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Aspects of product tracking systems in the supply network for caught seafood

Molde University College
Specialized University in Logistics

PhD theses in Logistics 2012:1

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Dissertation submitted to Molde University College
Specialized University in Logistics
for the degree of Philosophiae Doctor (PhD)

PhD theses in Logistics 2012:1

Molde University College – Specialized University in Logistics

Molde, Norway, 2012

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NO-6402 Molde, Norway
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This dissertation can be ordered from Molde University College Library
Biblioteket@himolde.no

Printing: EKH Trykk AS

ISBN: 978-82-7962-137-9
ISSN: 0809-9588

Preface

The information systems and supply chain management literature seems to indicate that succeeding in implementing a tracking system in a supply chain is wrought with difficulty even though the literature posits a long list of beneficial effects from using such systems. The supply chain management literature also holds that these beneficial effects accrue because of the improved quality of the information made available by the system to the supply chain players.

This thesis focuses on questions concerning the adoption of such systems in supply chains, the possible improvements in the information quality available to supply chain stakeholders and the possible effects that such improved information quality can have on supply chain effectiveness and efficiency. These questions are mainly approached through a discussion of the literature from the field of information systems concerning the adoption of inter-organizational systems and information quality and the literature on the field of supply chain management about the impacts of tracking systems. They are also approached empirically through a multi-case field study of several tracking systems implemented in the supply network for caught seafood in Northwestern Europe.

The neighboring East Atlantic is a rich fishing area where large amounts of seafood are captured by fishers from various nations, including Russia and Norway. Owing to the perishable nature of the catch and the remoteness of the fishing grounds relative to the main markets, a substantial part of the total catch is frozen at sea and then landed at the closest terminals along the long Norwegian coast. While the fishing vessels turn back to continue fishing, the catch is transported onwards to processing industries in Western Norway, the EU and the Far East by various modes of reefer transportation (reefer vessels, reefer containers or refer trailers).

This is a value chain where control is important to ensure that the product arrives at the correct destination without a loss of quality. During transportation, however, mistakes do happen, and as fish has become a scarce, palatable source of protein in high demand, and therefore an expensive product, losing a pallet because of incorrect tally, insufficient cooling or other errors can result in substantial claims, delayed payment and a lot of extra corrective work for the companies involved.

To reduce the number of mistakes, one shipping company has decided to implement a product tracking system in the supply chain and to try to convince the terminals to provide each pallet with a unique barcoded identity, which can then be “shot” with a barcode scanner when loading and unloading to ensure correct tally. After a while, one of the terminals decided to join the tracking project. The terminal wanted to extend the tracking system with a functionality that could support the terminal’s operations. The companies launched a joint research and development project around the initiative. This thesis is one of the results of the project.

The thesis also touches on a more important question for the seafood industry made topical by the United Nations Environment Programme, which maintains that the global catches of seafood peaked in the early nineties. This means that unsustainable fishery could be the main threat to the seafood industry, an industry that has considerable importance for the global population both from an economic and from a nutritional point of view. Therefore, it is an interesting question whether and how product tracking systems contribute to meeting that threat by supporting sustainable supply chain management practices.

Acknowledgments

A PhD project is as much a socialization process as it is a learning and research one. For me, the process has been an interesting and pleasant change from my lifelong work as a teacher of science, mathematics and information systems in secondary and higher education.

The PhD project was part of a BIP (user-steered innovation project[1]). The PhD and BIP industrial research project have been generously supported by the SMARTRANS program of the Norwegian Research Council. Here, I should especially mention our project secretary, Asle Johansen, who contributed to a well-structured project with a focus on the research goals.

Two industrial partners, a reefer shipping company and a third party logistics provider, constituted the arena for the main strand of research within this project. I am deeply grateful for the welcoming and openness with which I was received by the companies with special mention to Hans Martin Iversen, Elin Pettersen, Ståle Iversen, Øystein Høgden, Bjørnar Bendiksen and Stig Tommy Jenssen of Eimskip CTG, Leif Sperre, Sindre Eide and Kjell Vegsund from Tyrholm & Farstad and also a number of other participants in their supply networks, including the IT partners Robert Hansen and Espen Amundsen from EDI systems. A one-week field research trip on board a reefer vessel along the Norwegian coast to the Netherlands, UK and back stands out as a particularly interesting experience.

I also want to recognize the important roles played by many of my colleagues at the Molde University College. First, my supervisor Harald M. Hjelle, who defined the initial high-level research questions, also provided further structuring and guidance for the project as well as inspiring feedback on a number of written products. Harald has also participated as a researcher and project member in the industrial research project. Second, Berit Helgheim gave me an exciting introduction to the field of SCM research. Third, Bjørnar Aas commented on the early drafts of most of my papers and gave important tips on how to frame them. Bjørnar also pointed out the value of introducing additional cases, which lead to fruitful additional fieldwork in the UK, Norway and Denmark. Kai A. Olsen, Irina Gribkovskaia, Ketil Danielsen, Bjørn Guvåg and Berit Helgheim have also provided helpful feedback on one or more papers, while Lise Lillebrygfjeld Halse gave feedback on this thesis. The College has also been a superb, supportive and motivating work environment.

A stay abroad is mandated by the PhD program, and I want to thank the Transportation Research Institute (TRI) of the Edinburgh Napier University for receiving me for a six-month period. At the TRI, I received inspiring counseling as well as financial and moral support for a research trip to Shetland from Margaret Grieco. The TRI also proved a fertile and motivating working environment, where I received valuable input from Margaret, Alf Baird and Jason Monios. I am particularly grateful for the way the staff and fellow visiting researchers at the TRI received me into their community and for involving me in some of the many activities conducted by the institute.

[1] The term BIP belongs to the Norwegian Research Council and refers to projects that are governed by a defined user and not the involved research institution.

This PhD study also required my participation in a number of courses and seminars. Here, I particularly enjoyed the fall 2008 course in research interviews at the Århus University and the fall 2010 course in supply chain management research at the Ålborg University, both in Denmark. As my project is multidisciplinary, I have also attended conferences within a number of research areas including Information Systems (IRIS 2009 in Molde), Logistics and SCM (NOFOMA 2009 Jönköping, Steyr, 2010, NOFOMA 2011 Harstad), Transportation (NECTAR 2011 Antwerp) and Operations Management (EUROMA 2011). At all these conferences, I received stimulating comments and suggestions from reviewers and delegates.

Finally, I want to thank my wife, Kjellaug, for her supportive attitude, which has helped me complete this work.

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Abbreviations

AutoID	Automatic Identification Technologies (RFID or barcode)
DOI	Diffusion of Innovation Theory
EDI	Two meanings: 1)Electronic Document Interchange: The exchange of standardized electronic business document) or a more relaxed definition: 2) Electronic Data Interchange, the exchange of more or less standardized data between business partners using e.g. traditional electronic document standards, XML or flat files. In this thesis the relaxed definition is used and also includes the more stringent meaning.
ERP	Enterprise Resource Planning system. A comprehensive business support system containing a centralized repository for data for several business functions, including at least a module for accounting.
IOPTS	Inter-Organizational Product Tracking System
IOS	Inter-Organizational Information System
IQ	Information Quality
IS	Information Systems
IT	Information Technology
ICT	Information and Communication Technology
RFID	Radio Frequency Identification
SCM	Supply Chain Management
SSCC	Serial Shipment Container Code: A standard for identifying shipped units, i.e. boxes, pallets or containers.
sSCM	Sustainable SCM
SME	Small and Medium-sized Enterprise
TAM	Technology Acceptance Model
UPC	Universal Product Code. A barcoded product type identity used e.g. for grocery checkout in the US from the early seventies.

1 Introduction

Electronic inter-organizational product tracking systems (IOPTSs) combine technology for the automatic identification of product items with an inter-organizational information system (IOS) aiming to collect and disseminate information about the movement of products through a supply chain.

For researchers in food science, tracking systems are also known as "traceability systems" because it can be beneficial to trace the sources of food problems. Researchers within supply chain management (SCM) often call them "RFID systems" because the radio frequency identification (RFID) technology for automatic identification has been widely heralded within SCM as the solution to many problems besetting supply chains.

This thesis uses the term *product tracking system* (or more precisely electronic IOPTS) to emphasize that such systems can serve other purposes than making products traceable and can use other automatic identification technologies than RFID. Section 11 gives a short introduction to the most common automatic identification technologies.

However, product tracking systems represent a new technology for integrating supply chains. Such systems could make more detailed real time information available to stakeholders and thereby prove far more valuable than are other integrative technologies in supply chains (Spekman and Sweeney, 2006). Several authors point to how the improved information quality (IQ) from such systems could lead to substantial benefits for the players in the supply chain, and also for consumers and for other stakeholders, including the greater society. Sections 2.4 and 2.6 discuss the possible improvements in IQ and the resulting potential benefits, respectively.

Taking all the potential benefits into consideration, it is surprising that tracking systems are still sparsely implemented in real world supply chains (Fries *et al*., 2010). There might be a number of reasons for the low adoption rate. For example, the IOS that is necessary to store and disseminate information captured when using AutoID technologies to track goods through a supply chain could be an expensive technology to implement. Implementing such systems is challenging because of the large amount of data that needs be handled when tracking every movement of each product item. Also, major integration challenges might have to be handled because the tracking of individual items is not compatible with the account-centric data model of most material handling systems, including enterprise resource planning (ERP) systems, which are currently carrying out the bulk of information processing in businesses (Ilie-Zudor *et al*., 2011; Rönkkö *et al*., 2007). Integration is also a challenge at the organizational level, because new working procedures must be introduced to obtain consistent high quality tagging of product items with AutoID tags (barcodes or RFID) and the reliable capture of information about product movements. Finally, the main challenge might come at the inter-organizational level, because implementation throughout the supply chain is necessary for the full realization of the benefits of this new technology. Implementing throughout the supply chain means that other supply chain players must be enrolled in the system, and such enrolment can be hard to obtain when the costs of tagging and the benefits of doing so can be asymmetrically distributed. Further, detailed information about the movement of goods could reveal valuable internal information to competitors or counterparts. Section 2.5 covers some relevant research issues when discussing the adoption of tracking systems in supply chains.

Tracking systems are still in their infancy, and there is a lack of empirical research on such systems (Sarac *et al*., 2010). There are a number of possible research questions about the adoption of tracking systems, the IQ improvements that could be delivered by them and the benefits that might be obtained when using improved IQ to serve real world supply chains.

Obviously, a single PhD project can only scratch the surface of the problems mentioned above. It is thus necessary to delimit the research to form an approachable piece of work. The empirical objects for the study – a handful of real world tracking system implementations in the upstream supply chain for wild caught fish in Northern Europe – constitute the first delimitation. Further delimitation is described through the definition of the research questions in the last part of this introduction.

The study must be multidisciplinary because the questions raised span from logistics and SCM to themes from information systems (IS) and software engineering, with a sinister background of depleting fish resources, a global economy with fierce competition for resources and a number of recent food scares (Knowles *et al.*, 2007), all of which seem to make tracking systems more necessary and beneficial.

The research conducted in this PhD project treats an emergent and complex technology, where conceptual knowledge about the technology is scant among supply chain players. Thus, several methodological approaches have been applied. These have mainly been qualitative ones based on interviews with central actors within the supply chain, participant observations of operational activities and document studies. In addition, text available on the Internet and in newspapers has been studied. Quantitative methods have also been applied to operational data and documents. A full discussion of the methods applied can be found in Section 3.

1.1 From theoretical and empirical gaps to research questions

Studying the existing theory and empirical data covering the phenomenon of interest to identify gaps in that theory or the supporting empirical data constitutes a common approach to identifying relevant research questions . Theory and empirical results relevant to tracking systems can be found within several disciplines discussing such systems from different perspectives (Whitaker *et al*., 2007):

- In food science research, tracking systems are seen as a potential solution to the difficult problem of locating sources for the many food crises caused by food-induced illnesses (Knowles *et al*., 2007). A recent illustration is the five-week delay between the 2011 *E. coli* outbreak in Germany that killed 36 people and the localization of the source of the contamination. During those five weeks, a number of food products were under suspicion and their producers were hit by severe economic loss as scared consumers and authorities turned to other food sources. Tracking systems could support the swifter and less expensive location and subsequent “surgical” removal of offensive goods from the market.
- For logistics and SCM research , tracking systems are interesting because they can improve the visibility of goods through the supply chain, with a range of beneficial effects including the mitigation of expensive instabilities in the flow of goods (Lee *et al*., 1997a, 1997b),

which has been subject to much interest in SCM. RFID systems have thus been a high profile topic within the SCM area for the past 10 years.

- For IS research, tracking systems are relevant because IOPTSs are instances of IOSs. The adoption, or rather non-adoption, of such systems has been a major focus area within the IS field for over 25 years (Nagy, 2007). RFID follows the IOS pattern of slow or missing adoption in supply networks (Brown and Bakhru, 2007; Fries *et al.*, 2010). Sources from the IS and IOS fields might be consulted when trying to explain the lack of adoption and when theorizing about how to increase it. The perspective of the IS field is the adoption, use and benefits of information and communication technologies (ICTs) within organizations.

Identifying gaps in the existing knowledge is not enough; one should also justify that filling the gaps is worthwhile, both from a theoretical point of view – that it could generate new theoretical knowledge – and from an applied point of view – that the knowledge generated by the research could be used to inform managerial practices. That means that the practical goal of this research should be to support supply chain managers when evaluating, planning or implementing product tracking systems in their supply chains.

The high-level objectives when starting this research were to increase knowledge about the adoption process of product tracking systems in supply chains and about the resulting impacts on logistics effectiveness and efficiency for the companies involved.

For the three theoretical perspectives discussed in the previous section, gaps can be identified. Some of them can be partially filled by the results from other fields, whereas some have been approached by this work, but most remain open for further research.

1.1.1 The adoption and implementation of tracking systems

The SCM literature, by mostly discussing the beneficial effects of RFID, seems to have started by assuming that implementation in the supply chain is imminent because of the large benefits available, making RFID-based tracking systems a “technological imperative.” Subsequently, the RFID mandates imposed by channel captains such as Wal-Mart, Metro Group and the US Department of Defense have received much interest, and authors have used theories of power and dependency to explain RFID adoption. However, Lee and Özer (2007) summarize the state of SCM RFID research by discussing the partly failing empirical foundations for the posited benefits. The literature study by Ngai *et al.* (2007) finds no papers on RFID implementation and points out that there is a need to provide practitioners with guidelines on implementation. Furthermore, the literature review by Sarac *et al.* (2010) states that the empirical results from the adoption of RFID in supply chains is still largely missing.

