solutions that only increase the performance of one supply chain actor and overlook the possibilities to enlarge the tracking system to use same tags by other supply chain actors with few extra costs are wasteful. However, as some authors point out that supply chain integration does not always improve the performance of the supply chain (Fabbe-Costes and Jahre, 2007), and certain types of supply chains will benefit supply chain integration more than the other (Das et al., 2006; Germain et al., 2008; Gimenez et al., 2012), either implementation of supply chain-wide tracking, which fully integrates the key processes of different supply chain actors, might not always be considered as a reachable aim. Instead, the costs and efforts needed to build tracking should be compared with possible benefits, and based on that evaluation, the coverage of tracking should be defined.

Current literature about tracking system adoption mainly considers RFID adoption and related challenges from the perspective of a certain company. Larger attempts for RFID tracking system implementation are usually regarded

by evaluating the pros and cons of Wal-Mart's mandate in adoption. Therefore, SCM literature considers multi-company RFID tracking adoption from the viewpoint of a dominant, large retailer, and proposes explanation as to why some big retailers who plan to adopt RFID tracking have managed, either better or worse, to attract suppliers to adopt RFID tracking. However, this viewpoint neglects two issues: First, as Strüker and Gille (2010) assert, RFID tracking adoption literature diminishes the role of small- and medium-sized companies (SMEs) in RFID tracking adoption. According to their study, which does suffer from a small sample size, SMEs usually decide to adopt RFID tracking more easily than bigger companies, implement the technology faster, and implement RFID tracking more integrally as a part of the company's information systems (Strüker and Gille, 2010). Second, supply chains are different, and most probably the structure of the supply chain should be considered more as based on that consideration, and RFID tracking mechanisms other than retail-based mechanisms could be proposed for certain kinds of supply chains.

Some articles regarding RFID tracking adoption focus on the effects of RFID tracking to individual supply chain actors based on their position in the supply chain (manufacturer, wholesaler, LSP, retailer, etc.) and what kinds of costs and benefits fall upon this specific supply chain echelon (e.g., Hou and Huang, 2006; Veeramani et al., 2008; Bottani et al., 2010). Despite analysing the characteristics of specific supply chain actors, the approach in these articles is not actor-based in a sense that is understood in actor approach (Arbnor and Bjerke, 2009). Instead, in these articles, the viewpoint is to consider the whole supply chain as a single entity and different supply chain actors as just echelons where benefits may be realised or costs need to be targeted because certain operations just belong closely to specific supply chain actors. For example, every distribution centre has shipment receiving and dispatching processes, while in the actors approach, it is argued that it is impossible to make predictions merely based on external cause-effect relations of social reality due to human beings' intentionality (Gammelgaard, 2004). Therefore, in RFID tracking context, the actors approach does not allow for conducting research by considering different supply chain actors as pawns when trying to find optimal RFID tracking solutions for the whole supply chain. Instead, every supply chain actor makes its own choice based on its own understanding about its operating environment and what seems to be the most beneficial alternative. However, this kind of approach is rarely used in SCM literature and is absent in RFID tracking adoption literature.

In summary, the literature about RFID tracking adoption seems to lack a road map for supply chain-wide RFID adoption. There are articles about RFID tracking implementation phases, such as paper about Hellström's (2009) model for an RFID implementation process, but these models are designed for one company. Many of the experiences of implementing supply chain-wide RFID tracking implementation in practice are discouraging. For example, Wal-Mart's first initiative in 2003 has mainly remained pallet- or parcel-level tagging, where the suppliers use Slap & Ship strategy, while the aim was to move forward to item-level tagging and integrate RFID tracking as a part of the company's information systems within a few years after launching the implementation project (Veeramani et al., 2008; Fries et al., 2010; Keating et al., 2010; Roberti, 2010). Despite its potential to offer an accurate image of the nature of logistics and SCM, the actors approach (Arbnor and Bjerke, 2009) is seldom used in SCM literature (Gammelgaard, 2004). Therefore, the research, where every

supply chain member is considered an individual actor who makes decisions based on its own view of the operations environment, may offer explanations regarding why supply chain-wide RFID tracking systems are not widely in use and which kind of mechanisms would enable the adoption. To consider these viewpoints among different supply chain actors, technological frames (Orlikowski and Gash, 1994), which are used widely in information systems literature, may work as a framework to understand and align these different viewpoints.

3 Research design, methods and data

This thesis is a compilation dissertation consisting of six papers.

The first paper presents the logistics and transportation needs of Finnish companies from four industrial sectors. This paper presents the ongoing changes in the companies' operations environments and what kinds of effects these changes have on the logistics operations of the companies, and further, how improvements in tracking could contribute to these changes.

The second paper is a literature review regarding challenges for supply chain-wide RFID tracking adoption combined with an analysis of the experiences of five case studies conducted by the doctoral researcher. This paper shows the comparison of the benefits of tracking with reported challenges, which enables the researcher to estimate which kinds of trade-offs are needed when defining the realizable tracking coverage for supply chains.

The two following papers each and the last two papers together present a result of one in-depth case study about building supply chain-wide RFID tracking systems aiming at decreasing the barriers to adopt supply chain-wide tracking. Paper III presents how upstream tagging in the manufacturing phase of the product is an economically justified alternative with a rather small share of customers who are able to use RFID tracking in their operations. Paper IV proposes an alternative solution for RFID tracking adoption by presenting how a logistics service provider (LSP) can offer supply chain-wide tracking as a solution for its retailer customers. Finally, Paper V and Paper VI propose a model for RFID tracking adoption for specific supply chains, where retailers are missing or have minor role, and which therefore requires an alternative tracking adoption viewpoint than that presented in Paper III and Paper IV.

3.1 Research design

3.1.1 Design science approach

The research approach applied in the empirical case studies was design science (Simon, 1997; Denyer et al., 2008; Holmström et al., 2009b). Design science is selected as a research approach for this thesis, because it is known as actor perspective and solution orientation (Van Aken and Romme, 2009). According to Holmström et al. (2009b), design science methodology can be divided into four phases: 1) The problem is framed and the basis for potential solutions is developed. 2) The basic solution design is subjected to empirical testing in an iterative, trial-and-error error-type process where the solution is refined by improving, implementing and evaluating design. 3) The solution is examined and evaluated from a theoretical point of view, and theoretical justification and a demonstration of theoretical utility are sought by introducing the solution in several contexts. 4) The researchers seek broader generalisations with applicability beyond the limitations of the empirical context of the study. (Holmström et al., 2009b). Gregor and Jones (2007) name the new theory developed by using design science methodology as *design theory*.

In general, design science can be seen as developing a means to an end. Therefore, to answer the research questions, the doctoral researcher conducted several case studies which all aimed to explore the possibility of implementing

RFID tracking in the case supply chain or network. Previous literature, when compressed in a nutshell, led to these findings: 1) There is proof that RFID tracking is applicable and beneficial in numerous single operations in the supply chain (e.g. Holmström et al., 2009a; Visich et al., 2009), 2) the number and magnitude of benefits will multiply, and the higher-level benefits are possible to obtain if several supply chain actors join the same tracking system and the tracking data is shared between supply chain actors (Chuang and Shaw, 2007; Fosso Wamba and Chatfield, 2009; Johansson and Pålsson, 2009; Visich et al., 2009), and 3) different supply chain actors would consider the usefulness of the adoption of RFID tracking differently, mainly based on their positions in the supply chain (Vijayaraman and Osyk, 2006; Fries et al., 2010). The purpose of the case studies was to determine "How to implement supply chain-wide RFID tracking," while the desired outcome, "The supply chain would have common RFID tracking systems", was already set. During the case studies, the doctoral researcher, together with other researchers involved in the case studies, examined different opportunities to realise the means of combining the researchers' existing knowledge of the domain with the analysis of the characteristics of the particular supply chain given by the experts from the companies acting in the industry. Eventually, discussions with managers, developers and company workers, multi-company workshops, practical tests of RFID technology, and a comparison of existing literature enabled the researchers of the case studies to form the most appropriate RFID tracking solution for the network of the companies in the cases study. Later, the doctoral researcher considered this solution in the context of different theories in SCM, tracking and technology adoption, which enabled the theory building in the form of Papers III, IV, V and VI.

Even if the current concepts and forms of conducting design science research are rather new, similar research has been conducted for a longer time under many different rubrics, such as action science, action research, action innovation research, participatory action research, participatory cases study, academe-industry partnerships, and the like (Holmström et al., 2009b). For example, Kärkkäinen et al. (2004) has performed similar research with the case study approach similar to this thesis when studying the use of tracking in multi-company networks. They designed their research process by using the phases of "innovation action research" (Kaplan, 1998) and "constructive approach" (Kasanen et al., 1993; Oyegoke, 2011) as the foundation of their research design.

The idea in design science can be concluded as expressing that the researchers take an active role in designing the solution – or artifact – which is subject to empirical evaluation and theory building afterwards (Holmström et al., 2009b). By using design science methodology, the researchers involved in the empirical case studies managed to decrease the gap between managerial relevance and theoretical contributions in the problem-solving process by preceding the phases of the design science. In the first phase, the researchers of the case study presented usable RFID tracking alternatives for managers of the companies in the case study. In the second phase, the researchers asked for the managers' views of the applicability of the solution, and based on these views, they then improved the solution to take better into consideration the companies' needs, but also considered the transferability of the solution by distinguishing the factors particular to that specific supply between the factors that could also be applicable for other supply chains. In the third phase, the doctoral researcher, with help of other researchers of the case study, analysed these solutions

through different SCM, tracking and innovation adoption theories, and wrote papers in which the proposed solution is linked with existing theories. The review processes and multiple iterations of Papers III, IV, V and VI helped the doctoral researcher find the proper theoretical framework for those solutions. The fourth phase of design science remains beyond the scope of this thesis.

3.1.2 Case study research

A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not evident (Yin, 1994). The suitable number of cases in case study research is continuously under discussion when the value of the results is evaluated. In other words, the fewer the number of cases, the greater the opportunity for depth of observation, but multiple cases can augment external validity and help guard against observer bias, offering more likely possibilities to create more robust and testable theories than single-case study research (Voss et al., 2002; Barratt et al., 2011). Yin (1994) suggested single-case study research in a situation in which there are opportunities for unusual research access. Eisenhardt and Graebner (2007) also note that if the purpose of the case study is to develop theory, not to test it, researchers can select the most suitable cases for the study and not worry whether the cases should be representative of some population. Qualitative case study research is claimed to be useful especially in complex and practice-oriented fields such as operations management and logistics, because well-conducted qualitative research offers better information to understand the causes behind the results than traditional quantitative research methods (Meredith, 1998).

This thesis is based on six case studies which all handle supply chain-wide RFID tracking system adoption. The unit of analysis in all the case studies is the companies' supply networks.

At first, the doctoral researcher was involved in three smaller case studies, where the purpose was to research the opportunities to adopt RFID tracking in certain supply networks. These smaller three case studies were conducted in cooperation with one or two organisations in the supply network, and two of these case studies also included pilot installations. These case studies are named "Grocery", "Roll Cage Tracking", and "Hospital Equipment".

After these three smaller case studies, the doctoral researcher was involved in three larger, in-depth exploratory single-case studies, which consisted of companies in all the echelons of the supply chain: manufacturers, wholesalers or distribution centres, and retailers. When these three in-depth case studies consisted of networks of five to 16 major companies in a certain industry and there was unusual access to companies' data, the settings for all these in-depth case studies' research seem to resemble conditions where Yin (1994) suggested using single-case study methodology. These in-depth single-case studies are named "Book Retailing", "Clothes" and "Technical 'Trade". Paper III is based on Book Retailing, Paper IV is on Clothes, and Papers V and VI are based on Technical Trade case study.

For multiple case study research, Eisenhardt (1989) proposes that the suitable number of cases should range from four to 10. In Paper II, where the cases are handled on a more general level than in single in-depth case study-based Papers III, IV, V and VI, the number of analysed cases is five. The combination of the results obtained by conducting three in-depth case studies and three other case

studies offered the possibility to use multiple case study methodology to reach a wider understanding about how different supply chain actors consider tracking adoption in different circumstances. These findings were analysed and synthesized to propose justified answers for the research questions of this thesis.

Case studies can be either qualitative, quantitative or both (Eisenhardt, 1989; Yin, 1994), even if case studies are typically considered to be qualitative (Näslund, 2002). Case study research is not mainstream – it is seldom used in operations management or logistics research (Barratt et al., 2011; Pedrosa et al., 2012). Even if many more published articles in the fields of operations and supply chain management are based on qualitative case studies, the share of articles based on case study has remained small – less than 10% – among the articles published in top operations management journals (Craighead et al., 2007; Barratt et al., 2011).

Although the objective of SCM is to integrate all the firms in the value chain and treat them as a single entity, SCM research often fails to consider that perspective of SCM (Sachan and Datta, 2005; Giunipero et al., 2008). In this thesis, the main empirical research material was obtained from more than 30 companies or similar organisations. The research was divided into six case studies, and three were handled more profoundly in the form of in-depth case studies. All these in-depth case studies were composed by five to 16 companies creating supply networks in certain industries. Therefore, the development efforts in those three supply networks offered unusual material for the research, which enabled the researchers to choose the qualitative case studies as the primary research methodology for this thesis.

3.2 Data collection methods

The data collection methods used in the case studies of this thesis were literature surveys and mixed methods research (Johnson et al, 2007). In mixed methods research, a researcher or team of researchers integrates qualitative and quantitative research approaches within a single study or a set of closely related studies (Johnson et al, 2007; Creswell, 2009; Bryman and Bell, 2011). The main qualitative methods used were observation of the processes, interviews and workshops, while quantitative methods were mainly used to employ and analyse the data obtained in qualitative sources or complement the data obtained in interviews. The use of mixed methods is encouraged in SCM research, because SCM phenomena are often complex and dynamic (Golicic and Davis, 2012). Developing mechanisms to adopt supply chain-wide RFID tracking systems is this kind of complex SCM phenomena, as the literature on the research topic is scarce, and only few, open, supply chain-wide RFID implementation has been identified whereby the research questions 2 and 3, in particular, could be partly tested. Therefore, different methods were combined to obtain reliable answers to the research question instead of building an expensive RFID tracking system that might fail.

3.2.1 Literature survey

In design science approach, the knowledge of existing literature plays an essential role, as the results of the empirical research needs to be compared continuously with the existing literature (Holmström et al., 2009b). In the research of this thesis, the central role is the literature concerning RFID tracking adoption in SCM implementations. The existing literature about RFID

tracking implementations was searched by conducting a systematic literature review. The main survey method was a general search for articles published in 2010 or earlier and containing the search phrases *radio frequency identification* or *RFID* in the database called *ABI/Inform*. The literature review was summarized by defining 35 key articles which present different kinds of RFID tracking implementation challenges. These articles were compared in the table summarising the topics in the article. The table was formed by using the ideas of Webster and Watson (2002), and the results of this literature review are presented in Paper II.