The field of IS has a rich research stream on the adoption and benefits of inter-organizational systems based upon EDI (see Abbreviations) (Elgarah *et al.*, 2005). Early phases of this research stream in the ‘80s and ‘90s seemed to parallel current SCM research on RFID. EDI adoption research started by seeing EDI as a technological imperative around 1985, and then research entered a second phase where stagnation was explained using factor analysis to determine which factors lead to adoption or non-adoption. However, this research did not result in a single theory that reached consensus (Benbasat and Barki, 2007; Somasundaram and Rose, 2003). Afterwards, EDI adoption research was conducted using interpretative approaches, thus resulting in richer explanations involving factors from the individual to the global level (e.g. Damsgaard and Lyytinen, 1998).

Because tracking systems are also inter-organizational systems that seem to encounter similar adoption challenges in the supply chain to those encountered by EDI-based IOSs, it is surprising that the results of EDI adoption from the IS field have not been extensively applied when theorizing or empirically researching tracking systems adoption within SCM or food science.

A triple knowledge gap has thus been identified. First, there is an empirical gap regarding tracking systems adoption studies (Lin, 2009; Sarac *et al*., 2010); second, the fields of logistics and SCM, in which this thesis is positioned, has not taken into consideration relevant results from IS on EDI adoption; and, third, IS theory on the adoption of inter-organizational systems has not reached consensus despite more than 25 years of research efforts.

From an applied point of view, SCM practitioners desperately need knowledge on how to succeed with implementing product tracking systems in real supply chains to be able to profit from all the benefits that such systems could provide.

The first research question was developed from a surprising success observed in the main case study, where a private shipping company succeeded in implementing a tracking system within a substantial part of the supply chain largely composed of small and medium-sized enterprises (SMEs) that it services. The success challenges the current widely held assumption within the field of SCM that claims that you need to be a “Channel Captain” with the necessary power and vast resources to implement a tracking system within your supply chain. It also challenges a well-supported result from EDI adoption research, which holds that implementing such systems is especially difficult in SMEs (Iacovou *et al*., 1995, Chwelos *et al*., 2001, Morrell and Ezingeard, 2002).

To make the research question relevant for acquiring knowledge on practical relevance it can be formulated in this way:

> *Q1: How can a player with low power use various strategies to succeed in implementing a tracking system in its supply chain, and why are those strategies effective?*

This question is researched through a single explorative case study and tests strategies discussed in the IS and SCM literature.

The second research question goes one step further by aiming to develop a decision support model to help practitioners considering the construction of a tracking system. The actor that first decided to adopt a tracking system (i.e., the tracking system initiator (Fries *et al*., 2010)) will have to take decisions on what technologies to implement. Those decisions have far-reaching and difficult to assess consequences on how successful the implementation will be in terms of penetrating the supply chain. Thus, a technological choice model could be beneficial from a practical point of view. From a theoretical point of view, the research question could help fill the theoretical gap discussed by Benbasat and Barki (2007) regarding how system characteristics influence the perceived usefulness of a system:

Q2: How can a tracking system initiator make technological choices to promote further enrollment into the system by its counterparts in the supply chain?

This question is studied through a four-case exploratory study building on theory from SCM and EDI adoption research. These four cases cover the main technologies and architectures used in contemporary tracking systems.

1.1.2 Information quality in supply chains

Tracking systems can improve the quality of the information available to support supply chain operations. In some cases, improvement can be radical by giving access to information that was formerly not available. In other cases, the improvement can be incremental by providing more timely, accurate, detailed or reliable information.

Low IQ has been pointed to as a pressing problem by several authors within the overlapping fields of logistics, SCM and operations research (e.g. Wagner, 2002, Dutta *et al*., 2007). Dutta *et al*. (2007) propose a research agenda to approach the problem of erroneous inventory information: “We have to start with physical process details at the ground level to examine how inventory errors are created in real life.”

Most of the beneficial effects of tracking systems can be attributed to the increased IQ they provide. Improved IQ can thus be seen as the main driver for adopting such systems (Wixom and Todd, 2005). However, there seems to be a general lack of systematic research using approaches from IQ research within supply chains (Forslund and Jonsson, 2007). Furthermore, several authors in the SCM field call for more studies of the supply network level. There is thus an empirical gap for conducting systematic studies of IQ at the supply network level. There is also a methodological gap concerning how such studies could be conducted.

This multi-case, multi-site PhD project provided the opportunity to use a fine-grained approach to study the physical processes at the ground level as proposed by Dutta *et al*. (2007) and to chart how IQ evolves over time within a supply network. The aim was to detail how these IQ dynamics unfold for the different players and for the different information elements used to support supply chain operations.

Giving an overview of the IQ dynamics could be critical when assessing the potential impacts of product tracking systems for the different players and could thereby help motivate those actors to implement such systems. Furthermore, it could be used for more radical supply chain improvements by re-engineering business processes supported by information from tracking systems.

The most pressing concern to address in order to advance such research is to develop a method for evaluating and reviewing IQ and information processing in the supply chain. This results in the third research question:

Q3: How can the quality dynamics of information available to actors in a supply chain be assessed and mapped?

This question has been approached by adapting a measurement scale and a measurement method to the information in supply chains and by developing and testing a notation to give the necessary overview. The study is built upon literature from IQ research, SCM and software engineering. Different research cases have been used to develop and test the notation in three iterations.

1.1.3 The impacts of tracking systems on strategies for sustainable SCM

There is a substantial body of literature on the possible impacts of product tracking systems. Most such studies use guesstimates to evaluate the various potential benefits. However, there are large differences between these studies. There are some more reliable estimates based on motion studies and pilot studies performed by actors such as Metro Group or Wal-Mart, but there are few studies based on real supply chain scale implementations (Sarac *et al.*, 2010, Lee and Özer, 2007). This means that there are large empirical gaps to be filled regarding the impacts of tracking systems, which calls for case and field research on early implementations (Lee and Özer, 2007). However, many of the expected effects emerge over a long time period during which the inter-organizational system is extended to encompass a larger part of the supply chain, and the actors develop their business processes to use the new functionality (Mukhopadhyay *et al.*, 1995). Unfortunately, the cases being studied here are at a too early stage, and the benefits usually studied within SCM often prove too difficult to assess quantitatively given the limited access, time and resources available.

However, the present study provided intimate knowledge of the information handled by product tracking systems and of the motivation for implementing them. It also offered insights into the wild caught seafood sector and into the imminent threat to the viability of that industry posed by unsustainable seafood harvesting practices. These practices have resulted in declining catches worldwide since the early nineties (UNEP, 2010), meaning that seafood resources and the industry dependent on them could be facing extinction within the next 40 years if harvesting practices are not changed (Clover and Murray, 2009).

Leading actors in the wild caught seafood sector have met the threat by implementing various strategies for sustainable SCM, and the corresponding research question thus becomes:

> *Q4: How well can the information available from tracking systems in the upstream supply chain for wild caught seafood support strategies for sustainable SCM?*

This question has been approached by looking into the unsustainable catch problem using the literature on resource economics and fishery policy, and into the sustainable SCM strategies described in the SCM literature. I have also assessed to what degree the information content and the scope of the tracking systems studied in three research cases from the upstream supply network for seafood support these strategies. The study also hints at the limitations of the contributions of these systems to solving the underlying problem of unsustainable catch practices.

Each of the four research questions developed here correspond to a research paper that is placed in its own section of this thesis.

2 Theoretical Frameworks

When writing empirical research papers, there is limited space. This results in a conflict between giving a sufficient description of the empirical research and treating the corresponding theory adequately. This conflict is especially serious when carrying out case research that depends upon naturalistic generalization (generalization by similarity) for its external validity. The dependence on naturalistic generalization means that thorough case description takes priority over the adequacy of the discussion of theory. In a thesis, this problem can be solved by using the available space for a deeper treatment of the theory. The treatment of theory is the purpose of this section, in which the initial discussions treat a high-level framework and then subsequent subsections cover lower-level frameworks, each with a treatment of the corresponding literature.

2.1 Top-level framework

The top-level framework emphasizes that tracking systems adoption and development is not one single decision, but rather occurs through a process where several factors interact. The top-level framework is shown in Figure 2-1.

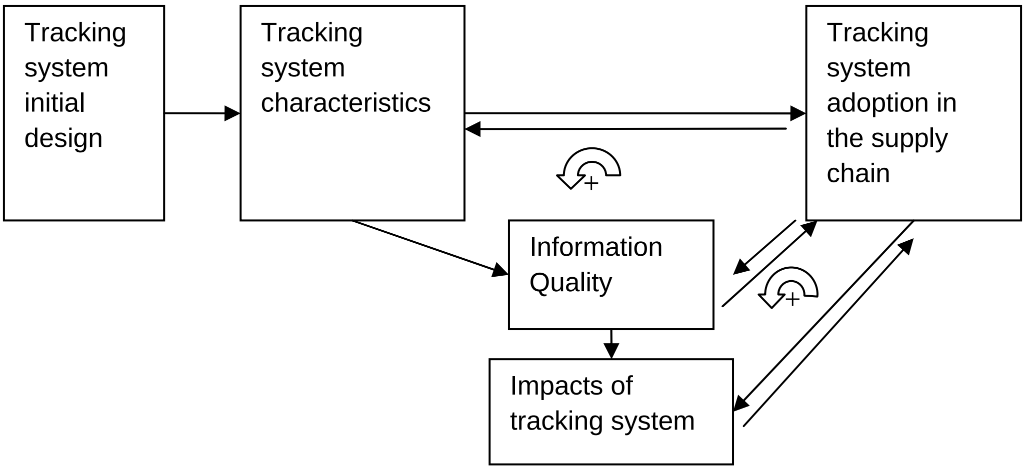

Figure 2-1 The top-level framework

A tracking system occurs when an actor decides that the benefits of implementing it are sufficiently compelling. That actor can be called the initiator.

Following usual development practices for IT artifacts, the initiator and its IT partners start by developing a business case showing how the system could create value. This business case serves as an initial definition of the system. Then, the system is constructed. Construction includes decisions regarding technologies for the automatic identification of traceable units, system architecture, standards to implement and which ready-made or custom-built hardware and software components to use. This means that the initiator and its technology partners perform the initial construction of the system. The initiator also has to consider how to make other actors in the supply network adopt the system.

Other players in the supply network take their own decisions about whether to adopt the system and become an adopter, and how to implement and adapt the system to their own organizations and processes. The proportions of supply chain players, goods and processes enrolled during the evolving implementation of the tracking system also influence the characteristics of the system. This partly accounts for the *emergent* properties of the system. As the users both in the initiator's and in the adopters' organizations discover new opportunities, the system can be used for more purposes, and this can also change the system characteristics to a substantial degree, thereby accounting for more emergent properties (Orlikowski, 1996). Thus, the system characteristics are dependent on both the initial construction and the following adoption of the system by supply chain players.

Tracking system characteristics further have a profound influence on the IQ available to system users. IQ is partly determined by the properties of the data provided by the system, but it is also determined by how the users make sense of that data and thus on the use of the data by supply chain players. In the framework, using the tracking system is an instance of adoption. Therefore, IQ is dependent both on the characteristics and on the adoption of the tracking system.

The benefits derived from tracking systems are closely connected to IQ (Wixom and Todd, 2005) and in particular to how the IQ delivered improves operations and organizational decision making (Sellitto *et al*., 2007). Generally, IQ can best be measured in terms of how well the data provided by the system support the tasks to be performed by system users. Most impacts of a tracking system can then be expressed in terms of changes in user task performance, which could be measured by comparing performance before and after the improved IQ from the tracking system became available.

Improved IQ and other beneficial impacts of a tracking system can lead to more players joining and thereby to increased adoption. This means that there could be positive feedback loops that could drive adoption throughout the supply network. These feedback loops are indicated in Figure 2-1. Adoption by supply chain players also depends on the IQ delivered by the tracking system (Wixom and Todd, 2005, Whitaker *et al*., 2007), on other tracking system characteristics and on a number of other factors (Somasundaram and Rose, 2003; Damsgaard and Lyytinen, 1998), which have not been included in the diagram.

Figure 2-2 shows where the research questions that were developed in the introduction are positioned within the top-level framework. The research reported here only covers fragments of the entire picture. The following sections will treat each factor of the framework with associated theories relevant to the research questions.

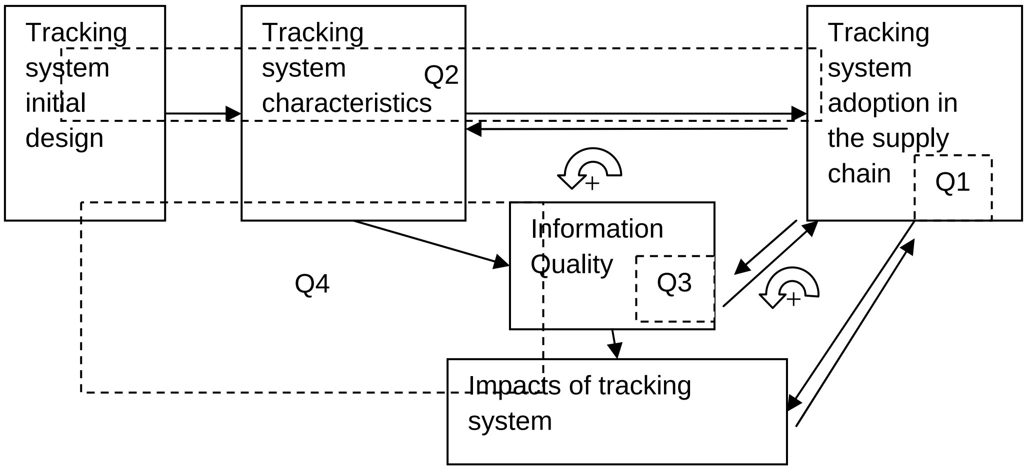

Figure 2-2 Position of the research questions within the top-level framework

2.2 Tracking system initial design

As discussed in the previous section, the evolution of a tracking system can be divided into two distinct phases. During what could be called the initial design phase, the initiator(s) enters a system development process with the goal of constructing a new tracking system to be used by the initiator(s). In the next "evolution" phase, system adoption by other stakeholders changes the game.

During the initial design, occurring in the system development process, a number of important decisions will be taken. The main decisions cover:

- The fundamental architecture of the system, i.e. whether the aim is to collect all tracking data in a central database that can provide users with complete, timely data on the product flows of an entire supply network, or to provide a distributed tracking system by using EDI to connect the systems used by each actor. This last solution leaves ownership and control over what data to exchange with each actor, but it could sacrifice the possibility for complete network-wide information.
- AutoID technology, i.e. whether to use, for example, RFID or barcodes to identify items. This decision could have profound impacts on the costs of tagging products, but also on the possible degree of automation and on the IQ available from the resulting system, and thereby on the obtainable benefits.
- The granularity, i.e. what level of tagging should be aimed for. Should each individual product be tagged or is tagging at the box or pallet level sufficient to obtain the aimed for benefits?
- Construction of a data model that can be used to construct a central database or to construct EDI messages for the distributed architecture scenario. The data model decides the extent of data that can be captured and distributed, and thereby to a large degree it also decides what user tasks can be supported by the system.

The initial design phase is critical, because a system can easily be changed in the initial phase. As the system becomes used by more and more actors for more and more tasks, these become dependent upon the system. Since changes could have serious detrimental effects on implemented functionality, systems tend to be less and less open to change as more actors adopt them, and the more functionality they implement based on it. Thus, the more successful a system becomes the harder it can be to change it.

When the initiator is a single stakeholder, this can easily result in taking only the myopic goals of that stakeholder into consideration. This might result in the less than optimal coverage of the requirements of other stakeholders. Deficient alignment with the requirements of other players could prove to be an effective barrier towards those stakeholders adopting the system.

2.3 Tracking system characterization framework

The characteristics of a tracking system are partly determined through the initial design of the system and they partly emerge through its adoption and use by supply chain players (Elgarah *et al.*, 2005). The resulting framework for tracking system characteristics is shown in Figure 2-3, while **Feil! Fant ikke referansekilden.** shows the characteristics, their definitions and whether they result from design (D) or are emergent (E).

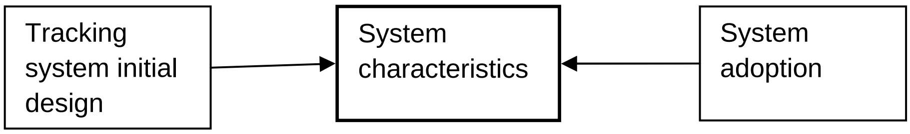

Figure 2-3 The tracking system characterization framework

The granularities generally determine the level of detail and thereby the possible benefits of the tracking system, but more detailed granularity corresponds to a higher cost (Ilie-Zudor *et al.*, 2011). Fine granularity tagging at the individual product item level increases costs and technical difficulties significantly, while most strategic benefits can be maintained even when limiting tagging to the pallet level. The tagging level is thus a critical issue when designing tracking systems (Saygin *et al.*, 2007).

A finer granularity generally supports more tracking system goals by providing the exact locations of each item for retrieval, by providing the exact processing histories of single product items supporting work to improve processing yields or determine the reason for other types of shrinkage or quality problems or by finding exactly what items have been affected by a problem to support lower cost product recalls by “surgical” precision. However, finer granularity can also increase tracking system costs substantially by needing more tags for product identification, more expensive tags for positioning, more tag reading equipment and more sophisticated computer systems for handling the larger amount of data generated.

Characteristic	Definition
Goods granularity (D)	Size of the tracked resource unit (Moe, 1998), henceforth called item. Ranges from theoretically a single fish, via single packages, pallets or containers to a full day's production. Called tagging level in Saygin *et al*. (2007) and Sarac *et al*. (2010).
Spatial granularity (DE)	Is the spatial precision of tracking information recorded – to the nearest cm, m, shelf position, storage track, storeroom, vehicle, building or industrial site.
Process granularity (DE)	Is the degree of detail recorded when tracking products through a production process
Scope S (E)	The set of supply chain actors recording information in the tracking system. Can be coarsely classified as dyad, "set" or network. (Elgarah *et al*., 2005). Also called "range" in Spekman and Sweeney (2006). |S| is called "extent" in Mukhopadhyay *et al*. (1995) and "breadth of impact" in Brown and Bakhru (2007).
Closedness (DE)	The percentage of tagged reusable containers being returned to a container pool for another trip through the supply chain. A more coarse two-level scale: Flow-through or closed circuit is proposed by Ilie-Zudor *et al*. (2011).
Connectedness (E)	The scope has no "disconnects," i.e. intermediate actors in the goods flow where adequate tracking is not performed.
Volume (E)	The relative proportion of the products handled that are being tracked by the tracking system. Adapted from Massetti and Zmud (1996). In currency units, the measure is called "penetration" in Mukhopadhyay et al. (1995).
Initiators	The set of (supply chain) actors participating in the initial definition and construction of the tracking system.
Followers	Scope – Initiators.
Extent (DE)	The set of information elements recorded in the tracking system.
Depth (DE)	The set of business processes supported by the tracking system/ the set of corresponding EDI messages used in the system. Corresponds to the Depth and Diversity facets of Massetti and Zmud (1996).
Architecture (D)	The architecture of the tracking system can be either central repository or distributed, i.e. the set of actor ISs connected using EDI (Bechini *et al.*, 2005).
AutoID technology (D)	Currently barcodes and/or RFID are the main alternatives. See Finkenzeller (2003) for alternative technologies.
Standardization (D)	The degree to which the system uses existing standards (Dutta *et al*., 2007).
Cost (DE)	The investment and running costs of the tracking system.
Automation (DE)	The degree to which the capture and dissemination of information is automated.
Integration (DE)	The other systems with which the product tracking system is integrated – and to what degree.
Real time (DE)	At least two meanings: 1) In the usual "event-based" tracking systems, real time could mean that information about an event is available to the user the moment it has been captured; 2) "real time" tracking systems deliver information about the position of e.g. a vehicle in real time, for example by transmitting the position obtained using GPS. As a measure in sense 1) To what degree are the information elements captured by supply chain actors made available to other actors in real time, i.e. when captured. The opposite, not being real time, can be measured as information lead times (Chen, 1999)
Identifier lifetime (DE)	Proposed by Ilie-Zudor *et al*. (2011). A product identifier can have a lifetime spanning from the time for handling the item in one process to the entire lifetime of the item, i.e. from its production via consumption and further to decomposition ending in the recycling of its materials.

Table 2-1 Tracking system characteristics

Granularities are generally determined by design, but some are also affected by adoption/implementation. Whether the position of a pallet is registered as a shelf position, track position (see Figure 2-4) or as present in a particular storeroom is, for example, dependent both on the existence of shelves and tracks and equipment and on implementing the necessary procedures for capturing the necessary data at each particular adopter's facilities. To complicate matters, granularities may also vary with types of goods.

Figure 2-4 Tracks are identifiable areas for bulk storage inside a warehouse, see floor markings. Photo: O. Bø

The scope of the tracking system is the set of actors participating in it. Spekman and Sweeney (2006) use "range" for a similar concept, but they also use a coarse categorization into four categories (see Table 2-2). Only two of the categories represent the inter-organizational tracking systems discussed in this thesis. Massetti and Zmud (1996) use "breadth" as the proportion of business partners a focal firm has established EDI connections with. The scope of a tracking system is certainly determined by the decisions on whether to implement the tracking system taken by each supply chain actor.

Discrete processes	Intra-company	Inter-company	Across the extended enterprise
Usually used to fix a process that can be improved by RFID	Links parts of the business that typically cross functional lines	Attempts to link a limited number of suppliers, but not the full supply chain	Goes beyond inter-company links and tries to gain synchronization over the entire supply chain

Table 2-2 Tracking system ranges (from Spekman and Sweeney, 2006)

The extent is the set of information elements recorded in the tracking system. This can be limited by the decisions taken when designing the system on what information elements to include in the system, but can be further dependent on what information supply chain actors are able to and willing to submit to the system. A larger extent could also lead to higher running costs for carrying out the necessary data capture and registration.

In a similar way, the depth of the system can be initially defined as being designed to support a set of business processes and EDI messages, but the actual depth when adopted in the supply chain may be further limited if players choose to use only a subset of the functionality offered by the system. The result is that the extent and depth might well be different for each member of the scope.

The depth of a tracking system describes to what degree it is integrated with business processes. The depth aspects can be regarded as phases in the evolution of RFID value realization, where a first technology and integration phase is initiated as a result of an RFID mandate from a powerful actor, resulting in better control over goods flow and reduced error rates. This is followed by a second phase where business processes are reengineered to yield higher benefits and eventually ending in a phase where new business architectures are developed that yield even higher performance. Increasing depth is associated with higher conceptual and implementation complexity and cost (Dutta *et al*., 2007).

In addition to the depth aspect describing the degrees of integration of tracking systems into business processes, the degree of integration with other IS should also be considered. Integration is an important driver for obtaining benefits in inter-organizational systems (Mukhopadhyay et al., 1995; Mukhopadhyay and Kekre, 2002). Even though examples of standalone applications do exist, the tracking system is usually integrated with other systems (Ilie-Zudor *et al*., 2011) because integration can give the completeness necessary to satisfy the IQ requirements of many work processes. In inventory management, for example, “Frequently the stock status level is hard to calculate, given the organization of corporate MIS systems – typically the components of stock status are in different transaction systems” (Wagner, 2002).

Integration problems can be accentuated in SMEs, because when implementing IOSs in SMEs, the integration level is typically minimal, meaning that the IOS is used manually as a separate system (Iacovou *et al.*, 1995). Thus, missing internal integration of IS including the product tracking system is one of the first problems to address when implementing such systems (Dutta *et al.*, 2007).

The set of initiators can be interesting because an initiator set containing different actors might lead to an initial design supporting more user tasks. For the five tracking systems encountered during this study, the initiators were 1) a shipping company, 2) a seafood processing company, 3) a box pool started by all the national fish producers’ organizations, 4) the national food authorities and 5) a pallet and box pool started by the four dominant national grocery chains.

The cost of a tracking system is strongly dependent on all other characteristics, and this can be divided into investment cost, namely the cost for equipment and systems and for the necessary integrations at the system and organizational level, and running costs, which are the costs for identification tags and the tagging of goods as well as for capturing, handling and disseminating data. Investment cost can be considerable because of the large network of software and readers, an expensive infrastructure that must be able to handle an enormous amount of data and the need to integrate it with other systems to create value (Brown and Bakhru, 2007).

Many of the measures considered here could be candidate members of a composite measure for the degree of implementation of a tracking system. Such a measure is highly desirable when carrying out adoption research, and it could be expressed relative to the maximum obtainable level for each tracking system (Tornatzky and Klein, 1982). However, many of the proposed measures will be different from player to player, or from business function to business function within each player (Tornatzky and Klein, 1982), so it might be challenging to develop a single composite measure representing “the size of a tracking system” in a supply chain, or even “the degree of implementation” for a single player. Another suggestion is to measure implementation in terms of implementing key features of the invention (Tornatzky and Klein, 1982). Obvious candidate key features include the implementation of product tagging by the producers of a logistic unit and the functionality for exchanging advanced shipping notices containing lists of items being shipped between supply chain partners. Thus, the proportion of identifiable goods and the proportion of goods where information about shipments are available in advance could be considered to be usable measures for the degree of implementation of tracking systems in a supply chain.

Another interesting point is that when regarding a supply network, there could be a number of more or less overlapping tracking systems in operation. This means that delimiting one such system might be challenging, especially when discussing a distributed tracking system.

2.4 IQ framework

A tracking system is an expensive investment in a technology to capture, store, process and disseminate considerable quantities of data. However, organizations having invested in IS with similar characteristics are often frustrated in their endeavors to translate the data into meaningful information and knowledge that can be used to redesign business processes, improve decision making and gain strategic advantages (Redman, 1995). These difficulties are caused by IQ problems (Madnick *et al*., 2009). Rather than being the exception, poor IQ seems to be the norm, leading to substantial costs, alienated customers and decreased trust (Redman, 1995; Strong *et al*., 1997). The economic and social repercussions of IQ issues cost billions of dollars (Strong *et al*., 1997). Conversely, high quality information can yield substantial benefits.

Striking examples of the importance of IQ are readily available. Information that could have been used to stop the September 11 attacks in New York and the July 22 attacks in Oslo seem to have been present in the data available to the relevant authorities, but the data were not correctly interpreted as a threat in time for prevention. It also seems that the second Gulf War could have been avoided with better quality information about the existence or non-existence of the much-discussed weapons of mass destruction.

Research on IQ in organizations has been going on for more than two decades, covering themes such as the impact, database-related technical solutions, measurement/assessment of IQ and other IQ issues in the context of IS, i.e. privacy and security and using a range of research methods (see Madnick *et al*. (2009) for a recent review of the field).

Two well-established findings of the field are the multidimensional character of IQ and the need to consider the context of use when studying it. Unfortunately, the many contributions over the years do not agree on a clearly defined common set of non-overlapping quality dimensions. Indeed, IQ seems to be an elusive concept (Lillrank, 2003).

However, research on the impact of IQ in the supply chain is scarce (Forslund and Jonsson, 2007). The goal of this section is thus to support a discussion on IQ in the context of IOPTSs. The goal will be pursued by first defining IQ and then by reviewing the literature on IQ dimensions and on how to measure IQ. The subsequent sections will discuss how these results could be extended into a framework for IQ for product tracking systems by taking into consideration the particular circumstances of the supply chain context.

2.4.1 Defining IQ

“The very concept of [IQ] is somewhat nebulous” (Ballou *et al.*, 2004).

Much of the literature treats IQ and data quality as synonyms, but discussing the terms information and data could improve understanding. As defined by Lillrank (2003): "Data are a communicable symbolic representation of entities, properties and their states." Data D become information when they are given a context C and thereby a meaning M. Thus, meaning can be expressed as a function f, which represents the knowledge of the sense-making agent: $M_u=f_u(D,C_u)$. The same piece of data can thereby lead to meanings that vary considerably depending on the knowledge of the user and the context (Lillrank, 2003). The subscript “u” has therefore been added.

Most data quality research treats data quality issues as independent of the context in which data are produced and used. However, data quality clearly depends on the actual use of the data. Data that may be considered good for one application may not be sufficient for another (Wand and Wang, 1996). As data quality issues may surface anywhere in a larger IS context, including organizational processes where personnel in different roles capture, process, disseminate and use data, the context should be included when conceptualizing data quality (Strong *et al.*, 1997). Gustavsson and Wänström (2009) also discuss how some IQs “reflect the knowledge and experience of the staff.”

The term information system could therefore be considered a misnomer, because computers cannot handle information. They can only handle data, i.e. strings of characters. These strings only become information and knowledge when interpreted by system users. Thus, IQ can only be judged with reference to that interpretation. It could be correct to use the term “information system” only if the definition of the system includes the use and the users.

The IQ literature also refers to the general quality literature when including the data consumer, resulting in definitions such as “high quality data is fit for use by data consumers” (Strong *et al.*, 1997; Ballou *et al.*, 2004) or the "ability to satisfy stated and implied needs of the information consumer" (Gustavsson and Wänström, 2009).