3.2.2 The qualitative research methods used

The qualitative research methods used for this thesis were participant observation and process observation in general, semi-structured interviews, and workshops.

In participant observation, the researcher immerses him or herself in a social setting for an extended period of time, observing behavior, listening to what is said in conversations among others and with the field worker, and asking questions (Bryman and Bell, 2011). Pålsson (2007) has written how participant observation is suitable for logistics research by using the method for collecting and analysing data of a study on an inter-organisational RFID implementation. Active participation in the case studies of this thesis enabled the observation of the supply chain-wide RFID tracking designing process from the first negotiations to form the case study until the end of the study (and sometimes even further, when the actual implementation process became topical in the case companies). Observation was also used as a research method when the researchers visited the case companies to familiarise themselves in the operations and operational environments of these companies. Book Retailing (Paper III) and Clothes (Paper IV) case studies included visits to places where RFID tracking was already in use. There were process observation visits for 34 different locations in six case studies in this thesis. The doctoral researcher participated in 28 visits. All the meetings, workshops and visits were documented in memo form. In addition, the doctoral researcher took photographs of existing RFID tracking solutions and possible process phases where RFID tracking could be used whenever photography was allowed.

Another important qualitative research method was semi-structured interviews. In participant observation, interviews are typically used to complete the data (Bryman and Bell, 2011). The interviews were conducted in several phases during the case study research: First, at the same time when the researchers visited the facilities of the case companies, the researchers asked, for example, about the current operations and challenges related to SCM in order to achieve an adequate understanding about the companies' positions in their supply networks, processes, development needs and possibilities to implement RFID tracking. Second, when the researchers needed to select the most suitable solution proposition for further development, or the selected solution concept required outside experts' evaluation, the researchers interviewed different kinds of experts such as representatives of tracking technology providers or representatives of companies that already use RFID tracking. In addition, in the Background Survey presented in Paper I, there were 10 separate face-to-face interviews and an internet inquiry, to which 49 companies responded. A similar survey was conducted in the Technical Trade case study (Papers V and VI), where 19 separate face-to-face interviews were conducted and 21 companies

responded to an internet inquiry. In total, 130 different persons were interviewed during the Background Survey and six case studies. Of these, the doctoral researcher participated in 98 interviews. Appendix A presents the guidelines for the interviews in the Background Survey of Paper I. Appendices at the end of Papers III, IV and V present the guidelines for the interviews conducted during the case studies of these papers. In addition, Appendix B presents guidelines for interviewing the representatives of the participating companies in the Technical Trade case study.

Workshops were an important data collection method for almost all the phases during the case study. When the case studies were designed, the researchers organised workshops to recruit different suitable organisations to participate in the study and discuss together which kind of case study would offer solutions for some of their practical problems in SCM. In the early phase of the case study, the purpose of the workshops was to share the existing essential data related to the research topic. In the Technical Trade case study, the researchers also organised workshops during their visits in the case study participant companies. Later, the workshops were used to construct solution ideas and to select an applicable solution. After selecting the applicable solution, the purpose of the workshops was to plan the tests or pilots and to evaluate the results of these tests. Later, the results and the experiences of the case study were discussed, and the future steps of the companies related to the phenomenon under research were defined in workshops. Altogether, the researchers organised 55 workshops directly related to six case studies presented in Papers II, III, IV, V and VI. The doctoral researcher participated in 47 workshops. The researchers wrote memos for all of these workshops.

The qualitative data collected was analysed to some extent throughout the case study. The preliminary analysis of the collected data was conducted when the memos of each observation visit, interview or workshop were composed and the experiences of these events were discussed with all the researchers involved in the case studies. This preliminary analysis helped pinpoint the most relevant data that the specific event offered and also helped compare them with the researchers' prior understanding of the subject. Then the larger analysis was conducted after each phase of the case study. At this time, the researchers involved in the case study compared the findings of different events, searched common patterns or exceptions, and discussed the experiences and results of the analysis. The summary of the discussions was included in a timely version of the case study report in question. In some case studies, the data analysis was also included, combining qualitative data with quantitative research data from quantitative simulation models or quantitative analysis (see next subsection). Again, the data collected was searched at the end of the case studies when writing the final case reports, and thoroughly again when writing the different versions of the appended papers of this thesis.

3.2.3 The quantitative methods used

The quantitative simulation model was created to evaluate the costs and benefits of possible RFID tracking implementation. The model was used in Book Retailing (Paper III) and Technical Trade (Paper V and Paper VI) in-depth case studies. Quantitative models are usually based on a set of variables that vary over a specific domain, while quantitative and causal relationships have been defined between the variables (Bertrand and Fransoo, 2002). Also, in the data analysis of those in-depth cases studies, the model employed the result of the

qualitative methods. Modelling consisted of a quantitative cost model where the costs and realizable benefits of RFID technology were calculated by comparing different RFID tracking scenarios.

Quantitative analysis was used to summarize the answers of focus interviews and internet inquiries in the Background Survey and Technical Trade case studies. In those studies, the qualitative research method interview was supplemented by requiring the respondent to evaluate his or her opinion on a Likert scale with five or seven categories. The use of qualitative and quantitative data collection provided possibilities for data triangulation (Creswell, 1998; Miles and Huberman, 1994) as the averages, with standard deviations enabling the comparison of alternatives or the evaluation of the importance of different factors rather than simply analysing the qualitative interview data.

3.2.4 Summary of the data collection methods used

Table 1 summarizes the used data collecting methods in different cases and indicates the involvement of the doctoral researcher in observation visits, interviews and workshops (in brackets).

Table 1. The data collection methods used in different studies. The figures in brackets indicate the number of visits, interviews or workshops where the doctoral researcher participated.

Name of the study	Number of process observation visits	Number of interviews	Internet inquiry	Number of workshops	Used quantitative methods	Technology testing
Background Survey of logistics needs (Paper I)	0	10 (10)	Yes, 49 respondents	2 (2)	Statistical analysis	No
Grocery case (Paper II)	0	1 (0)	No	2 (1)	No	No
Roll Cage Tracking case (Paper II)	1 (1)	2 (2)	No	2 (2)	No	Pilot installation
Hospital Equipment case (Paper II)	3 (2)	4 (3)	No	4 (4)	No	Two different pilot installations
Book Retailing case (Paper III)	6 (6)	12 (12)	No	5 (4)	Quantitative simulation model	Functionality tests of RFID tags and readers
Clothes case (Paper IV)	3 (1)	11 (0)	No	7 (1)	No	Pilot installation
Technical Trade case (Paper V and Paper VI)	21 (21)	90 (71)	Yes, 23 respondents	35 (35)	Quantitative simulation model, statistical analysis	Testing numerous operations in 14 sites

3.3 Design propositions to synthesize the results

Design science methodology relies on design propositions. Subsection 3.1.1 emphasises that the design propositions used for exploration are termed “means-ends propositions”. In exploration, means-ends propositions specify the means to reach desired ends in particular situations (Holmström et al., 2009b). When the research results should be synthesized, such as a compendium that aims to develop a new design theory based on empirical material presented in six appended papers, Denyer et al. (2008) forms design propositions by using the term “CIMO-logic”. Denyer et al. (2008) explain the constructs of CIMO-logic as follows: “In this class of problematic Context, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)”. These four components of design propositions can be further defined as follows (Denyer et al., 2008):

1. *Context* constitutes the surrounding (external and internal environment) factors and the nature of the human actors that influence behavioural change.
2. *Interventions* are purposeful measures (products, processes or activities) that are formulated by the designer or design team in order to solve a design problem or need.
3. *Mechanisms* indicate why the intervention produces a certain outcome. The mechanism is triggered by the intervention in the context and is an account of the cognitive processes (reasoning) that actors use to choose their response to the intervention and their ability (resources) to put the intervention into practice.
4. *Outcomes* are the results of interventions.

While design science research in information systems research emphasizes the intervention and its evaluation (Hevner et al., 2004), the design science approach in operations management concentrates more on novel combinations of context, intervention and outcome than in novelty and evaluation of interventions (Holmström et al., 2009b).

In this thesis, CIMO-logic is used to synthetize all the results of the studies backing this thesis. The first research question, "What are the tracking needs of companies in changing operational environments?" intends to define the context where tracking systems should be designed and adopted. The second research question, "How do we define the most suitable tracking coverage for different kinds of supply chains?" aims to describe the type of intervention that is suggested to obtain the desired benefits in SCM with affordable resources. The third research question, "What types of mechanisms would enable the adoption of supply chain-wide RFID tracking systems?" aims to find, of course, the proper mechanisms to enable the adoption. The initial outcome instead has been already locked in the beginning of the case studies, which all aimed to design and implement RFID tracking across the entire supply chain, or at least tracking systems that cover the major part of the supply chain. However, after defining the context, intervention and mechanisms, the outcome is evaluated again by locking other propositions. Then technological frames are used to determine whether the outcome is still the implementation of supply chain-wide tracking or which kinds of misalignments of frames could risk the achievement of that aimed outcome.

3.3.1 Research process for defining context

The context in the research of this thesis consists of the operational environment, where the companies operate, and how tracking could improve the SCM of these companies.

To learn which kinds of logistics needs industrial companies have and which kinds of solutions they are ready to acquire in general, a four-phase study was conducted. The study began with a literature review to source background data for selected industrial sectors and used transportation modes in Finland. In the second phase, focused interviews of logistics directors / managers of selected industrial sectors were conducted to determine the companies' current use of logistics services and to explore the possible future needs of logistics services based on the major trends reshaping the competitive environment and companies' needs to develop their operations. Partly parallel to the second phase, the third phase of the research, internet inquiry, was conducted to obtain answers from a larger group of respondents than logistics directors / managers

that were targeted in focus interviews. The fourth phase compared the answers of phases two and three using the database of DHL Finland's transports from one year to ensure that the results obtained in interviews and internet inquiry described the overall situation. The analysis of development needs found in SCM and the requirements for new logistics solutions highlighted the context in which the companies operate and how improved tracking could improve the companies' SCM.

Later, when conducting case studies in specific supply networks, the context of that specific supply network was studied by defining the current state of the supply network. This study was performed by conducting literature reviews, interviewing experts, observing current processes in visits to case study participant companies and companies where RFID tracking is in use, and arranging workshops in single companies and for the representatives of all case study participants.

3.3.2 Research process for defining intervention

Intervention is simply the action that should lead to the desired outcome in a certain context. The context of the research of this thesis is companies forming and operating in supply networks aiming to improve the SCM in the entire supply network. The desired outcome is a tracking system that would offer possibilities to improve SCM. Thus, the intervention is to design a realisable RFID tracking system. Tracking system design has several attributes, such as accuracy of tracking (pallet-, parcel- or item-level) or levels of integration of tracking systems. However, as the Theoretical Background chapter concludes, the difference between the aims of supply chain-wide tracking systems with the reality of tracking systems covering only a certain company or function between two companies raises the question of the coverage of the tracking system as the central topic in system design. Therefore, intervention defines the suitable coverage for the tracking system.

The coverage of the tracking system is basically a trade-off between the benefits that tracking systems spanning across the whole supply chain would offer with the resources that building and maintaining tracking systems with larger coverage would require. SCM concepts postponement and speculation were used to develop potential tracking options. The Book Retailing case study approached tracking coverage by using value chain analysis (Dekker, 2003) to evaluate the costs and quantifiable benefits of RFID tracking for each supply chain actor. To calculate exact costs for each supply chain actor, a quantitative simulation model was employed, and sensitive analysis was enabled to estimate exact values, which change the most economical tracking coverage. In the Clothes case study, the required tracking coverage was researched by interviewing the potential users of tracking system to find out the tracking applications that they require. Based on the desired applications and capabilities of the case LSP, three different forms of RFID tracking were formulated for fashion companies.

3.3.3 Research process for defining mechanisms

The mechanisms indicate why the intervention produces a certain outcome in a certain context. When the outcome should be the implementation of the RFID tracking system and the intervention specifies the coverage of the system in a particular supply chain or network, the first issue in developing mechanisms in an actor-based approach would be to define the focal actor, who will initiate the

realisation of this tracking system. The possible focal actors can be found when analysing how different actors of the supply chain view tracking systems.

To find the mechanisms to build and implement supply chain-wide tracking, three in-depth case studies and three other case studies were conducted. The unit of analysis of these case studies was the entire supply network, and the member organisations in those supply networks were handled as actors. The key issues were to first study what kinds of benefits the whole supply chain would achieve if RFID tracking were applied in the most suitable scenario (intervention) and what resources were needed to realise this intervention. If the profitable intervention was found, then the focus was to consider each actor's perspective for the adoption. In the Book Retailing case study, this consideration was done by applying a value chain analysis perspective (Dekker, 2003) to evaluate the financial effects of the implementation and usage of item-level RFID tracking for different supply chain actors in different scenarios. In the Clothes case study, the focal company, LSP, aimed to design a configurable tracking solution which would be a beneficial solution for different kinds of companies. In that case study, the representatives of potential customer companies for that solution were interviewed, and together with the representatives of the LSP company, the researchers designed a solution that would be beneficial for user companies and easy to adopt. The Technical Trade case study considered the decision of a single network actor to join the common RFID tracking system through the perceived usefulness and perceived ease-of-use approaches of TAM (Davis, 1989). The companies' views were mainly obtained by conducting interviews and in observation visits and workshops.

3.3.4 Summary of the synthesis

As already pointed out, the purpose of design science is to develop managerial-relevant problem solutions into new design theory by using four phases of design science. Conducting single-case studies usually offers possibilities to develop theory in the first and second phase of design science, which are Solution Incubation and Solution Refinement (Holmström et al, 2009b). Therefore, the aim to employ CIMO-logic in this thesis is to synthesize the results of the case studies and related papers, and then move forward from solution refinement to the third phase of design science to develop a more substantive theory. The development of design theory is summarized in Figure 2.

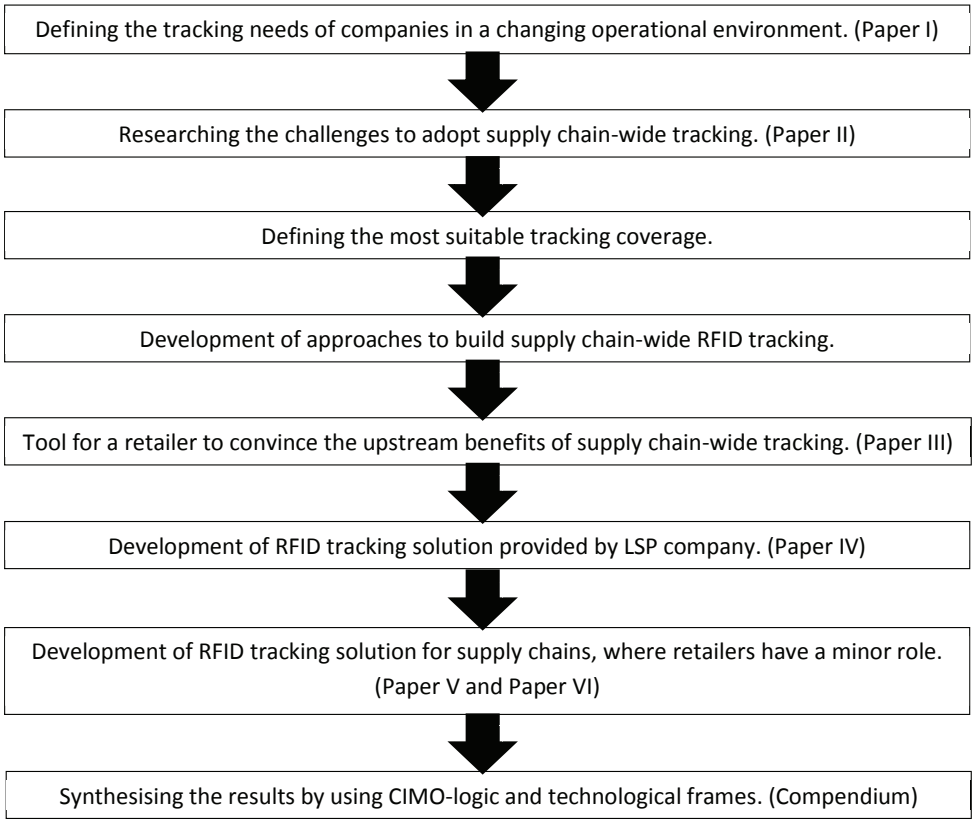

Figure 2. Development of design theory in this thesis.

4 Appended papers

4.1 Paper I – Selection criteria of transportation mode: a case study in four Finnish industry sectors

Paper I presents the results of the study, where the purpose was to define changes in the logistical needs of companies to thus enable logistics operators to deliver needed services to their clients.

The doctoral researcher collected all the empirical materials for the article. The first author of the paper Dr. Mikko Punakivi, helped contact interviewees and DHL, and helped design research. The doctoral researcher wrote the larger study report and also a 15-page Finnish summary of the study. This summary was published in the annual book of the Finnish Logistics Society 2004, and it became the frame for the article. Dr. Punakivi was mainly responsible for translating this summary in English, elaborating the summary further to the format of a conference paper for NOFOMA 2005 and to the format of the journal article, and finally selecting the suitable journal and handling the review processes to eventually publish the manuscript.

4.1.1 Purpose

Paper I takes a closer look at the very basics of logistics and analyses the selection criteria of transportation services from the industrial point of view as the main research problem. It also attempts to establish a better understanding of which industrial sectors use certain modes of logistics services, and why.

4.1.2 Contribution to the thesis

Based on the results, some of the future logistics needs were identified. This information was used to help logistics service providers (LSPs) offer the exact services needed and thus provide better competitiveness for Finnish shipping companies operating in global markets. Paper I proposes, for example, that LSPs are expected to have more powerful SCM capabilities than a single service provider can typically offer. Additionally, LSPs should have compatible operating systems with different parties of various supply chains to enable deliveries to different customer groups according to their industry's required speed. Paper I also concludes that industrial customers as well appreciated reliability, accuracy, safety, convenience of service, service speed, fluency and punctuality.

Paper I contributes mainly to research question 1.

4.2 Paper II – Challenges for building RFID tracking systems across the whole supply chain

Paper II presents the literature review of the challenges in building RFID tracking systems across the whole supply chain. In addition, the article compares the results of the literature review with the doctoral researcher's experiences from five case studies of this thesis: Grocery, Roll Cage Tracking, Hospital Equipment, Clothes and Book Retailing.

The doctoral researcher is the sole author of Paper II. The first version of this paper was published in NOFOMA 2010's conference proceedings.

4.2.1 Purpose

Paper II concentrates on researching the reasons for the slow adoption of RFID tracking in the SCM by using literature review and multiple case studies as the research methodology. The literature review of the articles classifies different challenges for RFID tracking implementation and elicits academic explanations for the slow acceptance of the technology. In addition to the literature review, five RFID tracking case studies are presented to provide experience and insight into managerial decisions concerning supply chain-wide RFID tracking solutions.

4.2.2 Contribution to the thesis

The paper divides the challenges of supply chain-wide tracking adoption into nine categories. According to Paper II, the biggest challenges in supply chain-wide RFID tracking adoption are inter-organisational problems between the companies. To understand the relevance of different challenges, the doctoral researcher proposes a framework that suggests three levels on which different potential challenges to supply chain-wide RFID tracking system implementations should be handled: the supply chain, inside a company or inside a certain function.

Paper II contributes mainly to research question 2, but also for research question 3.

4.3 Paper III – RFID tracking in the book supply chain: the transition from postponed to speculative tagging

Paper III was written based on the Book Retailing case study.

The doctoral researcher collected almost all the empirical material for the article, created the model used for quantitative analysis, and discovered the paper's theoretical connection to postponement – speculation literature. Prof. Jan Holmström offered valuable help in developing the paper further between submissions, finalising the paper and responding to reviewer comments. Dr. Kary Främling participated in the Book Retailing case study, and therefore, he was able to provide comments for the analysis of empirical material. The first version of this paper was published in NOFOMA 2009's proceedings.

4.3.1 Purpose and outline

Paper III addresses the question regarding the point at which books should be tagged in the book supply chain, and where such tracking could begin at different levels of adoption among retailers. Alternative solution designs are analysed by comparing the costs and benefits of supply chain-wide RFID tagging with RFID tracking solutions that cover only part of the supply chain. The analysis is based on modelling the RFID tag as the product's feature and considering the tagging of books as a potential postponement decision. The cost estimates are based on activity-based costing and are used to compare alternative solution designs for introducing RFID tracking in book retailing.

4.3.2 Contribution to the thesis

Paper III presents how the SCM concepts postponement and speculation can be used to evaluate different RFID tracking scenarios and how speculative tracking becomes gradually more attractive, as the early attachment of RFID tags in the manufacturing phase is in many settings likely to be cheaper than downstream tagging. However, early tagging requires that a threshold share of retailers

adopt RFID tracking in their store operations and are willing to bear the additional product costs.

Paper III contributes mainly to research questions 2 and 3.

4.4 Paper IV – Typology of configurable RFID tracking in fashion logistics

Paper IV was written based on the Clothes case study.

The doctoral researcher designed the current form of the article, and he wrote the majority of the article. In addition, the doctoral researcher conducted the literature review part of the article, where the existing use cases are also analysed. The second author, Ms. Maiju Häkkinen, collected the majority of the empirical material by conducting almost all of the interviews, workshops and observation visits. The third author, Prof. Jan Holmström, offered valuable help for developing the paper further between submissions, finalising the paper and responding to reviewer comments. The fourth author, Dr. Kary Främling, also helped develop the paper further.

4.4.1 Purpose and outline

The aim of Paper IV is to propose an RFID-based tracking solution that can be configured for differing supply chains. The solution design is presented from the perspective of an LSP interested in designing a tracking solution for its customers in fashion logistics. An LSP and four fashion companies were involved in the study. The tracking solution was developed based on mapping customer needs, recognizing and quantifying the most important benefits for different customers and formulating value word equations representing those benefits.

4.4.2 Contribution to the thesis

Paper IV proposes three alternative RFID tracking solutions for the fashion company customers of the LSP company: 1) Supply chain-wide tracking, 2) Postponed tracking start, and 3) Postponed tagging. The relevant and quantifiable customer benefits of RFID tracking include improved availability, reduced shrinkage and improved processes. The proposed tracking concept also enables fashion companies to increase their responsiveness. For those fashion companies who feel the adoption of RFID tracking would be difficult despite the obvious benefits, the proposed mechanism offers an incremental alternative to uniform supply chain-wide implementation.

Paper IV includes all the research questions, even if its main contribution is in research question 3.

4.5 Paper V – RFID tracking implementation model for the technical trade and construction supply chains

Paper V was written based on the Technical Trade case study.

The doctoral researcher was responsible for designing and conducting the Technical Trade case study and Paper V. The second author, Mr. Jaakko Tätilä conducted all the interviews in customer companies and performed the internet inquiry. In addition, he occasionally conducted the case study and helped write different versions of the paper. The first version of the paper was published in NOFOMA 2011's proceedings.

4.5.1 Purpose and outline

While most of the current RFID tracking systems are designed for retailers' purposes, Paper V presents a model for RFID tracking implementation in a supply chain where retailers play a minor part. The research method employed is a case study, and its unit of analysis is a network of companies (manufacturers, wholesalers and customers) acting in the Finnish technical trade industry. This paper concentrates on exploring the benefits of RFID tracking downstream in the case supply chain, as RFID tracking system building in the upstream of the case supply chain is presented in Paper VI. To discover benefits in the downstream of the technical trade supply chain and to design tracking implementation models for the supply network, 19 semi-structured interviews for customers of technical trade manufacturers and wholesalers were conducted. A supplementary internet inquiry was used to validate the results.

4.5.2 Contribution to the thesis

The survey results were analysed with the wholesalers' results, and an RFID tracking adoption model based on the ideas of the Technology Acceptance Model (TAM) for the case industry was designed. Based on the findings of the case study, a three-step model for RFID tracking implementation in the entire technical trade supply chain is proposed.

Paper V contributes mainly to research question 3, but also to research question 1.

4.6 Paper VI – Supply chain tracking: aligning buyer and supplier incentives

Paper VI was also written based on the Technical Trade case study. While Paper V presents RFID tracking implementation for the entire technical trade and construction supply network, the development of the model in the upstream part of the supply chain is excluded from that paper. Paper VI fills that gap.

The doctoral researcher was responsible for collecting the empirical material and designing the paper. The second author, Prof. Kary Främling, participated in some of the meetings in the Technical Trade case study and helped modify the paper. The third author, Mr. Jaakko Tätilä, helped plan the workshops, where the key empirical material for the paper was collected. In addition, he contributed to writing the paper. The first version of the paper was published in NOFOMA 2012's proceedings.

4.6.1 Purpose and outline

This paper presents how the success of IOIS implementation projects can be increased by aligning the different incentives of buyers and suppliers. Although suppliers feel that adoption is difficult and fear buyers will gain more than they if tracking is applied, they were ready to implement the solution because they understand that improvements in IOIS help apply common industry data exchange standards and will lead to better supply chain collaboration, which also increases their operational performance in the long run. If the buyer takes a cooperative approach to IOIS integration, suppliers can be motivated to integrate tracking as a part of their own operations. This high-level integration offers more options to improve the management and hence the performance of the whole supply chain than low-level integration.

4.6.2 Contribution to the thesis

This paper highlights the different roles that different supply chain actors have in the RFID tracking implementation process. In addition, this paper explains several Technical Trade case study findings that are excluded from Paper V.

Paper VI contributes to research question 3.

5 Results

The results of this doctoral study are presented in this chapter. This chapter is outlined to follow CIMO-logic (Context, Intervention, Mechanisms and Outcome) (Denyer et al, 2008). In section 5.1, the context is defined and elaborated to answer research question 1. Then, in section 5.2, the intervention is defined, which offers material for discussing the answers for research question 2. Finally, in section 5.3, three different mechanisms to produce desired outcome – building supply chain-wide RFID tracking systems – are presented to answer research question 3.

5.1 Context: What are the tracking needs of companies in changing operational environments?

In design theory and CIMO-logic, the context proposition defines the surrounding factors and nature of actors that influence change (Denyer et al., 2008). This section is divided in three subsections: 5.1.1 defines the tracking needs of companies in changing operational environments. 5.1.2 presents the general challenges of implementing supply chain-wide RFID tracking systems. 5.1.3 presents a highly developed and simplified view of the supply chains, where different tracking coverage (intervention) should be evaluated.

5.1.1 Tracking needs in supply chain management

Paper I discusses the results of the Background Survey of the Finnish industrial companies' use of logistics services. The paper starts by explaining the current state of their logistics and the use of logistics services. However, the primary focus of the paper explains how companies would like to develop their SCMs and their future needs of logistics services.

According to the Background Survey, the four major trends (1) globalisation, (2) concentration on core competences, (3) the shortening of product and service life cycles, and (4) enlargement of e-business supply networks, mean that companies' supply networks become more complex and global, which complicates SCM. To respond to this challenging environment, the companies aim for more integrated supply chains, and smaller companies, in particular, are willing to outsource more of their logistics and give more power to their logistics service providers (LSPs).

The Background Survey emphasises that the relative importance of the quality of logistics services over price has grown rapidly. The paper highlights the fact that companies want more flexibility, which in practice means that they want the following, for example:

- Better service for smaller delivery lots.
- More information about the performance of the delivery, and the possibility to obtain feedback to improve their delivery operations.
- More punctual logistics services.
- The possibility to use transport as moving stock.

Implementation of supply chain-wide RFID tracking would increase the visibility in the supply chain. Increased visibility enables supply chain actors to examine their realised performance on a step-by-step basis, which enables the

division of operations into smaller phases to pinpoint, for example, those phases that cause delays or other uncertainties in deliveries. Improved visibility in the supply chain also enables the modification of the schedules of transports under delivery, for example, by choosing the slower or more rapid transportation mode in the hub of the transportation route.

The tracking solution alternatives for the fashion industry proposed in Paper IV are based on in-depth interviews of possible tracking solution customers of the case LSP company. The following needs were mentioned at least by two different customers:

- Flow of information should be fast and reliable throughout the entire supply chain. External help is needed, at least in organizing the tracking systems into the Asian production facilities (operated mainly by subcontractors) and transport routes.
- Products should arrive on schedule. Speeding up the processes is important, especially in the warehouses.
- Better optimisation of inventory levels and availability is needed.
- Inventory taking and receiving of the shipments in the shops are laborious processes. Therefore, RFID tracking applications for the retail environment are interesting in general.

Paper V is based on an in-depth case study for the technical trade and construction industry, and during that case study, the tracking needs of the customer companies of technical trade wholesalers and manufacturers were determined. According to Paper V, improved tracking of materials could improve the receiving process of the customer companies considerably, and in that way offer more standardised ways to handle operations in often temporary operating sites, which currently lack fundamental development of processes.

5.1.2 Challenges and obstacles for supply chain-wide RFID tracking implementation

The cost of RFID technology is a central issue where tracking adoption is concerned. Paper II divided the costs thusly: The cost of new technology (RFID tags, other hardware, software, system integration and data management); the costs of changed operations (tagging costs and the costs of operational automation); implementation costs (support, training and reorganisation); financial problems related to high investments; and overall uncertainty about the costs versus estimated benefits.