2.4.2 IQ dimensions

Much of the IQ literature discusses different dimensions of IQ. Unfortunately, even though the authors agree on the multidimensionality of the concept (Wand and Wang, 1996), they use different sets of dimensions. Lee *et al*. (2002) and Gustavsson and Wänström (2009) provide tables showing the dimensions used in the literature. The problem is exacerbated by overlapping dimensions having different names and by dimensions with the same or similar names having different definitions by different authors (Wand and Wang, 1996).

Wand and Wang (1996) attack the problem using ontology, which understands the world in terms of the things (entities) it contains and the attributes of those things, and holds that the state of the world can be described by capturing the values of attributes. They then discuss IS in terms of being a representation of the relevant part of the real world in terms of containing attribute values that can be interpreted. The system has good IQ to the degree that system users are able to get the same perception of the real world by using data from the system compared with the perception achieved through observing the real world. By analyzing various problems in the design and operation of the information system, the authors are able to make a formal definition of the complete, unambiguous, meaningful and correct data qualities. However, their analysis excludes the use and value of the information system. Furthermore, they do not consider the requirements of the data processing that is necessary to deliver usable data to users.

The user perspective is handled in a seminal work by Wang and Strong (1996), which examines the quality dimensions systematically through an elaborate study among users of computerized IS using methods from marketing research. The study starts by identifying 179 IQ attributes and sorts them into 20 quality dimensions based on factor analysis. It then grades the dimensions by importance and arrives at classifying 15 of them into four categories (see Table 2-3, where the numbers represent the ranks of each dimension). Five dimensions including “cost” and “ease of use” were omitted because they do not fit into the classifications.

Intrinsic data quality	**Contextual data quality**	**Representational data quality**	**Accessibility data quality**
1 believability 4 accuracy 8 objectivity 12 reputation	2 value added 3 relevancy 9 timeliness 10 completeness 19 appropriate amount	5 interpretability 6 ease of understanding 13 representational consistency 17 concise representation	7 accessibility 18 access security

Table 2-3 IQ categories, dimensions and importance (from Wang and Strong, 1996)

The idea of the classification is to distinguish between qualities that could be connected to 1) the data per se or to 2) the context of using the data. Thenext two categories could be connected to 3) the data system used to make the data available to users. Unfortunately, as can be seen from the table, the resulting dimensions could still overlap and the short descriptions of the dimensions given by the authors are vague for some of the dimensions.

Distinguishing between the dimensions can also be difficult because problems in one IQ dimension create perceived problems in other quality dimensions, as shown in Figure 2-5.

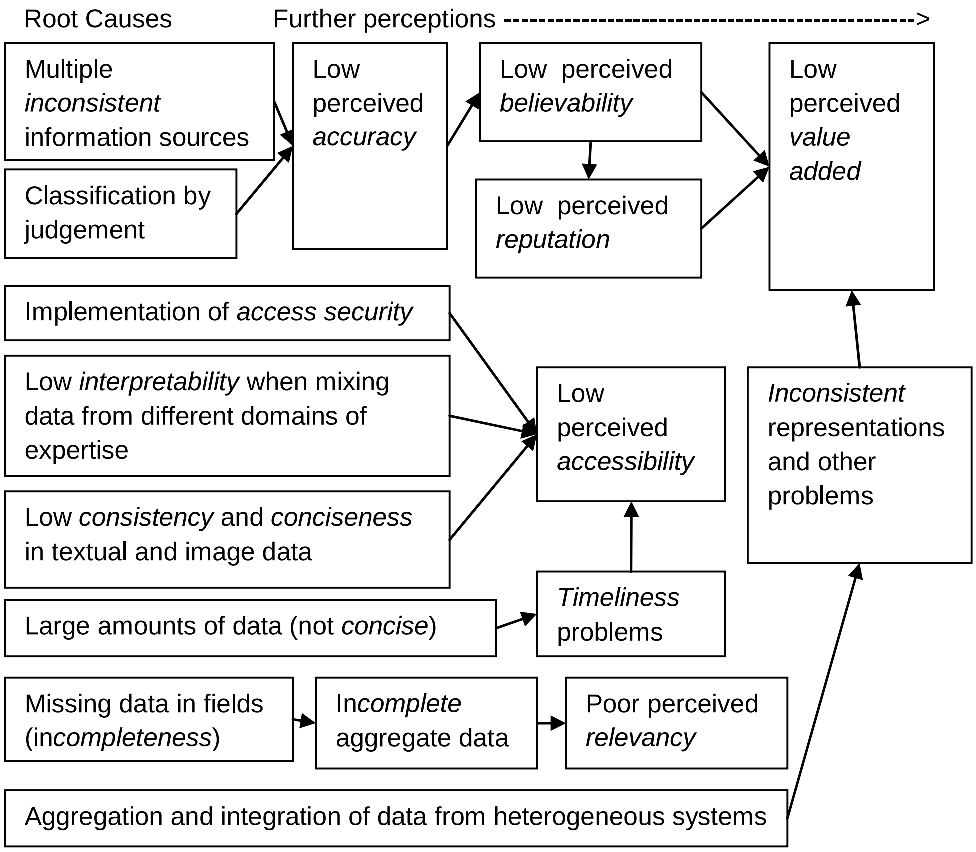

Figure 2-5 Root causes and perceived problems, qualities in italics (derived from Strong et al., 1997)

The IQ literature first considered data to be a product, but it seems that also seeing data as a service could direct efforts towards improving quality by identifying which parts of the information production and delivery process should be focused on. Furthermore, IQ assessment can also be directed by distinguishing between quality dimensions that might be evaluated through measurement against specifications and qualities that could only be evaluated against users' expectations. These new perspectives result in the "product service performance model for IQ" (PSP/IQ; Kahn *et al*., 2002) shown in Table 2-4.

	Conforms to specifications	Meets or exceeds customer expectations
Product quality	Sound information Free of errors Concise representation Completeness Consistent representation	Useful information Appropriate amount Relevancy Understandability Interpretability Objectivity
Service quality	Dependable information Timeliness Security	Usable information Believability Accessibility Ease of manipulation Reputation Value added

Table 2-4 The PSP/IQ model (Kahn et al., 2002)

Comparing the PSP/IQ model with the model proposed by Wang and Strong (1996), it seems that the sets of dimensions are identical, except for the replacement of accuracy with “free of errors” and the introduction of “ease of manipulation,” which could be justified by the following:

> *"Data consumers evaluate [Data Quality] relative to their tasks. At any time the same data may be needed for multiple tasks that require different quality characteristics. Furthermore, these quality characteristics will change over time as work requirements change. [..] Providing high quality data along the dimensions of value and usefulness relative to data consumers' task contexts places a premium on designing flexible systems with data that can be easily aggregated and manipulated. The alternative is constant maintenance of data and systems to meet changing data requirements"* (Strong *et al*., 1997).

Authors using IQ dimensions for special purposes (e.g. Forslund and Jonsson, 2007; Gustavsson and Wänström, 2009) are wrestling with the number of dimension, with which ones to include in their study and with their precise definition and operationalization.

IQ dimensions will be discussed again in the following section and also when discussing how the results from IQ research can be applied to discuss the impacts of tracking systems on IQ.

2.4.3 IQ evaluation and improvement

A central goal of IQ research is to develop approaches for evaluating and improving IQ. An early contribution is represented by Madnick and Wang (1992), who proposed a Total Data Quality management process with Define, Measure, Analyze and Improvement phases being applied cyclically. Redman (1995) proposes a three-step IQ improvement starting with locating quality problems, continuing with treating the data producing processes and the resulting data product as assets and finally applying data quality principles. IQ can be improved by changing the data values directly or by changing data generating processes. Quality can also be improved by actively using the data integrity rules and mechanisms in databases and adapting them to the shifting requirements of data users (Lee *et al*., 2004).

But "despite a decade of active research and practice, the field lacks comprehensive methodologies for [the] assessment and improvement [of data quality]" (Lee *et al*., 2002). In the literature, at least five different methods for assessing IQ can be distinguished:

Approaches to assessing IQ
Compare the state of the real world as inferred from the information system with the view obtained by directly observing the real world (Wand and Wang, 1996), i.e. compare the state of the real world with the state of the system. However, determining true values is expensive (Lee *et al*., 2004)
Compare data with the system requirements for the data. Syntactic data quality (Price and Shanks, 2005)
Compare data from one database with another database covering the same data: “database bashing” (Redman, 1995)
Conduct a survey among system users to obtain their scoring on the different quality dimensions for a dataset (Lee *et al*., 2002)
Conduct a study of problems occurring in business processes to discover the data quality issues causing the problems (Redman, 1998)

Table 2-5 Approaches to assessing IQ

The assessment methods in the table above can be classified into three groups: data-centric, which contain the first three methods, user-centric and process-centric methods.

The quality literature in general emphasizes taking the consumers' perceptions into consideration when evaluating quality. This user-centric perspective also has a salient place in the data quality literature, as shown below.

Lee *et al*. (2002) propose using a survey where the 16 quality dimensions of the PSP/IQ framework (see Table 2-4) are operationalized using four questions for each dimension and most of the questions are formulated using only the name of the IQ. Forslund and Jonsson (2007) operationalize IQ as one question for each of the four IQ variables, asking to what degree forecasts from customers were a) on time, b) accurate, c) convenient to access and d) reliable on a 1–7 Likert scale.

The user-centric perspective implies that we can dispense with the expensive yardstick of perfect IQ in the sense of data being absolutely accurate, complete and current:

> ““Perfect” IQ, whatever that means, is difficult, if not impossible, to achieve, but neither is it necessary. If users of the data feel that its quality, which can be described by such attributes as accuracy, completeness, timeliness, and consistency, is sufficient for their needs, then, from their perspective, at least, the quality of the information available to them is fine.” (Ballou *et al*., 2004)

However, relying only on user perception might result in too low ambitions. Users will always try to make do with whatever IQ is available to them. They often do not know what could be made available through the increased use of information technologies (Lillrank, 2003).

The user-centric perspective could also be ineffective when aiming for IQ improvements, because user perceptions about IQ issues can be ambiguous about the root causes, as can be seen in Figure 2-5.

Redman (1998) advocates a more process-centric perspective, where IQ assessments start from known issues in the user tasks of business processes, continues by discovering the IQ problems causing the issues and ends by remediating the information handling process causing them. Strong *et al*. (1997) hint at the same approach when discussing the usual causes for complaints about available data not supporting tasks because of missing or incomplete data, inadequately defined or measured data and data that cannot be appropriately aggregated.

A further step in the process-centric direction can be found in research on how practitioners approach data quality improvement. Lee (2004) researches data quality activities in a multi-site longitudinal study and finds that data quality problems are solved by reflecting on knowledge about contexts that are embedded in or missing from data and by creating rules on the data products and processes. The five contexts playing central roles when data quality practitioners reflect in action and change the set of rules are: 1) the *goals* or purposes of the information, 2) the *role* in terms of data collector, custodian or consumer, 3) the *paradigms* or principles agreed upon, taught and used when individuals from different fields (e.g. databases or accounting) design, collect, store or use data, 4) the *place* that determines the socially constructed meaning of data and 5*)* the *time* for how some data are represented and used.

When comparing this with Lillrank's (2003) formulation, as discussed in Section 2.4.1, it seems that the contexts discussed by Lee (2004) contain both the context of use by including the time, place and goal of the interpretation, but also partially cover the interpretation function by including the role of the user, the paradigm and the place-dependent culture within which the user operates.

It thus seems that the research focus within the assessment and improvement of data quality has moved on from discussing data qualities in the data per se, via user perceptions of data qualities to a process-centric perspective that discusses how data quality issues cause problems in business processes.

2.4.4 IQ research in supply chains

IQ issues including delayed and distorted demand information from the lower towards the upper echelons of supply chains have been thoroughly studied by SCM researchers aiming to reduce the infamous bullwhip effect causing expensive instabilities in perceived demand. This research stream was initiated by Forrester (1961) using the system dynamics approach and it still seems to accumulate new contributions using a variety of methods.

Because this thesis discusses tracking systems, the discussion among authors in the RFID stream within SCM research about how IQ for operations and planning can be improved by such systems is clearly relevant. Sellitto *et al*. (2007) review the literature from the late 1990s onwards, finding that the quality dimensions in Table 2-6 are salient. They propose that the benefits of tracking systems are predominantly because of improved IQ in the time-based dimension and that RFID-based systems could be most beneficial by enabling earlier decision making in organizations with time-critical activities. Some authors (e.g. Lee and Özer, 2007) propose that a "supply chain visibility” dimension should be considered a new IQ dimension in the SCM context (Sellitto *et al*., 2007).

IQ dimension	**Count of contributions discussing the dimension**
Accuracy	8
Timeliness	6
Completeness	5
Accessibility	3

Table 2-6 Salient IQ dimensions in the SCM literature on RFID (derived from Sellitto et al., 2007)

Much research within the IQ research stream also goes on within the confines of supply chain actors. Still, Forslund and Jonsson (2007) maintain that research on the quality of information in supply chains is scarce, a view that could be justified if “research on the quality of information” means using the concepts and methods of IQ research on the information used for coordination between supply chain actors. The next paragraphs discuss such research.

Forslund and Jonsson (2007) apply the following IQ dimensions to forecasts: in-time, accurate, convenient to access and reliable. “In-time” means that fresh forecast data are received at the right time, “accurate” that they are free from obvious errors and “reliable” is defined as the probability that the forecast will not be changed. Finally, the dimension “convenient to access” refers to how easily the information can be input into the planning system, referring to information being received by fax and requiring manual input as being of low quality in this dimension. The study, using the user-centric survey method discussed in Section 2.4.3, shows that forecast reliability is the main problem, while convenience of access is the next. Closs *et al*. 1997 point to “convenient access” as the main issue in their study of the IQ of orders.

Gustavsson and Wänstrøm (2009) study the information problems of manufacturing management processes in terms of quality dimensions and indicate that earlier studies mainly treated information problems using the accuracy dimension, with a few studies also including timeliness and availability. They point out that using a too limited set of dimensions could result in missing nuances.

Applying the concepts and methods of IQ research within SCM research could be a good idea, but to do that properly, the concepts of IQ research might need to be adapted to the supply chain and tracking system context. The proposition of a supply chain visibility dimension and a new “convenient to access” dimension indeed point to the need to adjust the set of dimensions. It could also be beneficial to consider whether the user-centric perspective applied in the studies discussed above could be replaced by more process-centric approaches in such studies.