According to Paper II, most of the existing articles about RFID tracking adoption challenges and obstacles were on presenting technological obstacles in RFID tracking implementation, while today's problems are increasingly organisational or inter-organisational. In some older articles, the challenges of building supply chain-wide RFID tracking systems were even considered to be so high that those systems remained as unrealisable visions due to the high costs and risks added by inter-organisational challenges (Fontanella, 2004; Spekman and Sweeney, 2006).

One organisational problem is related to the ideas of Orlikowski and Gash (1994) about technical frames. The idea of technical frames is that different stakeholder groups see the adoption differently, and in the RFID tracking context, for example, top management, the information systems department,

production and logistics, and marketing see the nature of the technology, technology strategy and technology in use differently. These varying roles in an organisation are a challenge. As an extensive RFID tracking system is a big investment and requires changes inside organisations, considerable management commitment to system adoption is necessary (e.g., Brown and Russel, 2007; Lim and Koh, 2009; Li et al., 2010). Asif and Mandiviwalla (2005) also point out that the biggest potential benefits of RFID tracking arrive when supply chain concepts are combined with customer strategies. Therefore, they emphasize the involvement of marketing people in RFID system development, because SCM experts tend to concentrate on cost-saving issues while marketing people attempt to find added value for a customer. However, combining marketing and SCM strategies is challenging. (Asif and Mandiviwalla 2005).

The biggest inter-organisational problem relates to the fact that if the products are RFID tracked throughout the supply chain, the tag should be attached at the earliest phase possible in the supply chain. However, the common understanding is that the retailers will get the biggest benefits when introducing an RFID tracking system (e.g., Vijayaraman and Osyk, 2006; Soon and Gutiérrez, 2008). Therefore, product manufacturers may not be willing to pay the largest single cost of the system – the tags – while those downstream in the supply chain would get the biggest benefit (Dutta et al. 2007). Conversely, Whang (2010) also noticed that those downstream on the supply chain may be reluctant to lead the way for tracking adoption, because they may prefer to wait for the RFID tracking decisions of upstream companies before planning their own tracking system, as joining the tracking system when a company upstream attaches RFID tags is cheaper if those downstream can use the existing tags attached by upstream supply chain actors. Whang (2010) names this situation a "free rider problem". After following the development of Wal-Mart's RFID system implementation, several authors also believe that RFID technology adoption will increase the power of large retailers relative to suppliers and smaller retailers (e.g., Rutner et al., 2004; Soon and Gutiérrez, 2008). Bradley and Guerrero (2010) suggest a similar example related to the U.S. pharmaceutical industry, where smaller, secondary wholesalers may encounter huge problems if their larger competitors refuse to share electronic pedigree data related to RFID technology, or charge exorbitant fees for this data. Still, in addition to suppliers' sense to give power to a buyer, buyers may also have similar feelings at the same time, while they may consider certain suppliers' investments to RFID tracking as a competitive advantage over other suppliers (Boeck and Wamba, 2008). Curtin et al. (2007) proposes that RFID tracking system adoption will lead to a situation in which smaller companies must either adopt the RFID tracking system or lose out. This situation also increases resource dependences between supply chain companies (Cannon et al., 2008). Cannon et al. (2008) also evaluate the adoption of RFID technology through transaction cost economics theory and propose that the threshold to adopt RFID tracking in a supply chain level is high because the risks and uncertainty included in the adoption are great.

5.1.3 Simplified view of supply chains where RFID tracking should be implemented

The basis for tracking system coverage examination is a simplified supply chain (Simchi-Levi et al., 2003), where the suppliers of the manufacturer are ignored, because the systems under study are designed to start at the earliest time, when

the product is made. In a simplified supply chain, there are four different options to attach RFID tags and start tracking: (1) in the retailer's facilities, both (2) outgoing from the distribution centre (DC) and (3) incoming to the DC or (4) in the manufacturing phase. These options are presented in Figure 3.

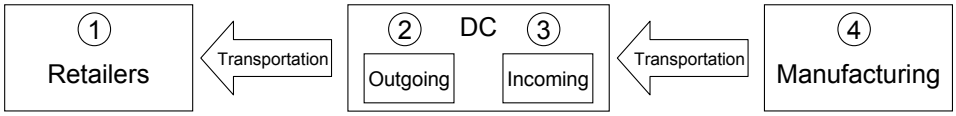

Figure 3. Different possible echelons to attach RFID tags in the simplified supply chain.

5.2 Intervention: How do we define the most suitable tracking coverage for different kinds of supply chains?

Intervention is simply the action that should lead to a desired outcome in a certain context. The previous subchapter 5.1 began by presenting the motivation for implementing tracking and then continued by presenting the challenges of building supply chain-wide RFID tracking systems. It ended by presenting a simplified view of a supply chain. When the outcome is set as the implementation of a supply chain-wide RFID tracking system or a tracking system that would cover the major part of the supply chain, the purpose of this subchapter is therefore to evaluate various possible options for tracking coverage by using SCM concepts of postponement and speculation in a context presented in the previous subchapter. This subchapter starts by developing Figure 3 further as three possible RFID tracking options provided by an LSP company (Figure 4) and as a form of framework matrix for classifying different item-level RFID tracking options (Figure 5), and then comparing the benefits and weaknesses of speculative and postponed tagging.

5.2.1 Development of frameworks to classify different tracking options

Paper IV developed typologies as a possible approach to synthesizing design knowledge on the different options regarding where to attach tags, when to start tracking, and when to stop tracking in different supply chain contexts. Comparing implementation costs with the possible benefits of tracking in different supply chain echelons makes trade-offs explicit. When tagging is done in the manufacturing echelon, there are more possibilities to gain benefits, but at the same time, in many supply chain contexts there is excess tagging of products that will be distributed through channels where RFID tracking is not yet in use. For this type of comparison, the concepts postponement and speculation (Pagh and Cooper, 1998; Yang et al., 2004, Boone et al., 2007) are used to define different options for intervention.

One issue in RFID tagging is that attachment of an RFID tag and tracking need not to start in the same supply chain echelon, even if this usually occurs. Basically, RFID tracking cannot begin before the RFID tag is attached. However, there are cases when tracking begins later, or more downstream of the supply chain. The most common example is the Slap & Ship strategy of Wal-Mart's suppliers, who only attach RFID tags for shipments going to Wal-Mart, but the supplier company itself does not track or otherwise use these tags (Vijayaraman and Osyk, 2006; Fries et al., 2010). The postponement concept is also

applicable in these kinds of cases, and this situation is named “postponed tracking start”, although actual tagging might have been speculative.

During the Clothes case study, different options for an LSP company to arrange RFID tracking solutions for its customers were analysed, and the analysis resulted in following three realisable options for applying RFID tracking: 1) “Supply chain-wide tracking”, 2) “Postponed tracking start”, and 3) “Postponed tagging”. These options are illustrated in Figure 4.

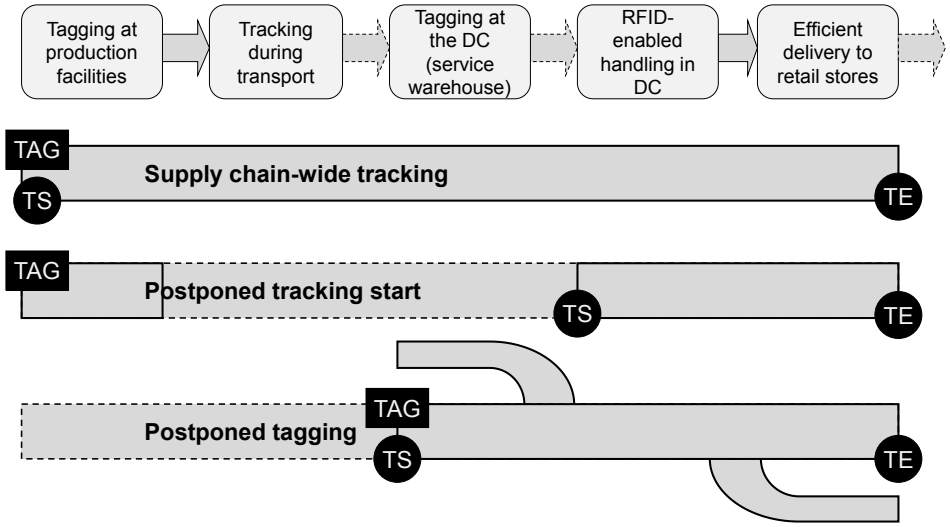

Figure 4. Three possible RFID tracking solutions provided by an LSP company.

Figure 4 presents only three options for RFID tracking coverage. To design a wider presentation of classifying different possible item-level RFID tracking options, the simplified supply chain presented in Figure 3 is taken as a basis for framework creation. Based on Figure 3 and Figure 4, the matrix shown in Figure 5 was constructed to sum up the factors for distinguishing between alternative item-level RFID tracking solutions designs.

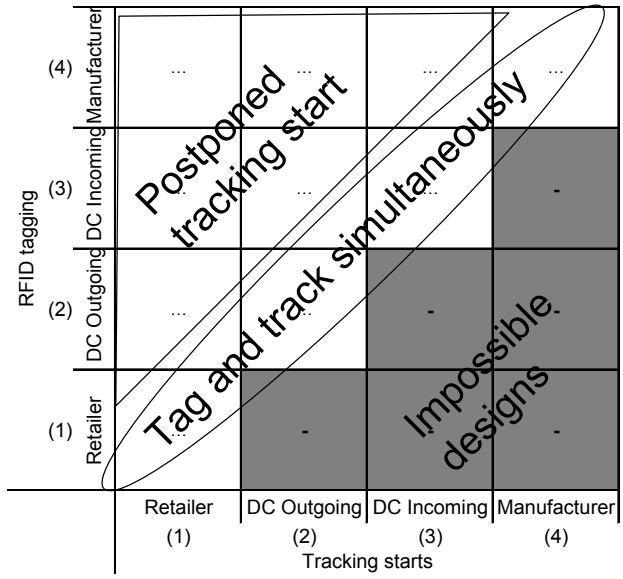

Figure 5. Framework matrix for classifying different item-level RFID tracking options by the echelon where the RFID tag is attached and the place where tracking starts in the supply chain.

5.2.2 Comparison of speculative and postponed tagging

When coming back to the place of tagging, basically, speculative tagging has the following advantages:

The farther upstream the tag is attached, the cheaper the cost / attached tag. In the Book Retailing case study, those four options presented in Figure 3 were present – to attach RFID tags for books, even if option number 3 was not handled in the calculations presented in Paper III. In speculative tagging (option number 4) an RFID tag can be attached automatically in the printing house when the book is bound. In that case, attachment can probably be done automatically, with low excess tagging cost per tag without delaying the binding process if the total number of tagged books is high enough. In option number 3, a book can be tagged when it arrives in the DC of the book LSP. In that phase, RFID tags probably need to be attached manually, and tagging may delay the receiving process. In option number 2, RFID tags can be attached when the customer orders are packed in the DC of the book LSP. Without testing and comparing options 2 and 3, it is difficult to say which one is more expensive. The space costs and workers are the same in both alternatives. Tagging may be easier in the receiving phase, when there are big batches of similar books, but alternatively, attachment of RFID tags may possibly be partly integrated to current order collecting and packaging processes when books are handled individually anyway. In full postponed tagging (option number 1) RFID tags are attached when the books arrive in the bookstores. This alternative is estimated to be the most expensive, because tagging requires space, and space costs are usually much higher in retail stores than in big warehouse or production facilities, and on the other hand, in the retail store, tagging may take more time because the salespersons would be trying to attach RFID tags while also waiting on customers.

In speculative tagging, the number of possible tracking applications is the highest. The more upstream the RFID tag is attached, the more echelons in the supply chain can use these tags for different tracking applications. In addition, the more upstream the tag is attached, more supply chain echelons can share the tracking data to improve the operations of the supply chain, and there are more possibilities to reorganise the supply chain to gain the full benefits of improved tracking.

On the other hand, postponed tracking has the following advantages:

The number of excess RFID tags can be limited by tagging only the items, which distribution channels can use these tags in their operations. In the Book Retailing and Clothes cases (Papers III and IV), the case companies' expert opinions was clearly that it would be too difficult to divide a certain manufactured batch by RFID-tagged items and items without RFID tags, because in that occasion, the number of SKUs (stock-keeping units) would double, and it would be time-consuming to estimate the share of items that require RFID tags. Therefore, the best option is to either tag every item in the batch or not tag any at all. Hence, speculative tagging will, in any occasion, lead to excess tagging if every item does not arrive in a distribution channel that is able to use these tags.

Postponed tagging is the easiest form of tagging from the business point of view because the tags will be used only inside one or a few companies. Speculative tagging requires the cooperation of several organisations situated in different echelons of the supply chain.

Table 2 summarizes the benefits of speculative and postponed tagging.

Table 2. Comparison of benefits and disadvantages of speculative and postponed tagging.

	Speculative tagging	**Postponed tagging**
Number of tags needed (Total cost of tags)	high	low
Cost of attaching single tag	low	high
Number of potential tracking applications	high	limited
Easiness in implementing the system	more difficult	simpler

When comparing the benefits of speculative and postponed tracking, the evident conclusion is that when the share of end customers who are able to use RFID tags increases, more attractive speculative tagging becomes. In the Book Retailing case study, a quantitative simulation model was used to compare the costs and benefits of both speculative and postponed tracking. By using RFID customers' market shares as a variable in a sensitive analysis in the simulation model, it was possible to estimate in which RFID customers' market shares speculative tagging becomes reasonable. Paper III presents how speculative tagging becomes more attractive when the RFID customers' shares increase, and when the RFID customers' market share exceeds 27%, the benefits of speculative tagging become larger than the costs of excess tagging.

5.3 Mechanisms: What types of mechanisms would enable the adoption of supply chain-wide RFID tracking systems?

Mechanisms indicate why intervention produces a certain outcome. Obviously, a supply chain-wide tracking system offers the biggest possibilities to gain benefits for the companies involved in the supply chain. For that reason, at least, the reasonable long-term aim for tracking system design is to plan a system which, at a minimum, offers possibilities for different supply chain actors to join. Therefore, building supply chain-wide tracking systems – or a tracking system that would cover the major part of it – is proposed as an intervention, and the outcome should logically be the implementation of that tracking system. As already mentioned, the contexts in which the companies operate have numerous and especially inter-organisational challenges to build supply chain-wide tracking systems. To beat these challenges, the case supply networks presented in Paper III, Paper IV and Paper V declared that they will start to build supply chain-wide tracking systems by using different mechanisms.