2.4.5 Discussion

The characteristics of a tracking system, which were discussed in Section 2.2, determine the data available from the system and thereby some aspects of the IQ. However, as discussed in Section 2.4.1, the context of use and the knowledge of the users co-determine the resulting IQ. Users will also have access to data from other IS, which will contribute to the total perceived IQ, but unless those systems are tightly integrated, it might be difficult to interpret the data from the tracking system. The resulting framework for IQ is shown in Figure 2-6.

Figure 2-6 The first approach to an IQ framework – getting the context in place.

2.4.5.1 A model for IQ problems

To be able to discuss the IQ improvements that could be obtained using product tracking systems, it is necessary to be more specific about where, why and how IQ problems occur in IS. The origin of IQ issues can be found both in the design of the information system and in the processes performed by the different user roles when using it.

An information system is constructed to support the management of a real world system. Almost all IS use databases in the sense that they store data in data structures consisting of tables. Databases are designed using a process called data modeling, where the real world system is conceptually mapped into a set of tables. Cost and complexity sets firm limits to the scope of the information system, but even so, current ERP systems can contain thousands of tables.

Design weaknesses may result in the IS not covering the necessary set of distinct real world states, leading to problems in obtaining complete, unambiguous and meaningful data quality (Wand and Wang, 1996). As the real world system changes because of changed policies, regulations or business processes, the information system must also change in order to remain true and useful (Lehman and Belady, 1985). Necessary changes also include the data model and its data integrity rules (Lee *et al*., 2004). Changing the information system can be expensive and risky. It seems that in many organizations, required changes can wait a long time before being implemented, resulting in IS that are continuously out of line with user requirements.

The data quality literature discusses three categories of actors: data capturers (i.e. personnel involved in capturing data), data custodians (i.e. those responsible for data storage, maintenance and processing) and data consumers (i.e. those interpreting data to form a meaning) (Lee *et al*., 2004).

Data capturers observe and perceive the real world system and capture data about it by entering data representing the state of the real world system into the IS. They may enter incorrect data because of deficient perceptions and mistakes as well as to deliberately misrepresent the state of the real world (Wand and Wang, 1996; Ilie-Zudor *et al*., 2011). Incorrect data might also be entered to compensate for the system being out of line with current user requirements (Gasser, 1986). capturers might further choose not to enter complete information because they do not prioritize capturing and entering the data into the system. Timeliness could also suffer if there is a lag before changed or new data is manually entered into the information system.

Data custodians are responsible for processing the data. Processing is necessary to reduce the often unwieldy masses of data in databases and to compile data from different tables to make complete, interpretable, consistent and concise data, which means an appropriate amount of high quality data accessible to the consumer. Errors coming from the data capture process might have serious repercussions in the IQ of the data presented to data consumers. In the database systems where the processing is carried out, such knock-on problems can be discerned in the following fundamental database operations: selecting and projecting, joining, grouping and aggregating.

Selecting and *projecting* is used to select and retrieve a subset of the contents of a table based on seeking rows with particular attribute values. This is also known as using an access path to access the data. Access paths fail mainly because of missing or erroneous data in the attributes used to find the correct table rows to retrieve. Thus, incomplete or erroneous data may result in impaired accessibility (Mikkelsen and Aasly, 2005).

Selecting is also known as filtering, and its fundamental role for data quality is to ensure relevance. Properly designed filtering can use attribute values to distinguish between relevant and irrelevant data and results in only relevant data being forwarded to the user. If the data values used for filtering are missing or erroneous, data might be wrongly filtered, resulting in reduced completeness.

Joining is a mechanism for assembling data from different tables. In data quality terms, the role of joining is to give a result containing more complete, understandable and interpretable information about a real world item. Joining depends on putting together data about the same item from different data tables. Within most databases, this is based on having a common attribute in different tables. The integration of different IS implies joining data from tables in different databases. Unfortunately, integration can be challenging in such cases because a common attribute might not exist. Then, more advanced but error-prone methods can be used to solve the “inter-database instance identification” problem (Wang and Madnick, 1989). Anyhow, if data in the attributes used for joining are amiss or wrong in one of the tables, all data about the corresponding real world entity could be left out of the result, reducing completeness. In addition, if there are different delays before data in different tables are updated, the result of the joining may be wrong or inconsistent with the state of the real world (Wand and Wang, 1996).

Grouping and *aggregating* means grouping data based on one or more attributes and calculating sums or other aggregate measures over the group to generate an appropriate amount of concise summary data. If attributes for correct grouping have missing or wrong data values, aggregations might fail, leading to summary data being erroneous.

The processed data are finally presented to the data consumer, who interprets the data to form a perception or meaning about of the state of the real world system based on that data (Wand and Wang, 1996).

The interpretation process can be discussed using the following expression (Lillrank, 2003):

$$M_u=f_u(D_u,C_u), \qquad (1)$$

where D_u is the data presented to the user, C_u is the context and f_u is the knowledge-dependent interpretation performed by the user when forming meaning M_u. Each user could have a different f_u and C_u depending upon user experience, education and knowledge. Therefore, the subscript u has been added. A well-known result is also that decision makers do not use all the data available. Lillrank's model can be expanded to cover the whole information chain from system design via capture to use. The coverage can be obtained by discussing datasets, information processing and resulting error terms.

Let D_{rr} be all data that could conceivably be captured about the state of the real world and that could be supportive for the task of the user, i.e. the complete relevant information. From D_{rr} other sets representing a loss of completeness in different stages can be subtracted:

- D_{ld} Data lost by design when the information system design precludes capturing data, for example by selecting not to include an entity or an attribute in the data model.
- D_{lc} Data lost by capture deficiency – the data is not captured, even though it could be possible to input it to the information system.
- D_{lp} Data lost by processing problems because of other incompleteness or errors

The data actually used for processing, D_p, can thus be described by (2)

$$D_p = D_{rr} - (D_{ld} \cup D_{lc} \cup D_{lp}) \quad (2)$$

Let p be a processing function that could consist of selecting the relevant data and then of any combination of joining, grouping and aggregating data, resulting in the data presented to the user D_u.

$$D_u = p(D_p) \ (3)$$

Inserting the data processing into (1) gives the following:

$$M_u=f_u(D_u,C_u) = f_u(p(D_p),C_u) \ (4)$$

If D_{0p} and D_{0u} are error-free versions of the data used for processing and presented to the users respectively, error terms can also be introduced, giving (5):

$$M_0+E_m =M_u=f(D_{0u}+E_u,C_u)=f(p(D_{0p}+E_c)+E_p+E_t,C_u) \ (5)$$

Here, M_0 is the meaning that would have resulted from an experienced and well-educated user having access to complete high quality information, i.e. the meaning formed by an omniscient user:

$$M_0=f_0(p(D_{rr}),C_0) \ (6)$$

and E_m are the errors in M_u, whereas E_u are the errors in the data used to support the task and E_c are the errors in the captured data that are increased by further E_p errors when processing the data. E_t are the errors because of changes in the real world that have not yet been updated in the datasets, i.e. errors because of timeliness issues.

To cater for the user not taking into account all the data made available, the data actually used could be defined as:

$$D_{au} = D_{rr} - (D_{ld} \cup D_{lc} \cup D_{lp} \cup D_{lu}) \quad (7)$$

where D_{lu} is the data lost because of non-use.

2.4.5.2 Extending the quality issues model to the supply chain

Most supply chains consist of a number of independent actors typically having:

1. Relationships ranging from arm's length to close cooperation
2. More heterogeneous IS compared with those within a single company
3. Mainly manual or semi-manual information exchange processes, especially between actors
4. Limited time for decision making
5. Involvement in many supply chains, forming a supply network
6. A changing set of relationships and business processes
7. Data mostly generated in transaction systems and other operational systems

The supply chain context can result in the following increased challenges to IQ:

Manual and semi-manual data exchange processes mean that information from other actors often must be re-entered into the recipient's IS, and that substantial manual information processing must be carried out to make the data ready for registration. Manual processes are 1) expensive, 2) error-prone and 3) time consuming. The limited time and resources available in combination with the manual processes, arm's length relationships in a network and changes further limit the interchange of data and introduce errors and time lags.

The model from Section 2.4.5.1 can be extended by including additional data loss and data error terms present in supply chain IS.

- E_{sc} errors resulting from manual re-keying operations and from deliberate "strategic" low precision or misrepresentation by other supply chain actors.
- D_{lsc} loss of data captured by supply chain counterparts. Information can be lost because it is internal proprietary data that the counterpart selects not to disclose, but it could also be lost at the interface between organizations if the receiver selects not to re-key some of it because of the expense of doing so.

These could then be used to extend (5) and (7) for the supply chain context, giving:

$$M_0+E_m = M_u = f_u(D_{0u}+E_u,C_u) = f(p(D_{0p}+E_c+E_{sc})+E_p+E_t,C) \quad (8)$$

and

$$D_{au} = D_{rr} - (D_{ld} \cup D_{lsc} \cup D_{lc} \cup D_{lp} \cup D_{lu}) \quad (9)$$

2.4.5.3 The impacts of tracking systems

Electronic product tracking systems can improve the IQ available to actors in supply chains by:

- Reducing manual information capture and processing, resulting in decreased capture and processing errors, time and cost
- Automating data capture resulting in more timely data availability
- Reducing the cost of acquiring data, which could support more data capture and thus contribute to a higher degree of completeness
- Using the product item ID as a common attribute in all systems, capturing data relevant to that product item and thereby supporting the problem-free joining of data from different actors
- Using the tracking system as an infrastructure for increased data interchange, leading to more complete data for more actors in the supply chain

However, without an intimate knowledge of the counterparts' material handling operations, it might be difficult to make sense of data being generated by their processes. Without users with the necessary knowledge, there is a risk that the extra available data from the tracking system will not be used or will be misinterpreted.

Translated to the model, these considerations can be translated into the following changed terms:

- D'_{ld}: Decreased data loss by design because tracking system technologies permit the efficient capture of more product-related data.
- D'_{lc}: Decreased loss by deficient capture, because tracking system technologies support low effort and possibly even automatic data capture.
- D'_{lp}: Decreased data loss by processing, because tracking systems introduce a standard common identifier for product items and can provide automatic data capture resulting in more complete attributes used in data processing operations. Reduced data errors because of high accuracy data capture also contribute to a reduced loss of data in the processing stage.
- D'_{lsc}: Reduced loss of supply chain counterpart internal information because of new data from the tracking system and decreased loss at the interface between supply chain counterparts.
- D'_{lu}: Data disregarded by the user could *increase* if the user is not able to use the data or does not find it helpful. If tracking systems increase the amount of data presented to the user, a corresponding increase in D'_{lu} might occur.
- E'_{u} decreased errors in information to users because the tracking system provides higher quality data in the following terms:
- E'_{c} decreased errors during data capture because of a higher degree of digitalization and automation of the data capture operations
- E'_{sci} decreased errors in information from supply chain counterparts because of a higher degree of digitalization and automation of data transfer. However, such data could be deliberately garbled by counterparts to safeguard internal information.

- E'_p decreased errors because of processing more complete and error-free data, especially in standardized common attributes for joining.
- E'_t decreased errors because of improved timeliness of automatically captured and disseminated data.
- f'_u: the interpretation function might need to change by user training to enable users to make sense of the data made available by the tracking system.

The model now becomes:

$$M_0+E'_m = M'_u = f'_u(D'_{0u}+E'_u,C_u) = f'(p(D'_{0p}+E'_c+E'_{sc})+E'_p+E'_t,C) \quad (10)$$

and

$$D'_{au} = D_{rr} - (D'_{ld} \cup D'_{lsc} \cup D'_{lc} \cup D'_{lp} \cup D'_{lu}) \quad (11)$$

It seems that many of these IQ improvements are connected to the increased digitalization of the product identification and of the dissemination of the captured information. It could therefore be an idea to consider if "level of the digitalization" could be developed as an IQ dimension.

2.4.5.4 The digitalization level as a dimension of IQ

In many supply chains, information integration using the electronic interchange of data is still sparsely implemented. In many cases, the information is provided by other means, e.g. phone or fax. However, even though produced by a computer system and relayed by e-mail, the further handling of the information is carried out manually. The expensive and error-prone process of manually re-entering information is, therefore, more the rule than the exception in the main cases studied in this thesis. Similar plights have been reported from other supply chains, however (Forslund and Jonsson, 2007; Kauremaa *et al*., 2009).

This means that the IQ literature discussed in the first subsections of Section 2.4, which has information in computerized IS as their unit of analysis, could need to be expanded to cater explicitly for a lower baseline of manual information capture, processing and dissemination used in many supply chains. One way to extend the literature could be by creating an extra representational IQ dimension that could be called the "digitalization level."

The importance of "digital" IQ in supply chains is supported by Closs *et al*. (1997), who call the dimension "formatted to facilitate usage," and find that this variable has the lowest rating when measuring the IQ of orders. A similar dimension that points to how digital IQ could reduce the information handling effort is also manifest in Wang and Strong (1996) and Lee *et al*. (2002), namely the "ease of manipulation" dimension discussed in Section 2.4.2. The most important quality for ensuring that information can easily be manipulated is clearly that it is represented in a digital form.

Such a dimension finds further support in Mukhopadhyay and Kekre (2002) and Kauremaa *et al*. (2009), who find that automated data transfers provide significantly increased information integration benefits compared with information exchange involving manual routines. Information exchanged through manual methods, e.g. fax, requires substantial processing before becoming useful (Forslund and Jonsson, 2007; Gustavsson and Wänström, 2009).

To better support discussing IQ in real supply chains and to include the manual baseline, the representational IQ category discussed by Wang and Strong (1996) can be extended to include a digitalization-level quality dimension. The following paragraphs cover tentative characterization scales for the digitalization level of data from inter-organizational systems and product identification systems. The digitalization level quality dimension can be characterized along the scale shown in Figure 2-7.

0 → Maximum IOS digitalization level

<table>
<tr><td>method</td><td>phone / fax</td><td>e-mail/web</td><td colspan="3">system to system data transfer</td><td rowspan="2">common database</td></tr>
<tr><td>auto-mation</td><td colspan="2">manual re-entry of data</td><td>manual</td><td>semi-automatic</td><td>fully automatic</td></tr>
</table>

Figure 2-7 The digitalization-level IQ dimension

The lowest levels of the scale represent purely manual data transfers, where data must be re-entered manually. Manual system-to-system data transfer, which involves receiving, for example, an Excel file via e-mail and then uploading it into the local system, is placed at the medium level of the scale. Such manual handling of digital data can require significant work before being able to use the information (Forslund and Jonsson, 2007). Higher levels of digital IQ are obtained through fully automatic data transfer between systems.