In the Book Retailing case study (Paper III), an RFID tag is seen as a product feature, and considers book tagging as a potential postponement-speculation decision. This mechanism option especially helps retailers evaluate different RFID tracking and tagging options, when the costs and benefits of enlarging the system more upstream can be evaluated by using a simulation model for calculations. This mechanism also helps convince the upstream of the supply chain to understand the usefulness of supply chain-wide RFID tracking, as upstream companies are usually rather reluctant to participate even in surveys about the effects of multi-organisational RFID tracking.

Paper IV offers an alternative mechanism option for adopting the RFID tracking system. Especially for the supply chains of the fashion industry, the solution where an LSP builds an RFID tracking system and provides it as a configurable tracking solution for its customers could be an alternative mechanism for current retailer-driven design of RFID tracking systems.

Paper V and VI present a model for RFID tracking for industries in which the downstream of the supply chain cannot see itself as an initiating actor of the RFID tracking system design as in the Book Retailing case of Paper III and mostly in the Clothes case of Paper IV. In Papers V and VI, it turned out that wholesalers have a rather vital role in the supply network, and therefore the wholesaler-driven mechanism to adopt supply chain-wide RFID tracking was developed for that case supply network.

Based on Papers III, IV, V and VI, three different mechanism options for building supply chain-wide tracking systems are proposed in the three following subsections. The first mechanism, “Retailer as an initiator”, is mainly based on Paper III, but also on the literature review about current RFID tracking system applications in the fashion industry, which we learned in Paper IV. The second mechanism, “Wholesaler as an initiator”, is mainly based on Paper V and Paper VI. The third mechanism, “Tracking provided by an LSP company”, is based on Paper IV. All the mechanism options are presented in their own subsections, as follows.

5.3.1 Mechanism option 1: Retailer as an initiator

Most of the largest RFID tracking solutions in the grocery, fashion and book industries are initiated by retailer companies, although the form and the function of these tracking systems vary considerably. Some of these existing item-level RFID tracking initiatives in the fashion and book industries have remained to only cover one or a few retail stores of a certain company, and attachment of RFID tags may be postponed until after delivery to the retailers' facilities, or RFID tags are attached by using the Slap & Ship approach in the distribution centres for the items to be shipped to these stores.

As the purpose in tracking system building is to cover the entire supply chain, different strategies to adopt supply chain-wide tracking have been used. Wal-Mart's strategy to enlarge its tracking system to cover the whole supply chain was to first involve its suppliers to attach RFID tags, and then the suppliers would apply RFID tracking also and spread RFID tracking adoption for their suppliers and LSPs systematically. In fashion retailing, where retailers may have their own brand of clothes which are sold only in certain retailer stores, supply chain-wide RFID tracking systems are more common than in other industries. Often, these supply chain-wide RFID tracking systems are built by first ensuring that the factory is able to attach RFID tags, and tracking is later enlarged to cover the whole supply chain, as the case examples of American Apparel (O'Connor, 2008; Swedberg, 2012) and the company with the pilot installation in the Clothes case study show.

Depending on the industry and its supply chains, the retailer has two options to enlarge the scope of the simplest system (postponed tagging in retailers' facilities) based on the analysis above. The first option is to ask the DC to attach RFID tags for the products going to that retailer. Gradually, the DC may also start exploiting the technology. Tracking could be started when tags are attached for outgoing shipments, and later the DC may exploit the technology by also attaching RFID tags for incoming products, which would enable tracking products inside the DC. The DC may find cost savings when asking the manufacturer to attach RFID tags to the products arriving at the DC. This also enables the manufacturer to use these RFID tags for tracking, which then completes the supply chain-wide tracking system. The second option for the retailer is to ask manufacturers directly to attach RFID tags to the products. When manufacturers attach these tags, it would be possible for manufacturers and DCs to track the products all the way from the manufacturing phase. Figure 6, which uses a framework presented in Figure 5, summarizes these two options.

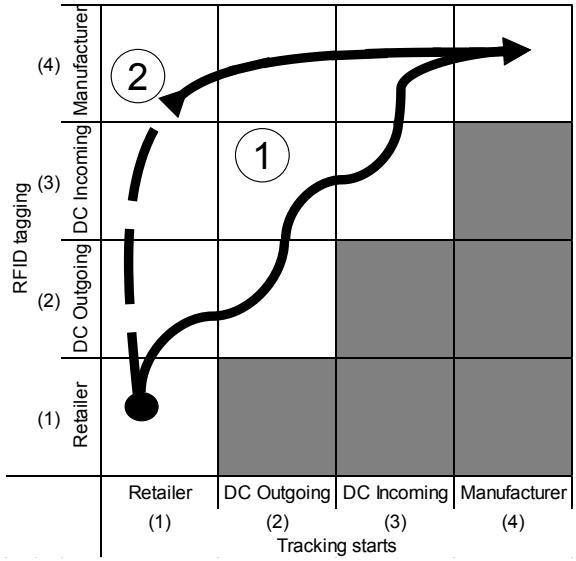

Figure 6. Two different road maps to enlarge tracking to cover the whole supply chain in the "Retailer as an initiator" mechanism.

Some interesting notions can be seen when analysing Figure 6. Moving upwards in the matrix usually means that the obtainable cost decreases if the volumes are large enough. Moving to the right increases the costs, because extended tracking requires investments and adds work tasks. However, moving to the right is the only way to increase benefits, as moving tagging upwards alone does not bring any supply chain improvements. Therefore, path 2 on the road map in Figure 6 describes a system development, where the costs are at first minimized by increasing the volume, and then the investments for better tracking are made by different supply chain actors as the business case becomes clear enough. The improvements on the other path where tagging and tracking move upstream jointly, can be seen as the development path, making simultaneous trade-offs between costs and benefits.

There are differences between book and fashion retailer companies. Book retailers seldom specialise in only selling products from a single publisher. Also, in bookstores, the books are arranged by topic, not by publisher. Therefore, the first road map path is more probable in the book supply chain, because at least in Finland, these chains consist of hundreds of publishers and printing houses, but only a few book DCs. Conversely, different fashion clothes brands may have specific stores or their own sections in the department stores. That enables the adoption of tracking systems in both ways in fashion supply chains.

5.3.2 Mechanism option 2: Wholesaler as an initiator

As already pointed out, in a traditional supply chain, which consists of manufacturers, distribution centres and retailers, the more downstream in the supply chain, the bigger the benefits (Vijayaraman and Osyk, 2006; Soon and Gutiérrez, 2008). Therefore, the majority of existing RFID tracking solutions have been designed for the purposes of a single retailer, and not for a supply chain-wide system. If the supply chain-wide RFID tracking system is seen as an extension of retailers' tracking systems, building a tracking system for

industries where the retailers have a minor role can be regarded as challenging. Paper V discusses the technical trade and construction industry, where the retailers are minor actors in the supply chain perspective, and other customers of technical trade wholesalers are not willing to be initiators in supply chain-wide tracking system adoption. Based on the findings of the Technical Trade case study, a three-step model for adopting an RFID tracking system adoption model for the technical trade supply chain in Finland is presented in Figure 7.

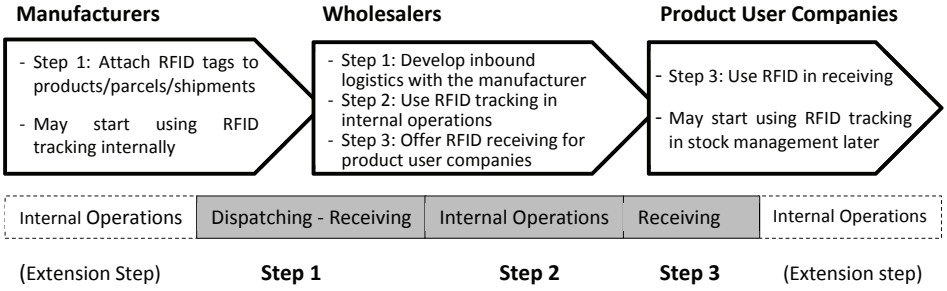

Figure 7. Three-step model for adopting an RFID tracking system in Finnish technical trade and construction supply chains.

In the following, each step of the model is first described, and thereafter, the reasoning behind it is explained. The model offers a structured, sequential way to implement RFID tracking so that it covers most of the supply chain as can be seen in Figure 7.

Step 1) The wholesalers develop their inbound logistics with the manufacturers, who are encouraged to attach RFID tags to their shipments.

The wholesalers were seen as the most dominant players in the supply chain, and they also could benefit increasingly from RFID, so they have the most power to push through RFID adoption. The leverage of the wholesalers arises from the following features: most products in the supply chain go through wholesalers – some suppliers do not even sell without wholesalers acting as intermediaries; in practice, there are only four of them in Finland, and they have strong buying power over suppliers, who are afraid of losing markets to foreign competitors.

Step 2) After successfully introducing the RFID tracking upstream, the wholesalers can enlarge tracking to cover their own operations and internal transports between their own sites. Then the wholesalers would have an adequate RFID tracking infrastructure to offer RFID tracking solutions for their customers.

Wholesalers are motivated to develop RFID tracking systems also for their internal operations because they could improve their materials handling processes considerably with RFID tracking, as was discovered in the case study. This step would be less complicated to achieve than the first step, as wholesalers

are the only stakeholders involved. The suppliers, also, have the opportunity to start using the RFID tags in their internal operations.

Step 3) Having the biggest improvement potential in goods receiving, the wholesalers may start to offer shipments with RFID tags that would enable customers to automate the receiving process by matching the goods with the orders electronically, which would reduce errors. If the initial service offered proves to work for the customers, it may spark the use of RFID tracking even further down in customers' operations – for instance, in stock management.

Because customer companies perceived RFID tracking to be useful, they would be willing to adopt it if wholesalers helped them increase the ease of use to overcome the effort. The wholesalers' motivation to strive for this step is the possibility of strengthening their relationship with customers by improving services based on high reliability and better visibility, which would facilitate customers' order receiving.

The participating wholesaler companies were willing to take the role as initiator in the deployment in the Technical Trade case study. They did not perceive the adoption of RFID tracking as too difficult, because they felt their operations and processes to be rather straightforward compared to their manufacturer's suppliers and customers. The wholesalers' purchasing power over suppliers may give them a good advantage to push through step 1 of the model, and then they can work internally with step 2. Step 3 can be seen as a long-term goal: The respondents of semi-structured interviews and internet inquiries of the case study identified the possible uses of RFID tracking but did not provide specific means for deployment. However, the next paragraph provides guidelines for the implementation of step 3.

As downstream companies were not willing to be proactive in adopting RFID tracking, the key issue in product user companies' adoption of RFID tracking for shipments – whether the accuracy is pallet, parcel or product – is that the system must be useful for them and not too difficult to adopt. In practice, the wholesalers need to offer a clear and usable service or solution to their customers. The interviews revealed that downstream companies are not likely to adopt RFID tracking if only generic tags are offered. Instead, interactive planning and cooperation in the development process is needed to ensure that customers can address their problems with RFID tracking. Cooperation in planning is also needed to overcome their fears of technological problems, costs and complexity. The best solution for wholesalers may be to follow the same idea that was used in the exploratory case study: take a few of their biggest and most technologically advanced customers and start cooperation with them. When RFID tracking can be shown to work with them, it will become easier to implement in a wider customer base.

5.3.3 Mechanism option 3: Tracking provided by an LSP company

The two mechanism options presented above rest on some or several active companies in the supply chain. In the first mechanism option, the focal actors are retailers, and in the second mechanism option, they are wholesalers. Both of these mechanism options require that at least focal actors need to be ready to familiarise themselves with the possibilities and requirements of RFID technology. As Paper II asserts, the companies may feel this is too challenging if

RFID tracking can seem complex and the realisable benefits seen unsure. In addition, the inter-organisational challenges might complicate the adoption when the supply chain sources from a wide variety of suppliers, and the retailing is delivered over logistics service providers and franchisees. For those companies who want to improve their operations with RFID tracking but find the initiator's position of RFID tracking adoption challenging, the tracking solution provided by the LSP company could be a suitable alternative. In the Clothes case study, an LSP company had introduced RFID tracking in its own service warehouse and gathered the know-how to offer RFID tracking for its customer companies as a solution, where tracking becomes part of the logistics services that the LSP company provides for its customers.

Figure 4 in subsection 5.2.1 presented three different options for applying RFID tracking: 1) "Supply chain-wide tracking", 2) "Postponed tracking start", and 3) "Postponed tagging". Different options are analysed as follows:

"Supply chain-wide tracking" is potentially the most beneficial, as well as the most resource-intensive configuration. It provides the greatest benefits, as tracking is started in the manufacturing echelon, but it is also quite demanding to implement. In this option, all the events related to the product between the manufacturer and the retail shop can be linked to the RFID tag, making it possible to determine the complete cost of the product, from the manufacturer to the retail store.

"Postponed tracking start" is a less demanding option, as tags are attached in the manufacturing echelon where it is the cheapest, but tracking between the manufacturing site and the warehouse of the LSP is not introduced. Most of the benefits in the supply chain-wide configuration can be achieved this way, but the costs for tracking are lower. Even if some events in the supply chain remain inexact, this tracking option still offers enough information to define the total cost of the product with sufficient accuracy because among other possible factors, all the transportation modes during the stages of incomplete tracking can still be known.

"Postponed tagging" is a configuration where RFID tags are attached to products just before they enter the operations of an actor capable of benefitting from RFID tracking. The most common place to attach RFID tags in this configuration is the retailer or LSP-operated DC. This option provides flexibility when flows of goods are complex. It enables tagging products that are sourced from any manufacturer, and tags only those products that are sold in certain shops. As such, however, this type of postponement is not especially cost-efficient for retailers. Even if this option is the easiest to implement, the information about product manufacturing cannot be obtained, and the item-level costs of products reaching the end-consumer cannot be reliably defined.

The proper alternative for each situation depends primarily on the desired intervention. However, if these three alternatives are compared based on the results of Clothes case study, "Postponed tracking start" is usually seen as the most beneficial alternative when evaluating the costs and potential benefits of tracking, because it would be most useful to tag products already in the manufacturing phase, but especially in fashion retailing, tracking products when they are somewhere between Asia and Europe brings little, if any, added value for the customers of the LSP. Still, the other two alternatives are also possible in certain situations. "Postponed tagging" is a proper alternative at

least for a certain share of the products in situations where the products are procured from multiple sources. In the long run, “Supply chain-wide tracking” may become a realisable alternative if other LSP companies handing the shipping between the manufacturer and the LSP company start to use RFID tracking in their own operations.