The highest level of digital IQ is represented by the ideal case of all supply chain actors sharing a common database, eliminating the need for system-to-system data transfer. For the supply chain, such a system is equivalent to an ERP for a single firm, a single database, which has been characterized as a technological tour de force that could deliver great rewards (Davenport, 1999). However, arriving at common standardized database solution for an entire supply network might be a Gargantuan and perhaps also a Sisyphean task, even for a large, powerful organization such as the US Department of Defense (Gulledge, 2006). Such a centralized solution would also need to have huge data storage and processing capacity because of the sheer amount of detailed information being collected (Spekman and Sweeney, 2006).

Reaching a higher digitalization level is important for other quality dimensions as well, especially because error-prone and time-consuming data re-keying operations are eliminated. For the ultimate level of digitalization, a common database, timeliness issues, processing errors and data losses could also be reduced substantially compared with lower-level solutions.

For the important task of identifying goods, the difference between manual identification and automatic identification (through barcodes or in an even higher degree of automation using RFID) also has important impacts on operational efficiency and effectiveness (Ilie-Zudor *et al.*, 2011). A tentative scale for the digital IQ adapted to goods identification operations is shown in Figure 2-8.

0 → Maximum identification digitalization level

method	No ID info	location-based	characteristics - based	visual unique ID label	electronic type ID	unique electronic ID
auto-mation		manual/visual identification of goods			semi-automatic	automatic

Figure 2-8 The digitalization-level IQ for goods identification

The scale starts from uniform goods having no means of identification. When such goods are placed at a fixed identifiable location, this can be used to identify the goods; but if the goods are then accidentally moved to another location, identification is lost. Another way of visual identification is using the characteristics of the goods. Then, the identification is more robust for goods displacement, but it could still fail if more goods with similar characteristics are being handled. The next quality level is represented by a goods label or tag carrying a visually recognizable unique ID, e.g. the identification plate numbers on vehicles or on shipping containers. Here, manual identification is possible, but expensive and error-prone. Errors and costs can be reduced using electronically readable IDs, for example the well-known universal product code (UPC), which is used in retailing to speed up goods identification during grocery checkout. However, the UPC only identifies the type of product, and accidentally scanning the same item more than once can occur. More accuracy can be obtained when each item has its own unique electronically readable identity, and the top level of identification quality is reached when the electronic ID is read in a well-designed automated process.

2.4.5.5 Product tracking system characteristics and IQ

Product tracking systems can generate huge amounts of detailed, precise and timely data, i.e. high quality data about the movements of products through the supply chain. However, other and possibly more important data qualities might easily be sacrificed when expanding a tracking system in all these dimensions. The main challenges when collecting large amounts of data from a range of different organizations are to maintain relevancy, interpretability, ease of understanding, consistency and conciseness in the resulting information infrastructure. Table 2-7 shows how the different characteristics of tracking systems as discussed in **Feil! Fant ikke referansekilden.** could have both beneficial and detrimental effects on the IQ provided by such systems.

Characteristic	Beneficial IQ impacts	Detrimental IQ impacts
Goods, Spatial and Process Granularities	Finer granularities imply more complete data	Finer granularity implies more data about how a counterpart handles its internal goods, which could lead to relevancy and conciseness problems, and also to interpretability issues (Jacobs, 2006)
Scope and Volume	A larger scope and volume implies more complete data	Larger amounts of data from more counterparts could lead to conciseness, relevancy, consistency and interpretability problems
Closedness and Cost	Closed systems decrease the cost of data collection and could lead to increased scope and volume, and thereby to more complete data	Reused containers having same identity could lead to confusion and errors
Connectedness	Increases completeness in the sense of including all actors handling the goods	No
Initiators/ Followers	A larger and more diverse set of initiators could lead to more complete data being collected by design	No
Extent and Depth	A system designed for a more extensive data set covering more business processes will have more complete data	No
Architecture and Standardization	A centralized standardized architecture could improve timeliness, consistency and completeness. A decentralized architecture could lead to more adapted, i.e. concise and interpretable data being exchanged in each dyad	Attempting standardizing across a large number of contexts for a centralized system could still result in consistency and interpretability problems (Gulledge, 2006). Relevance could also become a problem for some of the data
AutoID Technology and Automation	RFID could support a higher accuracy, granularity and digitalization level than could barcodes	The large amount of resulting data could be hard to interpret and to turn into a concise set of data for the user
Integration	Integration with other systems makes the total data available to the user more complete and eases the interpretation of tracking data	Obtaining conciseness could be a problem, but the standardization of goods identifiers provided by the tracking system could support the necessary join operations
Real Time	Improves timeliness	No
Identifier Lifetime	A long identifier lifetime improves data consistency across the supply chain by providing the same identifier for an item to all actors handling it	Short identifier lifetimes could inhibit consistency.

Table 2-7 Tracking system characteristics and their beneficial and detrimental effects on IQ

2.4.6 Conclusion: the IQ framework and further research opportunities

From the discussion in the preceding sections, it seems that the digitalization level should be added to the IQ framework presented by Kahn *et al*. (2002) and that the IQ derived from tracking systems is both dependent on the data as determined by the characteristics of the tracking system and by how the adopters use the system. The use of the system to generate meaning, and the possible errors and incompleteness in the data and in the meaning resulting from it, can be described by the IQ issues model (equations (8) and (9)). All these aspects have been included in the IQ framework depicted in Figure 2-9.

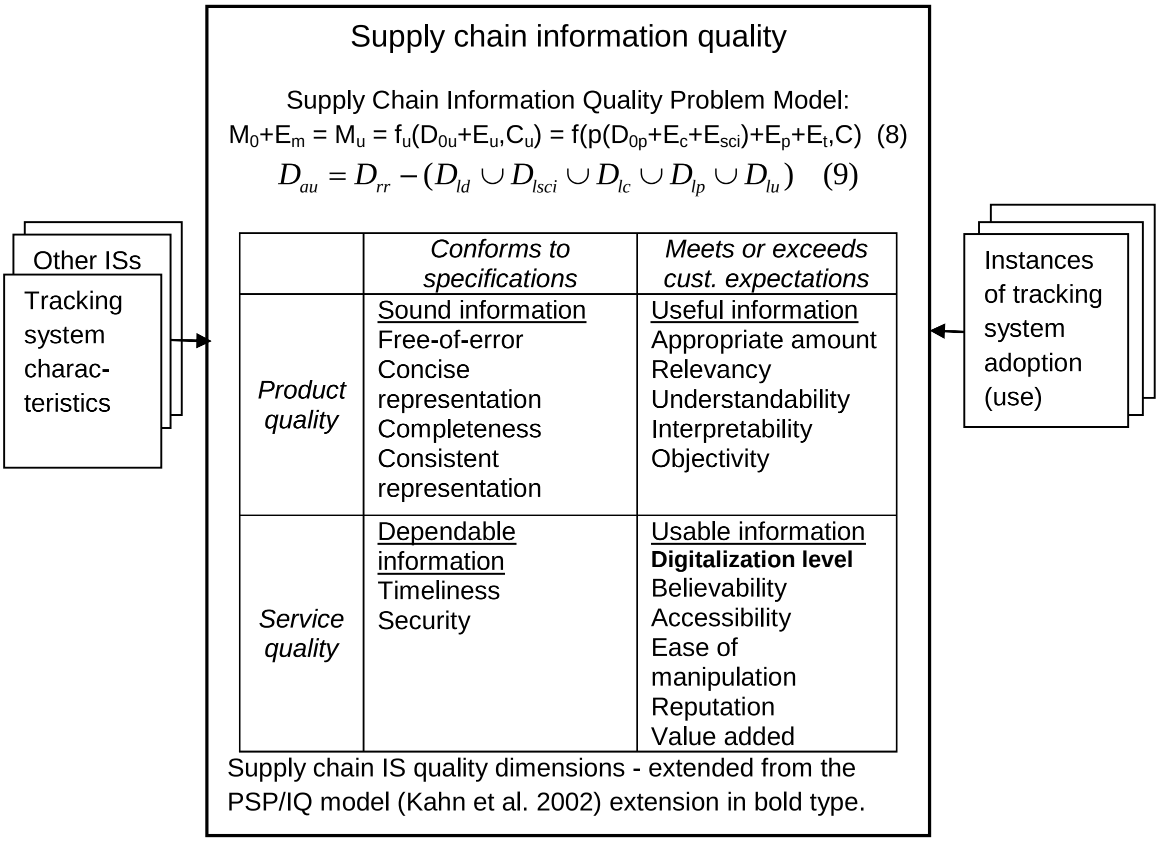

Figure 2-9 The supply chain IQ framework.

There are few contributions using approaches from IQ research to study the IQ available in supply chains and to assess how tracking systems can change the IQ available to supply chain players.

A contribution to such research is included in Section 9 of this thesis, which discusses a measurement scale and a mapping notation for information processing and the resulting IQ in the supply chains. The contribution proposes the use of process-centric IQ evaluation using field research focusing on the processes of the supply chain and on the quality of the different information elements that are used in such processes.

It seems that tracking systems can indeed lead to more complete, accurate and timely data being made available to supply chain actors. Research is needed to confirm this widely held hypothesis in the SCM literature. Other important IQs, for example, interpretability, conciseness and consistency, are scarcely discussed in the SCM literature. Here, tracking systems can encounter challenges that need to be solved to make the data add value to planning processes. It seems that research is needed to discover how these challenges can be handled by supply chain actors implementing tracking systems.

2.5 Tracking systems adoption framework

From a pure financial point of view, the decision to invest in a tracking system is ideally approached using a simple return on investment calculation (Sarac *et al*., 2010). However, determining the return on investment for such systems is a difficult process (Ilie-Zudor *et al*., 2011). The implementation of such systems in supply chains could give huge benefits, but there are many challenges, especially because benefits depend on whether counterparts are willing to follow the lead (Spekman and Sweeney, 2006). Therefore, gaining more knowledge on what could lead to adoption by counterparts would be highly interesting.

Research on the adoption of tracking systems in supply chains seems to be scant within SCM research, but there is a rich research stream on the adoption and impacts of EDI within the discipline of IS. Using this part of the IS innovation research stream to guide the studies of tracking systems adoption was proposed by Brown and Bakhru (2007). Lee and Özer (2007) also point out that EDI is parallel to RFID. To further justify the applicability of EDI adoption research results when discussing the adoption of tracking systems, Table 2-8 shows the similarities and differences between EDI and tracking systems.

	EDI IOS	Electronic product tracking IOS
Definition	The electronic exchange of structured data between supply chain stakeholders. See EDI in **Feil! Ugyldig resultat for tabell.** for an elaborated definition.	The electronic identification of logistics items and the capture of events concerning these items. The electronic dissemination of the captured information to supply chain stakeholders.
Main purpose	Support electronic business transactions.	Support physical material handling processes.
Expected benefits	Connect counterparts with timely and accurate information (Lee and Özer, 2007). Reduce manual information handling. Quicker and more reliable processes. Improved supply chain visibility with a large number of ensuing benefits.	Reduce manual goods identification. Reduce errors and efforts in goods handling. Improve "real time" supply chain visibility with a large number of substantial benefits. See Section 2.6 for a more comprehensive discussion.
Prerequisite	Business process improvements are necessary to collect full benefits.	
Costs	Relatively high investment costs and initially significant running costs. Running costs have decreased with the introduction of Internet technology.	High investment costs and significant running costs in flow-through systems. Running costs have been decreasing substantially since the introduction of the technology.
Network effects	Significant. The benefits and costs could depend on the implementation of the technology by counterparts.	
	The technology might also be beneficial within a single company.	
Asset specificity	Could be substantial if the system is non-standard and specific to a single trading partner, and if it also requires significant investment in equipment, software and organizational adaption.	
Information risk	Transactional information usually only contains what the counterpart "needs to know," but EDI has also been used to disseminate point of sale information which could be considered sensitive.	A tracking system captures the amounts of detailed information about goods flow of supply chain stakeholders. Information risks are thus potentially far higher than they are for EDI systems, but could obviously be reduced by limiting data dissemination.
IQ	The defined transactional context makes EDI data easily interpretable.	Detailed data about the movement of physical products at counterpart's premises could be harder to interpret.
Technological maturity	Initially (1980s) immature with divergent and incomplete standardization and insufficient organizational knowledge about EDI and the necessary integration resulting in adoption difficulties.	Initially (2000s) immature with divergent and incomplete standardization and insufficient organizational knowledge resulting in adoption difficulties. The invisible nature of radiowave propagation could create problems demanding expertise to solve.
Adoption	Now used in many supply chains, but adoption is still limited.	Used in a few supply chains apparently through mandates by powerful actors.
Stepwise adoption process	Followers initially implement standalone EDI with manual data transfer to local systems. Initially low benefits for followers. Deeper integration with higher benefits could occur over time.	Adopters typically start with standalone "slap and ship" applications. Initially low benefits for the follower. Deeper integration with higher benefits could occur over time.
Interdependence between tracking systems and EDI	EDI can be used as the technological basis for information dissemination in some tracking systems. Improvements in IQ and in the resulting benefits from tracking systems also depend on the IQ baseline provided by the installed base of EDI.	

Table 2-8 Similarities and differences between EDI and product tracking systems

From Table 2-8, it seems that there are many similarities between EDI systems in the '80s and tracking systems around 2000, probably making the results from EDI adoption research relevant when studying tracking systems adoption, but there are also some differences between the two technologies. The potentially larger information risks and potential benefits of tracking systems could be the most notable.

2.5.1 IS research on EDI adoption – an overview

The EDI adoption challenges seem to be particularly acute for SMEs, with an adoption rate as low as 2% among the six million businesses not appearing on the Fortune 1000 list, and with larger businesses succeeding in obtaining only a 20% EDI adoption rate among their counterparts despite aggressively encouraging EDI adoption (Chwelos *et al*., 2001).

Unfortunately, research on EDI adoption has not reached consensus on a single accepted adoption model despite more than two decades of research (Somasundaram and Rose, 2003; Benbasat and Barki, 2007). In a review of 68 papers on inter-organizational data exchange published between 1993 and 2002, Elgarah *et al*. (2005) classify the contributions according to the theoretical lenses that were applied in the research:

Lens 1: **Causal agency for change:** 1) Technological imperative was used by 73%, 2) organizational imperative was used by 26% and 3) an emergent perspective emphasizing interaction between technology and organization as the causal agent for change was used by 11% of the papers surveyed.

Lens 2: **Organizational motive for the adoption of data exchange:** 1) Efficiency (97%), 2) reciprocity (51%) and 3) asymmetry for 44% of the surveyed research papers.

Lens 3: **Type of inter-organizational relationship**: 1) Dyads were studied in 47% of the papers, 2) sets in 31% and 3) networks in 22% of the studies.