6 Discussion about the outcome

Outcomes are the results of interventions in a certain problematic context where the generative mechanisms have been used. While the previous chapter presented the context, interventions and mechanisms, the outcome was locked as the implementation of a supply chain-wide tracking system (or tracking system that covers a major part of the supply chain). In other words, subchapter 5.2 presents which kind of intervention should lead to the implementation of a supply chain-wide tracking system if some of the mechanisms presented in subchapter 5.3 are used. This chapter, however, unlocks the initial outcome and reassesses whether the interventions defined in subchapter 5.2 by using the mechanisms defined in subchapter 5.3 will actually lead to the initial outcome in the context defined in subchapter 5.1, or if there are possibilities that the initial outcome will remain unrealised. This analysis of alternative outcomes is made by using technological frames to compare the frames of different supply chain actors to RFID tracking adoption, according to the division of Orlikowski and Gash (1994) to three potential areas of conflict: (1) Nature of technology, (2) Technology strategy, and (3) Technology in use.

This chapter is organised as follows: Subchapter 6.1 lists the frames of different supply chain actors to RFID tracking adoptions according to the division presented above. Next, subchapter 0 analyses the misalignments in frames, and finally, subchapter 6.3 proposes how each mechanism can be used to align different frames of different supply chain actors to assure the realisation of the initial outcome.

The presented technological frames are premised on an item-level RFID tracking system to simplify comparison, because the level of tracking is also one issue: pallet-level tracking fulfills the primary needs of manufacturers, parcel-level accuracy seems to be enough for at least technical trade wholesalers, but retailers benefit most if item-level tracking is deployed.

6.1 Frames of the supply chain actors concerning RFID tracking

6.1.1 Nature of technology

According to Orlikowski and Gash (1994), Nature of technology refers to people's images of the technology and their understanding of its capabilities and functionalities. When the question was about RFID tracking technology, many companies had partly unrealistic enthusiasm towards the technology because it had been highlighted for several years, and the companies expected that RFID tracking could solve many of their operational problems, even if the successful deployment of RFID tracking required solving those operational problems first.

For a manufacturing company, RFID tracking is seen as a technology to specify products or shipments. RFID tags are seen as a step towards intelligent (Främling and Nyman, 2009; Meyer at al., 2009) or extended products (Thoben et al., 2001), which was seen especially on the Book Retailing and Technical Trade in-depth case studies. The participating printing house saw an RFID tag as a value-added technological solution for a book, which could help it compete against foreign competitors from countries with lower costs. There were similar thoughts with technical trade product manufacturers, which saw RFID tags as a

demonstration of their products' advanced technical level. However, during the case studies, the manufacturers soon realised that they needed to do a lot of work to convince their customers of the benefits of "intelligent" or "extended" products, as otherwise RFID tagging would only become an extra cost for a manufacturer.

For a wholesaler company, RFID tagging is especially seen as a technology to automate warehouse operations, which would improve productiveness by decreasing the need for manual work and, as follows, human error. In the Book Retailing, Technical Trade and Grocery case studies, the wholesaler companies were rather well informed about the costs and benefits of RFID tracking before the case study, even though some of them had old information and therefore considered the performance of the technology worse than it is today. Their awareness about the new logistics technologies was based on the fact that logistics is an essential part of a wholesaling business. However, when the wholesalers compared the implementation and usage costs of RFID tracking with their rather small margins, and where they operate, there was always some doubtfulness about the use of RFID tracking inside wholesaler organisations.

For a retailer, numerous existing cases of RFID tracking have increased the enthusiasm toward RFID tracking and its possibilities to develop operations in retail stores, solve multiple current problems, and, in that way, increase sales. Basically, retailers see RFID tracking as very positive, and they were usually prepared to take wider tests, but it was challenging for a retailer to convince upstream supply chain actors to participate in those tests.

For a third party (3PL) LSP company, RFID tracking is mainly seen similarly as wholesaler companies. As the stored products in the facilities of LSP are owned by their customer companies, the LSP needs customers that are interested in RFID tracking. If the customers of LSP are interested in possibilities to improve operations with improved tracking, LSP will probably be willing to increase the variety of its services and take more responsibility of its customers' supply chain operations.

Some supply chains, such as technical trade supply chains, also have remarkable industrial product end-users. For these supply chain actors, sourcing and how the products are received play an important role in operations. RFID technology interests them because problems in receiving incoming shipments confuse other operations. Therefore, these companies are interested in RFID tracking, but according to the interviews conducted in the Technical Trade case study, the companies also soon realised that it would not be useful for them to implement RFID tracking alone.

6.1.2 Technology strategy

According to Orlikowski and Gash (1994), Technology strategy refers to people's views regarding why their organisation acquired and implemented the technology, which includes their understanding of the motivation or vision behind the adoption decision and its likely value to the organisation.

Manufacturer companies' perspectives seem to be that tracking offers mainly indirect benefits for them, such as improving the accuracy and punctuality of the dispatched shipments. In addition, realising the benefits is not easy, and process re-engineering may be required. In manufacturers' SCM perspective, RFID-tagged products and shipments may be seen as a competitive advantage

and a way to keep customers happy. Alternatively, big investments with RFID tracking ties in with the customer. In total, manufacturers find the investments and use of RFID tracking expensive, while the benefits mainly fall to the downstream of the supply chain.

Wholesaler companies' perspectives seem to be that RFID tracking offers mainly possibilities to automate warehouse processes. For a wholesaler, RFID tags can be value-added functionality for a customer, and RFID tracking may increase the service level that the wholesaler can provide. However, RFID tracking may shift relative power from wholesaler to retailer. Therefore, wholesalers easily seem to settle on following the development without being the most active actor in the supply chain, especially if powerful retailers are present.

Retailer companies' perspectives seem to be that RFID tracking offers multiple verified possibilities to increase sales with numerous useful applications and rather easily capitalised benefits. In retailers' SCM perspectives, RFID tracking could increase the visibility of the whole supply chain, which could decrease stock levels of retail stores, but also out of stocks. Active promotion of RFID tracking is needed to move upstream in the supply chain to join the same system and to attach RFID tags in order to get the full benefits of tracking. RFID tracking may increase the relative power of the retailer. However, if a retailer is not prepared to examine its own operations to re-design them to optimise the effective use of RFID tracking, then the retailer may feel the benefits of RFID, for example, in simplifying e-commerce, as a threat to its current business.

LSP companies' perspectives seem to be that RFID tracking offers possibilities to save costs by automating warehouse operations. If an LSP has customers who are interested in RFID tracking, that LSP has the possibilities to enlarge its operations by taking more responsibility of coordinating its customer companies SCM, which may upgrade the status of LSP as a fourth-party logistics service provider (4PL) company (Van Hoek and Chong, 2001; Win, 2008). However, implementation of RFID tracking in an LSP company requires active marketing of the tracking solution to customers who are willing to invest in process development, because LSP needs to have a threshold share of customers to justify the investments.

Industrial end-user companies' perspectives seem to be that RFID tracking can be beneficial in automating the receiving process, which helps keep also other operations in better order. In the SCM perspective of an industrial end-user company, improved tracking may help follow the plans in schedule. Development of tracking enables these companies to involve suppliers more to process development and also helps control subcontracting. The potential benefits of tracking are clear for these companies, but they need suppliers to participate in tracking systems development.

6.1.3 Technology in use

According to Orlikowski and Gash (1994), Technology in use refers to people's understanding of how the technology will be used on a day-to-day basis and the likely or actual conditions and consequences associated with such use.

The amount of resources needed in RFID tracking implementation in a manufacturing company depends on the level that the company plans to use tracking: the Slap & Ship level of implementation requires only a limited

amount of resources, but finding profitable implementations would require an analysis of the company's existing processes and perhaps process re-engineering.

A wholesaler company uses RFID tracking primarily to automate its warehouse operations and decrease delivery times by having more predictable operation schedules. The adoption of technology may require only a moderate amount of resources, because usually the wholesaler has well-functioning operation systems, which support inter-organisational data exchange, and the logistics processes of the wholesaler are rather straightforward. When the tracking is used, the logistics processes are probably simpler in an ordinary worker's viewpoint, and therefore, educating new warehouse workers might even become simpler when RFID tracking is adopted.

A retailer company probably has multiple profitable alternatives to use RFID tracking, depending on the industry and type of products. RFID tracking may be used to simplify normal store operations, decrease shoplifting, increase availability of the products or customer shopping experience, etc. In addition, the retailer may re-engineer its operations to better achieve all the potential that improved tracking offers. However, the adoption of especially higher levels of tracking requires a lot of process development and training, even if the daily use of RFID tracking will simplify many store operations.

An LSP can use RFID tracking simply by automating its warehouse operations, which also increases the visibility of the customers. However, the technology also offers possibilities to improve customer service, but it requires close cooperation with customers. For an LSP company, adopting RFID tracking requires a lot of work, because a tracking system needs to be compatible with different kinds of customers' systems. However, knowledge of technical requirements and possible profitable tracking applications accumulates for an LSP company, which helps and encourages its customers to join the RFID tracking system.

If an industrial end-user company receives RFID tagged shipments, it can automate the receiving process, which also helps keep other processes in better order. This rather low-level application is relatively easy to adopt, because usually this kind of implementation would require only certain hardware purchasing and some modifications for the current systems. If RFID tracking is adopted as a part of company's own processes closer, there is a need to re-engineer the processes, which requires more work, but will probably lead to simpler work and especially smoother administrative processes.

Table 3 summarizes the different frames of different supply chain actors according to the three domains of Orlkowski and Gash (1994).

Table 3. Frames of supply chain actors concerning item-level RFID tracking adoption

		Manufacturer	Wholesaler / DC	Retailer	LSP (3PL)	Industrial end-user
Nature of technology	*What is RFID tracking?*	Technology to specify the products or shipments and a step toward more intelligent products	Rather expensive technology to automate warehouse operations	Interesting technology, which could solve multiple problems and increase sales	Technology to automate warehouse operations	Technology to improve receiving and in that way put operations in order
	Attitude towards RFID tracking when more information available	Increases their costs while the downstream gains benefits	Suspicious about the benefits comparing to the costs	Familiarization to existing use cases has probably even increased enthusiasm	Multiple opportunities to develop customers' business processes	Still interesting technology, but difficult to adopt
Technology strategy	*Main benefits of RFID tracking for a company*	Tracking offers mainly indirect benefits	Can save costs in logistics	Can be used to increase sales, multiple easily capitalized benefits	Can save costs in logistics	Improvements in receiving, which may reflect to other operations positively
	The benefits of RFID tracking in SCM	Attaching RFID tags may help to keep customers	Tags can be value-adding functionality for a customer	Increases visibility towards upstream of supply chain	Improved tracking can be value adding service for a customer	Improved tracking may help to follow the plans in operations
	Inter-organizational effects of RFID tracking	Big investments in RFID tracking ties with customers	May increase the power over suppliers and industrial end-users, but decrease over retailers	May increase the power of retailer. E-commerce might be seen as a threat	Increases the influence of LSP and offers possibilities to develop towards 4PL company	Opportunity to involve suppliers more to process development and simplifies subcontracting
	Motivation to participate RFID tracking adoption	Tracking can increase costs more than offer benefits, which hinders motivation	Tracking interests, but powerful retailers decrease the interest to be an active actor	Active promotion of tracking to other supply chain actors is usually in the interest of retailer	If tracking is applied, active marketing of solutions necessary	Tracking could be a good solution, but active promotion and being initiator difficult
Technology in use	*Where tracking could be primarly used?*	Difficult to find profitable applications	Automate warehouse operations, decreasing delivery times	Multiple different applications to use tracking already available	Improve customers' logistics operations	Automate receiving and keeping operations in order
	Resources needed to implement RFID tracking	The amount of required resources depend on the level that the technology is used	Technology adoption requires resources, but moderately	Technology adoption requires a lot of resources, outside help probably needed	Technology adoption and related development work requires a lot of resources	Rather small amount of recources needed to adopt technology
	Ease-of-use	Attaching RFID tags is simple, but re-engineering the processes might be difficult	Rather simple, may even decrease the training need of new workers	The productive use of technology requires process re-engineering and training	Might be difficult to combine different processes of customers	Needs process re-engineering, which can lead to simpler processes in future

6.2 Analysis of misalignments of frames

By analysing the different frames presented in the previous subsection, the following misalignments can be highlighted:

- *Misalignment of costs and benefits between the upstream and downstream of the supply chai*n. The upstream of the supply chain has to pay a rather high share of the costs, while their benefits are more difficult to capitalise than in the

downstream of the supply chain. In addition, evaluating the monetary value of these differences is difficult, as there are so many uncertainties regarding the calculations of actual costs and benefits of RFID tracking (Visich et al., 2009; Hellström et al., 2011). Therefore, the upstream of the supply chain might not even be interested in researching the benefits of RFID tracking in more detail, because they may fear becoming the payer of the system, although RFID tracking could be a beneficial technological solution for the whole supply chain perspective.

- *The relative power balance between supply chain actors will probably change,* especially if higher-level RFID tracking is applied. Rather high investments in RFID tracking and common information systems will deepen buyer-supplier relationships and increase the interdependence of the companies, because switching costs are rather high. RFID tracking literature is consistent in claiming that RFID tracking will increase the power of large retailers (e.g., Cannon et al., 2008; Soon and Gutiérrez, 2008; Bradley and Guerrero, 2010), but there are contradictory results about the transition of channel-leading power between manufacturer and retailer in IOIS implementations in general (Rajaguru and Matanda, 2013). On the other hand, if an LSP company applies RFID tracking, it has the possibility to increase its power by taking more responsibility of customers' SCM and binding the customer more closely with a single LSP.
- *Wholesalers and LSPs will prefer to save costs, while downstream companies, especially retailers, want to increase sales* with the help of RFID tracking. For an LSP company, the anticipated benefits of RFID tracking are the reduction of costs (White et al., 2008), while the Book Retailing and Clothes case studies indicate that consumer product retailer companies get the biggest benefits from RFID tracking by increasing sales by improving customers' shopping experience. The LSPs emphasis on saving costs is similar in wholesaler companies, whose business is also built around logistics. This mismatch of aims is in line with the notion of Asif and Mandiviwalla (2005), who pointed out that marketing experts emphasise the finding of added value for customers while supply chain experts tend to find cost savings.
- *Technical capabilities of company workers to execute RFID tracking do not meet the requirements of potential application areas.* Manufacturers have the best possibilities to integrate RFID tagging as a part of their operations, because tagging in this phase is the easiest to implement automatically. While manufacturers may not consider RFID tracking as useful, tagging is postponed in numerous supply chains in later echelons, where tagging needs to be done manually. Manufacturing companies may also have more technically oriented workers, who could contribute to the RFID tracking system construction, while in retailer companies, where the most tracking system implementation possibilities exist, the workers may not have the skills to understand different technologies, which makes these companies more dependent on outside help in tracking system implementation.