Lens 4: **Research approaches and epistemologies**: Half of the contributions reported from surveys, followed by 18% conceptual and 16% case studies. Only 7% of the studies were interpretive, while 3% were critical.

Therefore, a typical contribution from that time period is a survey measuring what characteristics of a technology could lead to the adoption of the technology in the dyad because of the efficiencies the technology could provide. The dominance of such contributions could be caused by the first two of the three theories guiding much of the research: 1) the technology acceptance model (TAM), 2) the diffusion of innovation theory (DOI) and 3) transaction cost economics (TCE) (Robey, 2006). The same theories are also frequently used as a firm basis within SCM research (Arlbjørn and Halldórsson, 2002).

These theories will be discussed in the next sections. Then, alternative models will be discussed. The last section covers a synthesis of these models into an adoption framework that could be used as a point of departure for further research on the adoption of tracking systems.

2.5.2 The TAM

The TAM has been used in many contributions within IS. It proposes *perceived usefulness* and *perceived ease of use* as constructs that can capture all beliefs that are relevant for the *user's adoption* of IT (Davis, 1989). The TAM is probably the most frequently applied model at the individual user level (Brown and Bakhru, 2007). A large number of studies have confirmed the TAM, as depicted in Figure 2-10.

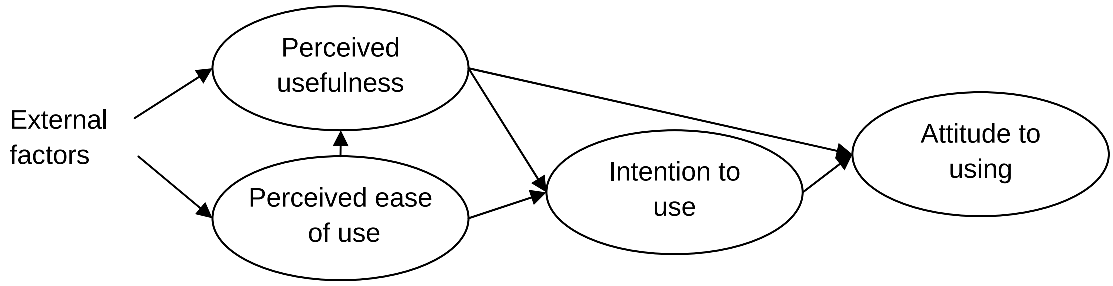

Figure 2-10 The TAM (Davis, 1989)

However, the TAM can be criticized for attracting too much interest to a too small area of research, which has not lead to actionable results in terms of guidance for practice and for system design. In particular, research based on the TAM has not provided knowledge about what characteristics make IT useful, nor has it considered user behaviors beyond use, e.g. reinvention and learning, which are important behaviors for the IT implementation outcome (Benbasat and Barki, 2007).

An interesting development and a response to the demand for more guidance for designing usable systems comes from Wixom and Todd (2005), who theoretically integrate a commonly accepted model from user satisfaction research as a front-end to the TAM. The authors use a survey to confirm the integrated model shown in Figure 2-11.

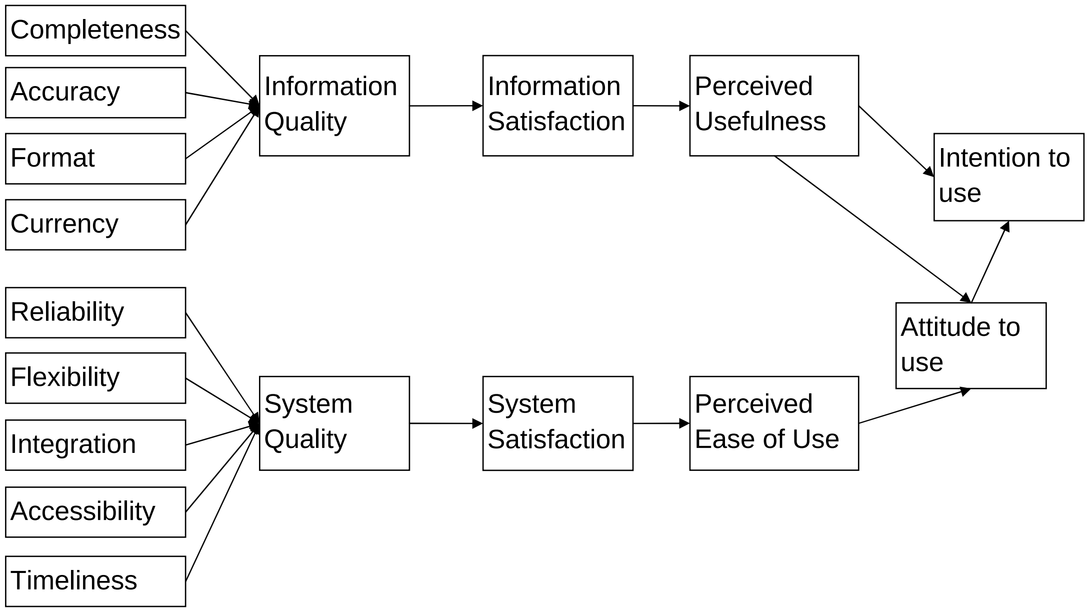

Figure 2-11 Using a model from user satisfaction research as a front-end to the TAM (Wixom and Todd, 2005)

As can be seen from the model, various IQ dimensions constitute the antecedents of an IQ construct that again determines the information satisfaction and further the perceived usefulness of the system. The model also uses the accessibility and timeliness IQ dimensions as antecedents to system quality, which is again an antecedent to system satisfaction and further to perceived ease of use.

2.5.3 The DOI

Many EDI adoption studies have used the DOI explicitly or implicitly (Iacovou *et al*., 1995; Chwelos *et al*., 2001). Lee (2007) applies the theory to explain the slow introduction of RFID technology in supply chains.

The DOI discusses how an innovation, which “is an idea, practice, or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2002), spreads among members of a social system.

According to the theory, the rate of the adoption of an innovation is determined by the following five characteristics of the innovation: 1) relative advantage, i.e. whether the innovation is superior to current practices, 2) compatibility, i.e. whether it is consistent with the values, experiences and needs of potential adopters, 3) complexity, i.e. whether the innovation is challenging to understand and use, 4) trialability, i.e. whether it can be experimented with on a limited basis, and 5) observability, i.e. whether results of the innovation are visible to other potential adopters. Innovations that are perceived as having higher relative advantage, compatibility, trialability, observability and lower complexity by potential adopters will be adopted at higher rates compared with other innovations (Rogers, 2002).

DOI research has been criticized for having low quality for a number of reasons: 1) by being often carried out after the adoption took place, leading to bias, 2) by using a too simple yes/no measure of the adoption, 3) by relying too much on single site qualitative case studies that cannot be generalized, 4) by not measuring the perceptions of adoption decision makers, 5) by considering too few innovation characteristics in each study, but covering a too large, vague and partially overlapping set of characteristics when regarding the entire body of research, 6) by focusing on only one innovation, and 7) by confounding individual and organizational adoption. The results from the entire research stream are meager in terms of showing significance for only the perceived relative advantage, the perceived compatibility and the perceived complexity factors (Tornatzky and Klein, 1982).

Another criticism that is raised against both the TAM and DOI models is their limited validity. Literature studies show that they fit well in situations where users can make independent decisions on whether to adopt and where technologies pose a low knowledge burden, i.e. are easy to learn. In situations where technologies are hard to learn or the decision to use them is dependent on decisions taken by other actors, the models have less explanatory power (Brown and Bakhru, 2007). Tracking systems are complex and hard to learn, and they are used in a network setting where much depends on the decisions taken by a set of more or less independent players.

2.5.4 Theory on the risks of conflicts in inter-organizational systems

Both the TAM and DOI look at how the perceived characteristics of an innovation influence the attitude to adoption and thereby the adoption decision. However, these theories do not take into consideration the special circumstances that are present when introducing inter-organizational systems into supply chains, where the adopters could be more or less dependent upon each other and could also have incompatible interests. Theories from TCE and common property resources can be used as a basis for theorizing the influence of supply chain circumstances on the adoption decision.

These theoretical perspectives have already been used in some adoption studies e.g. in Nagy et al.'s EDI adoption position model (2007) and in a study concerning the adoption of tracking systems in the food industry (van Dijk *et al*., 2003), which both build on a conceptual study by Kumar and van Dissel (1996).

Kumar and van Dissel (1996) discuss a typology of inter-organizational systems based on an interdependence perspective of the organization distinguishing between 1) pooled dependency where a common resource is shared, 2) sequential dependency where work is performed in series, e.g. on goods moving along a supply chain, and 3) reciprocal dependency, where work moves back and forth among players, e.g. when collaborating in a design process. These three types of interdependence correspond to increased degrees of contingency and thereby to increasing needs for coordination going from 1) a common standard, via 2) a plan to 3) mutual adjustment for the respective types of interdependency. The increased need for coordination using increasingly complex and indeterminate coordination mechanisms leads to an increased potential for conflict. The types of conflict and corresponding mitigation strategies can be derived from 1) common property resource theory for the common pool type of system or 2) transaction cost theory for the long-linked type of system used when dependence is sequential (Kumar and van Dissel, 1996).

Common property resource theory (Hardin, 1968; Ostrom, 1990) builds on game theory to explain a number of risks posed to such resources in terms of the overexploitation or pollution of land or water resources, or poaching from common game resources. For a common pool information system, these risks correspond to using up capacity, to inserting data of low quality into the pool or to collecting proprietary data belonging to other actors but available through the pool. However, such problems can be countered using technical safeguards (Kumar and van Dissel, 1996).

In common pool IS, those risks to information service, quality and safety can be considerable because of the value of the information. In fact, estimates indicate that 70% of the market value of firms in the US is connected to their trade secrets and intellectual property. Furthermore, these valuable assets have been increasingly attacked by former and current employees and competitors (Fitzpatrick *et al*., 2004). In addition, the technical safeguards are no better than is the organization implementing them and the routines of those organizations. Risks to information in inter-organizational systems can thus be perceived to be an important factor to firms considering the implementation of such systems in a supply network where collaborating players are also counterparts and/or competitors.

The risks in supply chain IS supporting sequential relationships can be discussed using TCE, which posits that actors will behave opportunistically in the sense of short-term self-seeking with guile. The transaction cost then has to include measures to keep such opportunism under control (Williamson, 1979). For IOSs, the transaction risk might be the most interesting part of the transaction cost. Here, three transaction risks can be discerned: First, asset specificity, which is the cost of assets that are specially developed to serve a single business relationship, i.e. software and training especially developed for communication within a dyadic relationship. If such investments are considerable, they can easily change the power relationship of the dyad. The second source of transaction risk is asymmetric information about the performance of the counterpart, i.e. whether the counterpart is fulfilling its commitment or is shirking. This risk can be reduced or eliminated using information from the IOS and/or incentives that align goals (Kumar and van Dissel, 1996). For actors in the supply chain that were previously able to conceal information from their counterparts and thereby create a situation with information asymmetry to their advantage, the transparency created by inter-organizational systems could be perceived as a risk of losing that advantage (van Dijk *et al*., 2003). The third source of risk is the “loss of resource control” for IOSs, which could mean the loss of control over information as discussed in the previous paragraph.

2.5.5 Specialized SME adoption models

Research based on the DOI and the technological acceptance model focus on individual decision making on the adoption of a technology based on its perceived characteristics. In supply chains, the setting is different. EDI adoption research has studied a number of models that incorporate these special circumstances of EDI adoption and that seem to have striking similarities with the circumstances of tracking systems adoption:

1. The business value of the system is highly dependent on the adoption decisions of other players, i.e. there are significant network effects, and thus interdependencies, power and trust become important considerations (Iacovou *et al*., 1995).
2. The context for many adoption decisions is within an SME where a larger counterpart has already decided to implement the technology.
3. The complexity and cost of the technology and of the necessary integration can be hard challenges for SMEs lacking the necessary economic, system and human resources.
4. The distribution of costs and benefits can be asymmetric.
5. The investment in implementing the system can be considered to be a specific asset.
6. The information disseminated via the system can constitute a risk for disclosing valuable business secrets to other players, which potentially are business counterparts or competitors.

Because of these special circumstances, models taking them into consideration can provide improved prediction about the adoption of EDI and the adoption of a tracking system.

A pedigree of such models can be found, starting with the EDI adoption in Small Firms model developed as an interpretive case study by Iacovou *et al*. (1995). The model starts from the DOI and incorporates the perceived relative advantage as a “perceived benefits” factor. It further uses an “Organizational Readiness” factor, which compares costs and complexity with the potential adopters’ economic and knowledge resources. Finally, an “external pressure” factor takes the asymmetry and trust and power relationships typical of the SME adoption decision context into consideration. The model thus incorporates circumstances 1, 2 and 3. The model partly responds to the criticism of DOI research for being non-specific about implementation by using a two-level scale for the integration of EDI with other systems, and it is strengthened through the eight-site qualitative case study.

The model (Iacovou *et al*., 1995) was further enhanced and validated through a positivist test by Chwelos *et al*. (2001). It was first extended by examining 11 papers using different conceptualizations and mapping those conceptualizations onto three factors: external pressure, readiness and perceived benefits. To accommodate the conceptualizations from other models, and to make the factors representative of the technological, organizational and inter-organizational levels respectively, the readiness factor now includes the readiness of trading partners, while the factor external pressure now also includes dependency on trading partner and industry pressure. A survey instrument was used to test the model, and significant influence for all factors was found, but only the competitive pressure and enacted trading partner power subconstructs of external pressure were found to be significant.

2.5.6 Other studies

While recognizing the accomplishments of earlier models including the TAM and DOI, and their validity in the cases of individual autonomous adoption decisions, Gallivan (2001) points out that in organizations the decision is often taken by an authority figure. Further, the subsequent adoption and assimilation of complex technological innovations can be modeled using a process/variance theory capturing implementation events over time and explaining how those events are influenced by various factors. The model is supported by a longitudinal case study. This approach and model can be used to study the implementation processes in tracking systems (Brown and Bakhru, 2007). However, the model is sculpted on a large organizational hierarchy, and it will have to be modified when applied to a more loosely coupled supply chain of more independent players including SMEs.

The "organizing vision" created by a diverse inter-organizational community around an IS innovation is the focus of Swanson and Ramiller (1997). The vision is determined by various institutional forces including the community's discourse, which serves as its development engine, while the content, structure, motivation and direction of the discourse is created by IS practitioners' worldviews, the motivating business issues, the core technology and the processes of adoption and diffusion. The vision is primarily developed during the early phases of innovation diffusion and it interprets and legitimizes the innovation and organizes and mobilizes economic roles and exchanges.