6.3 How different mechanisms to implement supply chain-wide tracking could align frames?

This subsection goes through all three mechanisms by summarising how they can contribute to the alignment of the differences of frames found. In the end of

the subsection, there is summarizing Table 4 which compares different mechanisms.

6.3.1 Mechanism 1:

Mechanism 1, "Retailer as an initiator", can be used to align different frames in the following ways:

First, in a typical supply chain, which consists of manufacturers, distribution centres and retailers, the more downstream in the supply chain, the bigger the benefits of RFID tracking (Vijayaraman and Osyk, 2006; Soon and Gutiérrez, 2008). Therefore, the retailer should have the highest motivation among the supply chain actors to implement RFID tracking.

Second, a retailer usually has a very strong negotiation power in the supply chain. Therefore, the retailer can use a mandate to enforce its suppliers to implement RFID tracking and fasten the implementation process.

However, the following differences in frames may remain when using this mechanism:

First, as the retailer will get the biggest benefit of supply chain-wide RFID tracking implementation and may increase its relative power in the supply chain, this mechanism is mainly based on the retailer's determination. Other supply chain partners probably will challenge the retailer's plans when the retailer announces its schemes to implement RFID tracking.

Second, if the retailer prefers to use a mandate, it may lead to a low integration level of tracking, which limits the possibilities of using the system for SCM purposes as in Wal-Mart's case.

In summary, if the retailer uses this mechanism for building supply chain-wide tracking systems, it needs to consider how to compensate the upstream companies for participating in common tracking system building. The retailer should also consider how its suppliers could benefit from increased visibility in the supply chain so that the upstream companies will not view the increased information exchange as a tool for retailers to get confidential supplier information to increase their negotiation power. The retailer company also needs to consider its resources to construct RFID tracking to ensure that the required technical and logistical understanding of the tracking system is present.

6.3.2 Mechanism 2:

Mechanism 2, "Wholesaler as an initiator", can be used to align different frames in the following ways:

First, in the Technical Trade case study, the downstream of the supply chain was not willing or even able to initiate the RFID tracking system building. In that case, the larger involvement of upstream supply chain actors is required. Industrial end-user companies expressed their willingness to get more exact deliveries and services from their suppliers, which is in line with the increased power of the wholesaler that building the RFID tracking system will produce.

Second, if the upstream of the supply chain is able to implement RFID tracking, downstream companies can more easily join the same system as "free-riders" (Whang, 2010), because RFID tags are already there; in reverse, enlarging the

system from downstream to cover upstream companies is more difficult, as the supply chain's echelon, where RFID tags are attached, changes every time the system enlarges more upstream.

However, the following differences in frames may remain when using this mechanism:

First, if the wholesaler company wants to be an initiator, it needs to cooperate with its suppliers and also inform its customers about tracking system building. Therefore, the prerequisite for this mechanism is the cooperation of several companies in different echelons of the supply chain.

Second, common standards have a bigger role in this mechanism than in a retailer-driven mechanism, because if the wholesaler wants its customers to adopt the same system, the used technologies and interface of the system to customer direction need to follow current practices of the industry. The retailer has better opportunities to define the used standards, as Wal-Mart did in its RFID tracking implementation (Drake and Schlachter, 2008).

Third, as the retailer will achieve the biggest benefit of supply chain-wide RFID tracking implementation (Vijayaraman and Osyk, 2006; Soon and Gutiérrez, 2008), upstream companies need to more carefully consider their own benefits of a potential tracking system if the biggest benefits fall to downstream companies.

In summary, if this mechanism is used, the wholesaler company needs to consider its role and processes in the supply chain with an open mind, because it is the key actor in this mechanism. The automation of processes may not justify the rather demanding adoption of this mechanism, but using improved tracking as the premise to improve service level and scope would probably be a decent reason for system building. Besides, the companies need to carefully consider the used technologies and standards.

6.3.3 Mechanism 3:

Mechanism 3, "Tracking provided by LSP company", can be used to align different frames in the following ways:

First, according to the Background Survey study (Paper I), companies aim to outsource warehouse operations, and a major part of their SCM to LSP companies if they would get the service they need. Regarding that trend, this mechanism becomes realistic, even for companies that have not yet outsourced their logistics considerably. On the other hand, if an LSP company is able to provide tracking solutions for its customers, companies are probably more interested in outsourcing their logistics, as outsourcing would improve their SCM by offering the new solutions for their SCM needs, which would not be possible without accurate tracking.

Second, as uncertain ROI (return on investment) is one challenge for implementing RFID tracking, as this mechanism enables the evaluation of the costs of tracking more exactly than the two other mechanisms, because an LSP company already has an RFID infrastructure and will continuously collect data about their customers' experiences. Similarly, the LSP company will obtain many of the benefits if RFID tracking is applied, and the LSP can use its experience and know-how to help its customer company in estimating the benefits beforehand and in offering guidelines to capitalise on these benefits.

Third, in the other two mechanisms, at least the initiator company needs relatively good knowledge about RFID tracking and the technology, if the company wants to implement and capitalise on RFID tracking. In this mechanism, the LSP company probably has good knowledge about RFID technology and standards, because the company has itself implemented the technology. Therefore, for the customers of the LSP company, technical knowledge is not as essential as in other mechanisms. In addition, if the LSP company offers similar tracking solutions for different industries and supply chains, the usable experience of RFID tracking in the LSP company accumulates more rapidly than in a single company which implements RFID tracking in its own supply chain.

However, the following differences in frames may remain when using this mechanism:

First, if an LSP offers tracking as a solution for its customers, effective tracking may require that the LSP takes a bigger role for other supply chain actors' SCMs. This, of course, increases the relative power of the LSP company.

Second, the differences in RFID tracking system's objectives (LSP seeks cost savings, while retailer customers look for increased sales) may still remain.

Third, the issues of responsibilities between the LSP and its customer may rise, if the customers have, for example, their own warehouses: Who, then, provides the hardware for these facilities, and who sets the conditions for this hardware?

In summary, if this mechanism is used, the LSP company needs to have customers who are ready to improve their logistics by giving a bigger role for the LSP company to take care of SCM. The LSP company needs to ensure that it has adequate resources to execute tracking and understand the processes of the customer, because the customer needs to trust the competence of the LSP to handle technical problems and provide added value for the customer. There is also a need to define the responsibilities between the customer and the LSP.

6.3.4 Comparison of different mechanisms

Table 4 compares how different mechanisms can align different frames of different supply chain actors but also indicates which differences may still remain.

Table 4. Comparison of different mechanisms.

	How this mechanism can align different frames?	Which differences may still remain, if this mechanism is in use?
Mechanism 1: "Retailer as an initiator"	1. A retailer has the highest motivation to implement RFID tracking. 2. A retailer usually has a very strong negotiation power in the supply chain (possible to use a mandate).	1. Upstream of supply chain may find it difficult to capitalize the benefits of RFID tracking. 2. Using mandate may lead to a low integration level of tracking.
Mechanism 2: "Wholesaler as an initiator"	1. Involvement of upstream may be in line with downstream of supply chain's willingness to involve upstream in SCM. 2. Enables downstream companies to join the system as "free-riders".	1. Wholesaler needs to cooperate with its suppliers and customers. 2. Common standards have big role. 3. Upstream companies need to carefully consider their own benefits of tracking.
Mechanism 3: "Tracking provided by LSP company"	1. In line with the trend of outsourcing more logistics operations. 2. Estimating costs and benefits of tracking can be easier. 3. Technical knowledge of RFID tracking is not so essential for the customers of LSP.	1. Increases relative power of the LSP company. 2. The differences between the objectives of RFID tracking system may still remain. 3. The issues of responsibilities between the LSP and its customer may rise.

7 Conclusions

This chapter starts by presenting the contribution of this thesis in subchapter 7.1. Then, in section 7.2, limitations of the research are discussed, finally followed by ideas for further research in section 7.3.

7.1 Contribution of this thesis

This thesis has developed new design theory by researching solutions for the practical and managerially relevant problems related to implementation of RFID tracking across the entire supply chain. Design science is so far a rather seldom-used approach in operations management problems, and therefore this thesis works as an example of how the combination of means-ends propositions in single-case studies and the use of CIMO-logic to synthesise the results of several case studies can be utilized to create a new design theory. The most relevant developed new design theory is presented in section 7.1.1 which summarizes the answers for the research questions of this thesis. Other theoretical contributions of this thesis are presented in section 7.1.2 followed by managerial implications presented in section 7.1.3.

7.1.1 Development of new design theory

The contribution of improved tracking to companies' SCM development needs

Supply chains have become geographically more dispersed, and they consist of numerous companies. Some major challenges for this development are to ensure that products and related information move forward as planned. Therefore, supply chain integration is needed, and smaller companies, in particular, want to secure this required integration by outsourcing a major share of their logistics management to a capable logistics service provider (LSP). In their vision, an LSP could be an integrator of different types of companies and their operating systems. But in addition to giving power in SCMs to LSPs, the companies also want to get feedback on their delivery performance in order to improve their operations. Industrial companies want to outsource a major part of their logistics management, which they feel not to be their core competence, but they would like to compensate for their decreased influence on SCM by utilizing the performance data that LSP can offer to improve the operations for which they remain responsible.

The vision of LSP's more central role in SCM clearly requires more integral supply chains with effective information sharing between LSP and the other companies of the supply chain. To realise separate examples of applications mentioned in section 5.1 as a part of the companies' SCMs, more accurate tracking is needed. Therefore, current barcode-based tracking, which is enough for the current operations of the companies, is not accurate enough in the future, if the SCM will be upgraded to the level that the companies desire.

The use of concepts postponement and speculation when defining the coverage of tracking in the supply chain

Designing the coverage of tracking in the supply chain requires the consideration of trade-offs between the benefits of supply chain integration that the improved tracking provides with the costs of building tracking systems.

Section 5.2 provides guidelines regarding how the SCM concepts postponement and speculation could be used to evaluate alternative coverage of RFID tracking by considering different possible supply chain echelons to tag the items and start tracking.

The supply chain strategy related to RFID tagging may change, while the adoption of RFID technology increases. At first, tagging of RFID tags is typically postponed to the downstream echelons of the supply chain, when only a limited share of possible distribution channels are able to use these tags. Later, more supply chain actors might be interested in sharing the larger costs related to speculative tagging, as the possible users of RFID tracking increase among the companies of different distribution channels.

Section 5.2 presents several reasons why postponement could be applied in tracking system design, at least in the first phase of adoption. These reasons can be summarised in the following list:

1) If only a small share of certain batches or products end up for a distribution channel that is able to use RFID tags, postponed tagging decreases the number of excess tags.
2) If the products are sourced from multiple suppliers, speculative tagging may be expensive to arrange, especially if the supplier has numerous other customers that do not need RFID tags in their products.
3) If only a small share of retailers or other customers are able to use RFID tags, postponed tagging of the products of those customers that can use RFID tags, is probably justified, especially if the benefits of RFID tracking in DC's or in other places in midstream do not cover the expenses of tracking.

In addition, despite the speculative tagging, tracking start can be postponed to later phases of the supply chain if upstream tracking is too expensive to arrange and brings only little added value for SCM.

On the other hand, speculative tagging is an applicable strategy in the following circumstances:

1) If a remarkable share of a certain batch or product ends up for a distribution channel that is able to use RFID tags, the costs of excess tags are probably lower than the costs of postponed tagging.
2) If improved tracking aims to contribute to the problems that concern the whole supply chain or require upstream tracking, for example, tracking the authenticity of the product, speculative tagging is the only option to achieve these aims.
3) If the shrinkage of the products is a problem in the different echelons of the supply chain, speculative tagging in the manufacturing echelon enables the attachment of an RFID tag inside the structure of the product for complication purposes. For example, preventing shoplifting, and helping identify the ownership of the found product.

Presentation of different mechanisms to implement RFID tracking

This thesis presents three different mechanisms that would enable the adoption of supply chain-wide RFID tracking: 1) Retailer as an initiator, 2) Wholesaler as an initiator, and 3) Tracking provided by an LSP company. These options are compared as follows:

Mechanism option 1, "Retailer as an initiator", is a worthy option, especially for the supply chains, where the large retailers dominate. The retailers will get the biggest benefits if RFID tracking is applied, and they usually have a strong negotiation power over suppliers. Most of the existing RFID tracking solutions are based on this mechanism.

Mechanism option 2, "Wholesaler as an initiator", is a worthy option, especially for the supply chains, where the retailers have a minor role or the products end up for other kinds of actors than retailers such as industrial companies. In these kinds of supply chains, wholesalers or other kinds of distributors typically have a major role. For wholesaler companies, RFID tracking offers possibilities to improve sourcing with the most important suppliers and also improves opportunities to develop new solutions and business concepts for its customers by contributing more to customers' operations.

Mechanism option 3, "Tracking provided by an LSP company", is a worthy option for various kinds of supply chains, especially if the companies consider RFID tracking as useful, but do not have the required resources to design and implement RFID tracking and must rely on LSP company, which can accumulate its knowledge related to RFID technology. This option enables all sizes of companies to take an active role in RFID tracking implementation, for example, for small- or medium-sized retailers. For an LSP company, this option provides possibilities to have a bigger role in its customer companies' SCM.

7.1.2 Other theoretical contribution of this thesis

The name of this thesis, *Implementation of RFID tracking across the entire supply chain*, indicates that its main contribution is in the field of SCM. While the adoption of tracking integrates the supply chain, and in mainstream SCM literature, the increased integration is seen as an aim for SCM (Cooper et al., 1997a; Pagell, 2004), the trade-offs in coverage of tracking that this thesis analyses contributes to the recent research regarding when supply chain integration is useful and when it is not (Fabbe-Costes and Jahre, 2007; Gimenez et al., 2012).

Actors approach and technological frames are seldom used in logistics and SCM research, although the use of actors approach is encouraged to solve complex problems of SCM (Gammelgaard, 2004; Mirzabeiki et al., 2012). This thesis attempts to analyse how supply chain-wide RFID tracking could be adopted by understanding the different frames of different supply chain actors and how these frames could be aligned to build tracking systems that could be realisable for each supply chain actor.

Numerous review articles and books have been written after 2000 about the use of postponement in the SCM (e.g., van Hoek, 2001; Yang et al., 2004a; Yang et al., 2004b; Boone et al., 2007; Cheng et al., 2010). All these papers consider how postponement strategy could improve the efficiency of the supply chain. The only place in these articles where the concept of "speculation" is mentioned is when they refer to the Pagh and Cooper (1998) article, where concept speculation is part of the title of the article. The lack of the use of concept speculation indicates that in the SCM literature of the 21st century, speculation is no longer considered as a realistic SCM strategy, even if, in the article of Pagh and Cooper (1998), full speculation was mentioned as one possible option among the presented four in a 2x2 matrix. However, in the RFID tagging and tracking context, speculation is a realistic option, which indicates that current

postponement literature should not eliminate the existence of speculation as a possible SCM strategy.

7.1.3 Managerial implications

First, this thesis presents how improvements in tracking are needed to respond to companies' needs for tracking in the current global business environment. Improved tracking increases visibility in the supply chain and enables more advanced SCM.

Second, this thesis asserts that, although supply chain-wide tracking may be a long-term goal for achieving a responsive supply chain, in practice, some trade-offs between the costs of enlarging the tracking coverage to span more supply chain echelons and the potential benefits need to be done. In this thesis, the SCM concepts postponement and speculation are used for this comparison to outline which kind of tracking coverage is realisable and executable.

Third, this thesis presents how a retailer, wholesaler or LSP company may lead to supply chain-wide RFID tracking adoption. In a retailer-driven adoption mechanism, the main issue is that retailers usually consider RFID tracking as useful and are able to find multiple possible applications, but they need to show the upstream of the supply chain that the supply chain-wide tracking is beneficial to sustain the competitiveness of the supply chain. Then, the next issue in this mechanism is to consider how the benefits could be shared between different supply chain actors, because the upstream of the supply chain needs to use a relatively large amount of resources to participate in common RFID tracking system building. For a wholesaler, improved tracking offers new possibilities to improve operations and participate more particularly in its industrial customers' processes by providing more punctual and exact deliveries. However, if the wholesalers want to initiate RFID tracking adoption, they need to cooperate with suppliers and customers to find new business models that higher-level integration with tracking could offer in order to justify rather high investments. For an LSP, improved tracking offers new possibilities to take a bigger role in customer companies' SCMs, which can be used as a step towards a fourth-party logistics service provider (4PL) company. However, regardless of the initiator company and the related mechanism, high-level information systems integration requires cooperation to consider other supply chain actors' viewpoints to adoption. In addition, using common standards are prerequisites for designing and implementing tracking systems that would cover several supply chain actors.

7.2 Limitations

There are some notable limitations to the findings of this dissertation.

First, the question of external validity is a remarkable challenge to the case study research (Yin, 1994; Gibbert et al., 2008). Papers III, IV V and VI are based on single-case studies, where the unit of analysis is a supply network of a certain industry. Each of these supply networks can be seen as unique to a varying extent, thus raising the question of the level of generalisation of the claims presented in those case studies. Therefore, there is no guarantee that the findings reported in Papers III, IV, V and VI hold universally. Instead, further research with other supply networks will likely provide clarifications, elaborations or even partial falsifications of the findings presented in those papers. However, to improve external validity, the different types of qualitative

and quantitative data collection methods were combined in case studies, which revealed multiple viewpoints to the research subject. The applied mixed methods research is argued to provide a richer understanding and more robust explanations for complex SCM phenomena (Boyer and Swink, 2008; Golicic and Davis, 2012), as the implementation of supply chain-wide RFID tracking can be considered. Later, after finalising the case studies, it was possible to perform a cross-case analysis to find consistent factors that could support external validity, and differences indicating lacks in validity.

Second, this thesis handles RFID tracking adoption, but so far, most of the tracking solutions presented in the case studies have not yet been realised. Therefore, the case studies include multiple assumptions, which might be proved to be incorrect when the actual installation is done. For that reason, particularly the results of the simulation model (see subsection 3.2.3) have to be considered as being rather suggestive instead of exact realisable values. In addition, three different RFID tracking implementation mechanisms presented in Section 5.3 should be regarded with this viewpoint, meaning that the mechanisms will become more exact when the actual tracking systems are built.

Third, the concepts proposed in this thesis are based on relatively simply supply chain settings which include a manufacturer, a wholesaler or distribution centre, and retailer or product user. This reduction of complexity was necessary to describe dependences between actors and to create mechanisms. However, in practice the supply chains are usually more complex which mean that those other actors may have an influence in RFID tracking implementation and the mechanisms do not consider all the effectual factors.

7.3 Future research

As already noted, the research of this thesis is based on the design science methodology, where the CIMO-logic was used to synthesise the results (Denyer et al., 2008). However, the use of design science in the field of SCM is still a new and rather rarely used approach, which means that the number of papers in the field of SCM that use design science as a methodology is limited. In addition, the design science as a methodology is also under development. Therefore, the research presented in this thesis can be used as case material when developing design science methodology further.

The use of actor approach and technological frames could be used more in SCM and operation management research. This thesis works as an example of employing those approaches, but because of the scarcity of their use in the discipline, it is too early to state to what extent these approaches could be contributed in SCM research. Therefore, more research based on actor approach and technological frames is needed within the SCM domain.

RFID tracking is spreading rapidly, and most probably in the near future, it will be possible to test the proposed mechanisms with empirical data from actual RFID tracking implementations. Then, it will be possible to test and modify the mechanisms to achieve a better consideration on their transferability in different settings.

All of the cases of this thesis use RFID as tracking technology. Therefore the results presented in this thesis cannot directly be generalised to cover other tracking technologies, even if the results are probably technology independent

to some extent. To ensure the generalisability of the results, studies with other technologies are also needed to verify the results.

Even if this thesis contributes to recent supply chain integration literature by challenging the usefulness of integration in every case, this approach needs more research. The Clothes case study illustrates that a big share of current supply chain-wide RFID tracking applications is in the fashion and apparel industries, where many supply chains are typically vertically integrated and customers' expectations of the products fulfil rather well the three criteria (high variety of products, small batches, high expectations with regard to flexibility and quality) that Gimenez et al. (2012) propose to be a prerequisite for situations where supply chain integration is the most beneficial. However, in the Book Retailing case study, these three criteria fulfil at least to the same extent as in the fashion and apparel industries, but in book retailing, RFID tracking implementations are still rare.

8 References

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Appendix A: Interview guide for the Background Survey of logistics needs

Multiple question form

The following are claims for quantitative analysis. Please tick the option that best describes the situation in your company:

(5 = totally agree, 4 = partially agree, 3 = neither agree or disagree, 2 = partly disagree, 1 = totally disagree)

	QUESTION	5	4	3	2	1
1	The **speed** of transportation is a very improtant factor when considering the selection of the transportation mode in our company.					
2	Flowing logistics and transports, in particular, are important, competitive factors for our company.					
3	Our company uses **sea freight** in many of its transports.					
4	Our company uses **rail freight** in many of its transports.					
5	Our company uses **truck freight** in many of its transports.					
6	Our company uses **air freight in many of** its transports.					
7	Our company uses as fast as possible **express freight** a great deal in its transports.					
8	The transportation modes that our company uses vary a great deal, depending on the urgency.					
9	The **price** of transportation is a very improtant factor when considering the selection of transportation modes in our company.					
10	Additional factors other than speed or price are also meaningful to our company when selecting transportation modes.					
11	Environmental factors play an important role in our company when selecting transportation modes.					
12	Our company's transportation needs are very seasonal.					
13	We can forecast our company's transportation needs rather well.					
14	Our current supply of transport corresponds well with the needs of our company.					
15	Our company would use wider base of suppliers if the transportation supply was better.					
16	Our company would provide its products to a wider area if the transportation supply was better.					
17	It is our company's responsibility to organise transport for our suppliers.					
18	Our company sets strict requirements for transports from our suppliers (e.g. schedules).					
19	It is our company's responsibility to organise transport for our customers.					
20	The customer needs to adapt for our company's requirements for their transport (e.g. schedules).					
21	We believe that our company's transport requirement needs are generally similar to others in our industry in Finland.					

Interview questions for semi-structured face-to-face interviews

1. What is the industry of your company? In the beginning of the interview, we would like to hear your views about the development of the industry where your company operates. How widely can you and would you like to discuss the industry?
2. What kind of value chain does your company's industry use, and what is the concrete form of the demand-supply chain?
3. Globally, where are the most important companies, customers, subcontractors and suppliers in your industry?
4. What kinds of structural changes has your industry gone through during the past five years?
    a) Has the number of companies of your industry changed? (Mergers, new entrants?)
    b) Has the location of operations changed?
    c) Has the other value chain changed, or the location of other parties changed? Have the subcontracting chains changed?
    d) Has the location and needs of customers changed?
    e) Has the location of inventories, inventory levels or turnovers changed?
    f) How have the transportation needs of the industry changed?
5. Where, on a global basis, are the most important companies, customers, subcontractors and suppliers of your company located?
6. Has the operational development of your company been similar to other companies in your industry?
7. Currently, what are the most important transportation routes of your company including transports from suppliers to customers?
8. What are the amounts of transports in these routes on an annual or monthly level?
9. How often does your company use these transport routes, and what is the size of a single transport?
10. What transport modes are used in these routes?
    a) Why?
    b) What are the selection criteria for these routes?
    c) What is the order of importance of these transport routes?
    d) What kinds of problems you have encountered in current transports and modes of transports?
    e) Have you considered other modes of transports? Do you have enough information about other means of transportation?
    f) What factors could change your current transportation modes in the future?
    g) Do the other companies in your industry use the same transportation modes? If not, do you know why they use different choices?
11. How big a share are the transportation costs in the price of the products that either your company pays (for your suppliers) or your customers pay (for the products they purchase)?
12. Is the current supply of transports enough for your company's needs? Does the lack of supply cause extra challenges for your company?
13. How, in your opinion, does the location of your company in Finland influence your future operations?

14. Is it possible that your company could gain savings or otherwise competitive advantage in its operations if it placed its operations elsewhere? (e.g., new EU countries, China, Brazil)?
    a) If a relocation would bring savings, in what area? (e.g., personnel costs, location close to the customer or cheaper suppliers)?
    b) In your viewpoint, how would a relocation affect the supply-demand chain and change the operations of the chain?
    c) How would the transports change, especially considering Finland?
15. What kinds of added services would you like to get from your logistics service provider?
16. To what extent are these issues that we have discussed generalisable for your industry as a whole?
17. If transportation costs dropped remarkably (e.g., halve from current prices), how would your company's operations and transports change?
18. If your company's logistics budget were unlimited, what investments would you make, and how you would change transports?

The form of internet inquiry

The internet questionnaire included the following parts:

1. The same multiple question form presented below
2. Open spaces for the respondent's company name and industry. The respondent could also give his or her e-mail address to obtain the results of the study.
3. Open questions, which were the same as questions 8-18 in the semi-structured face-to-face interview.

Appendix B: Guidelines for interviews in the Technical Trade case study

This interview guide was used for conducting semi-structured face-to-face interviews for the representatives of case study participant companies in the Technical Trade case study. The interview guide is proposed for a manufacturing company. Some of the questions are not relevant to wholesaler companies and can be omitted. Some questions also need some reformulation, if asked of the wholesaler.

1. Discussion about the company in general:
   The interviewer has researched information about the company beforehand on the internet, and the purpose of this question was to verify public information and perhaps get some additional inside information about the company.
2. What is the industry, and where does the company operate?
3. What are your main competitors?
4. What are your company's strategic plans for the near future?
5. Discussion about the production:
   a) Where are your company's production sites? Has there been any movement in the location of production?
   b) What is the output of production on a daily / weekly / monthly basis?
   c) How many different SKUs and product groups does your company produce?
   d) Describe the phases in the production process.
   e) What are the critical phases in the production process?
   f) What are the main problems in the production process?
   g) How long does it take to manufacture the products?
   h) How large are the production batches that your company produces?
   i) What is the automation level of the production?
   j) How many workers are in your company / this site employ in production?
   k) Do you work in shifts?
   l) What is your company's production strategy (make-to-stock, make-to-order, assembly-to-order, etc.)?
   m) What is the time span that you can promise to your customer if he wants to order typical make-to-order products?

   Usually, all these questions were asked after the visit in the production and logistics facilities of the company, and therefore the purpose of this and the following question was mainly to complete the information obtained in the observation tour.
6. Discussion about logistics:
   a) Do you have traffic between different operating sites?
   b) What is the number of handled units daily / weekly / monthly?
   c) How often do you have deliveries from this site?
   d) Describe the phases in the dispatching, warehousing and receiving processes.

e) How often and how much do you use pallets? What are the shares of full pallets, mixed pallets and short pallets?
f) How many gates do you have at your warehouse in receiving and dispatching? Are they all in use and necessary?
g) How many different SKUs does your company stores?
h) What is the size of your warehouse?
i) What are the critical phases in the logistics processes?
j) What are the main problems in the logistics process?
k) Which companies handle your logistics? Have you outsourced warehousing?
l) How soon your company can deliver make-to-stock products to its customers?
m) How many workers does your company / this specific production site employ in logistics?

7. Discussion about suppliers:
   a) How many suppliers do you have?
   b) Which suppliers are the most important (critical products, big amounts)?
   c) Where are your suppliers located?
   d) Does some other case study participant belong to your suppliers? Do you have traffic between different operating sites?
   e) How often you have deliveries from suppliers?
   f) Have you done VMI applications with your suppliers?
   g) Have you encountered any problems with your suppliers?
8. Discussion about customers:
   a) How many customers do you have?
   b) Which are the most important (critical products, big amounts)?
   c) Where are they located?
   d) How important are the wholesalers participating in this case study?
   e) Do some other case study participant companies belong to your customers?
   f) How often do you make deliveries to customers?
   g) Have you done VMI applications with your customers?
   h) Have you encountered any problems with your customers?
9. Do you subcontract your production? If so, how much? Why? Is subcontracting increasing or decreasing?
10. Discussion about information systems:
    a) What is your ERP provider?
    b) What kinds of information systems does your company use?
    c) Have you used inter-organisational information systems or other electronic trade applications such as EDI with your customers or suppliers?
    d) Have you used any other e-business applications?
11. Discussion about the used standards and markings:
    a) What kinds of barcodes does your company use? Is EAN code in use?
    b) How do you mark an individual, manufactured product?
    c) How do you mark an individual parcel?
    d) How do you mark an individual pallet?
12. Have you had any interests / tests with RFID before this case study?
13. Why did you decide to participate in this case study?

The use of RFID (Radio Frequency Identification) tracking to improve the supply chain management of today's complex and geographically dispersed supply networks has been highlighted in the past 10 years. Even if the use of RFID technology to smooth certain supply chain operations has grown rapidly, the number of supply chain-wide tracking systems, which would be highly integrated with the operations across the whole supply chain, has remained low. The aim of this thesis is threefold. First, it aims to study the context in which companies operate to thus understand their tracking needs in ever-changing operational environments. Second, the thesis develops the means to define the most suitable coverage for the tracking system for particular supply chains, and third, the thesis proposes three different mechanisms to implement supply chain-wide RFID tracking systems.

Aalto-DD 138/2013

ISBN 978-952-60-5318-9
ISBN 978-952-60-5319-6 (pdf)
ISSN-L 1799-4934
ISSN 1799-4934
ISSN 1799-4942 (pdf)

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