Damsgaard and Lyytinen (1998) argue that the complex and inter-organizational nature of EDI requires the use of multiple theoretical frames and observation points when studying the diffusion process. Using a field study, they identify factors at three levels of analysis: local dyadic, industry-wide networks and national initiatives. Factors at all these levels can support understanding five different diffusion patterns, i.e. the emerging EDI adoption in various organizational constellations. The patterns found in the Finnish study were: 1) creating a win–win deal at the dyadic level, 2) wholesale's gentle push, 3) long tradition of cooperation, and 4) concessioned companies showing the way at the industry level and 5) "EDI the Finnish way." The patterns indicate that the EDI diffusion is "a complex interplay of organizational, industry and institutional factors."

Rodon *et al*. (2008) conducted a longitudinal, sociotechnical, multi-level and process-oriented study of the implementation of an inter-organizational system in the seaport of Barcelona. The authors use actor network theory as a vocabulary to describe the dynamics of the implementation process in terms of "cycles of translation," within which the interests of the actors are iteratively aligned, and in terms of defining the system as an "obligatory passage point" that each actor can use to satisfy its interests. Further, they described the terms of handling "the installed base," namely the existing technologies and work practices used by the actors. The authors come up with the following requirements for managing implementation: 1) understanding the degree of the stability of the interests, 2) performing strategies to align those interests and 3) being open to the unexpected paths that implementation may take.

2.5.7 Tracking systems adoption studies

According to two recent literature reviews of the RFID literature (Ngai *et al*., 2007, Sarac *et al*., 2010), there are few studies specifically targeting tracking systems adoption.

Whitaker *et al*. (2007) builds on theory from IS including Iacovou *et al*. (1995) and Chwelos *et al*. (2001) to build hypotheses. The study uses data collected by InformationWeek from top IT managers about the expected deployment and return on investment. It finds that expected IT application deployment is associated with the adoption of RFID and that RFID implementation spending and a mandate from a partner heighten the expectance of early return on investment, whereas the expectance for return on investment is delayed when RFID standardization is perceived as lacking.

Lin (2009) studies whether factors that should in theory make firms more innovative also could be used to predict the adoption of RFID. The empirical study collected 151 questionnaires from logistics service providers in Taiwan. The study concludes that the perceptions of the explicitness of the technology, the firm's accumulation of similar technologies, the organizational encouragement and qualities of the human resources and government support for innovations determine the adoption of RFID.

Ngai (2009) discusses the issues and challenges of RFID adoption concentrating on the technical problems of standardization, interference from the physical environment, data management and security and tag failure rates. Ngai also discusses the organizational problems of securing the necessary expertise and commitment of top management through cost/benefit analysis.

Keating *et al*. (2010) study 21 possible antecedents for the decision to invest in RFID. The antecedents were collected through a wide literature study covering both academic and trade sources and tested using a questionnaire answered by 57 adopters and 76 non-adopters, totaling 133 readers of the RFID journal. The conclusion is that data accuracy, top management commitment, information visibility, inventory management, track and trace, service quality and process innovation are factors significantly contributing to the decision of whether to adopt for both groups, while costs are significant factors for non-adopters. The study did not measure the degree of adoption nor did it check whether respondents are potential initiators or followers. It is interesting to note that two of the significant factors relate to data quality, two to business processes, one to functionality, one to customer value and one to organizational support.

Fries *et al*.'s (2010) conceptual study considers factors that influence the implementation of collaborative RFID programs based on assimilation theory. They argue that successful implementation depends more on a favorable climate for organizational learning than it does on factors that are proposed by the DOI, which are more closely related to the properties of the technology. The proposed model includes the factors top management support, cross-functional teams and prior technical knowledge as antecedents to the internal implementation climate. The external implementation climate can be measured in terms of norms for flexibility, information sharing and solidarity. The two climates are then proposed to be the antecedents of a successful RFID implementation.

2.5.8 Conclusion: A tentative follower adoption model

Research into the adoption and implementation of inter-organizational systems has been carried out over a long time period and it has been based on a number of different theories with partly overlapping conceptualizations (Chwelos *et al.*, 2001). In later years, more interpretive, longitudinal and multi-level research approaches have been followed, and these have given increased insights. However, these considerable research efforts have still not resulted in one common accepted theory. This is perhaps unsurprising when looking at the complex and varied inter-organizational settings in which a substantial variety of such systems are adopted and implemented.

One of the insights from research is that turning technological concepts into an organizing vision requires contributions from various actors within and external to the supply chain and that the implementation process and subsequent benefits from the system evolve over a long time period (Brown and Bakhru, 2007, Mukhopadhyay *et al.*, 1995, Mukhopadhyay and Kekre, 2002). Adoption and implementation within an organization as a stepwise process starting with an adoption decision by an authority person is discussed by Gallivan (2001). The same idea can be transferred to an inter-organizational setting by looking at the primary adoption decision and implementation by the system initiators, followed by secondary adoption and implementation by followers – the other actors in the supply chain.

A low number of studies of the adoption of product tracking systems seem to follow the early pattern of research on inter-organizational systems by conducting factor analyses based on firm theories such as the DOI, various incarnations of the TAM or organizational learning. Of these studies, none discusses the crucial adoption by followers nor actualizes the question posed by Ngai *et al*. (2007 p. 517): “Does our RFID research meet the needs of practitioners and managers?” An important criterion for answering that question is whether the results of the research are actionable, i.e. that action can be taken by managers based on them.

It seems that the critical problem for practitioners and managers considering the initiation of a tracking system is making a sufficient number of other actors adopt the system and become followers. Possible actions from the initiator to increase the number of followers can be directed towards either the other actors or the nascent tracking system by changing the system characteristics defined under system construction.

The first two research papers presented in this thesis attack the problem of obtaining follower adoption. The first paper reports on the strategies pursued by an initiator to introduce a tracking system in a supply chain despite the limited power of the initiator. The second paper discusses how two key technological choices taken when first constructing a tracking system can influence adoption by followers that are largely SMEs. The focus of the research presented in this thesis is on how initiator actions influence follower adoption. It is thus actionable research.

The theoretical framework for this research is an extension of the SME EDI adoption model of Iacovou *et al*. (1995), which seems applicable when studying the adoption of tracking systems by followers, because of the similar circumstances of low industry competence on RFID and because of the well-supported result from the IS research community on lagging technology adoption among SMEs.

The model is extended by taking into account the growing consciousness of data risks and by considering the higher asset specificity because of higher investment and running costs necessary for tracking systems compared with IOSs based on EDI. The extension, therefore, follows the approach of Nagy (2007) by including the risk considerations from Kumar and van Dissel (1996) and costs as separate factors. As IQ is widely regarded to be the mediator of tracking system benefits (Sellitto *et al*., 2007), the ideas from Wixom and Todd (2005) are followed, resulting in the addition of IQ and system characteristics as antecedents to the perceptual factors. Finally, "other factors" have been included to cater for industry and institutional factors, and the role of the organizing vision (Damsgaard and Lyytinen, 1998; Gallivan, 2001). The resulting framework is shown in Figure 2-12.

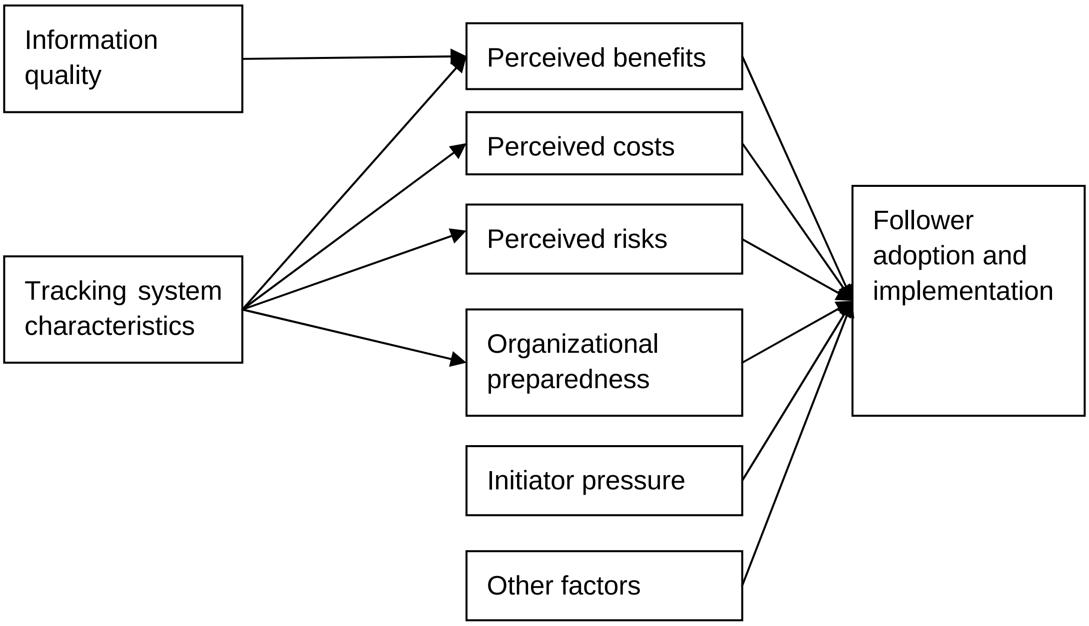

Figure 2-12 Tracking system follower adoption framework.

In addition, to the support from the literature used to develop the framework, the contributions presented in Sections 7 and 1 of this thesis give some support to parts of the framework. Both contributions discuss the various means of the initiator when working for adoption among the followers. Section 7 studies an implementation process and describes how and why various strategies used by the initiator fail or succeed in furthering follower adoption by influencing the determinants of adoption according to the model. Section 1 develops a model to support the technological decision making by the initiator. These technological decisions determine the system characteristics that influence the determinants of adoption according to the model. Section 9 reports on an effort to operationalize and map IQ in a supply chain setting. However, to obtain increased validity, further research efforts to operationalize and test the full framework are necessary.

2.6 Tracking system impact framework

2.6.1 Introduction

To support decisions when considering the adoption and implementation of tracking systems it is necessary to quantify the benefits of such systems, but strong externalities make such quantification difficult (Dutta *et al*., 2007).

There are few reports on full supply chain scale implementations of tracking systems (Sarac *et al*., 2010). Nevertheless, the literature includes a substantial number of papers discussing the possible benefits of RFID-based tracking systems (Lee and Özer, 2007, Ilie-Zudor *et al*., 2011). The discussion is mostly based on widely varying guesstimates and, in a few cases, on results from pilot testing or motion studies, but it is dubious whether meaningful results can be obtained using those two approaches in cases with significant technological advances such as RFID (Lee and Özer, 2007). Lee and Özer (2007) also discuss parallel experiences from studying the impacts of EDI within IS research, but rather suggest the use of analytical models starting from basic operating principles to evaluate how the technology might lead to a series of improvements and thereby values.

A recent literature review by Sarac *et al*. (2010) found a number of contributions using mathematical modeling to study the impacts of tracking systems on inventory management, but most of the analytical and simulation models presented were oversimplifications considering small supply chains and postulating a perfect RFID technology eliminating all problems.

As pointed out by Lee and Özer (2007), "the value of RFID comes in the form of increased visibility," which means that decision makers having access to information from tracking systems can base decisions on more complete and reliable information. In a literature review analyzing tracking system benefits, IQ improvements supporting the organizational decision making process can be connected to many of these benefits (Sellitto *et al*., 2007).

The next sections start by drawing some lessons from studies of the benefits of EDI. Subsequent sections look at what can be learned from the SCM literature on the impacts of RFID systems and then discuss the role of IQ in creating the various benefits. The final sections sum up what has been found and conclude by presenting an impact framework.

2.6.2 Some lessons from IS impact research

The difficulties when researching the impacts of IS are neatly expressed in the following:

> "Why is there so little consensus or cumulative knowledge about the impact of IT despite substantial research efforts in this area. [..] First IT is often treated as a single factor. Given the complexity of the technology and the difficulty of implementing it in organizations, some systems may be effective, while others may bring negative returns. Second, many [..] studies use cross sectional or short time series data. If there is a lag in achieving IT business value, data covering a limited time period may not reveal the impact.[..] Since the IT impact cannot be assessed in isolation, confounding effects of other inputs must be accounted for." Mukhopadhyay *et al*. (1995)

> "Research on the business value of IT can be characterized as a loose research area, where researchers have been striving to explain complex phenomena with greater fidelity using theoretical ideas, often drawn from other disciplines." (Robey, 2006)

Again, when approaching the benefits of tracking systems, the most relevant previous studies within the field of IS are those discussing inter-organizational systems. In particular, studies of systems based on EDI that were supposed to bring similar benefits of "vertical information integration" or "supply chain transparency" could be interesting. The following important lessons can be learned from that line of research.

Impacts over time: Benefits from the system can increase over a relatively long time period. The benefits for the initiator are lagging because the system's volume expands gradually through adoption among followers (Mukhopadhyay *et al*., 1995). Realizing the full benefit also requires a higher degree of integration, supporting the direct system-to-system communication of an extended set of transactions. Usually implementation by a follower starts at a low level of digitalization using the manual re-entry of data from the inter-organizational system into the local system. Deeper system-to-system integration then occurs over time (Mukhopadhyay *et al*., 1995; Mukhopadhyay and Kekre, 2002). Mukhopadhyay *et al*. (1995) find that inventory turns had an increasing trend within the 10-year period studied, while Mukhopadhyay and Kekre (2002) only find a significant impact on strategic benefits for EDI relations in operation for *more* than 3.5 years.

The considerable amount of data from high granularity tracking systems means that the first low-level implementation step of EDI permitted by the manual re-keying of data might not be possible for tracking systems. The low-level step reported for tracking systems that mandate followers is "slap and ship," meaning that identification tags are applied to the goods when shipping and not used by the supplier for its own purposes. Slap and ship thus provides no operational benefits to the supplier, meaning that tracking systems can be harder to implement. This implies that tracking systems impact studies aiming at catching the bulk of benefits should be longitudinal and could need more than a decade to complete.

The importance of digitalization level: The largest proportion of the benefits accrues from reduced information handling costs that are connected to the direct transfer of information from system to system. This benefit occurs for both parties in the information exchange, but depends on obtaining the necessary depth of integration. Direct transfer corresponds to deep integration and also to a high digitalization level (Mukhopadhyay *et al*., 1995; Mukhopadhyay and Kekre, 2002). Benefit studies should thus include digitalization level as a variable.

The importance of improved IQ and implementation processes leading to improved business processes: Various benefits coming from improved inventory management based on improved IQ accounted for more than 50% of the savings reported in Mukhopadhyay *et al*. (1995). The improved IQ was a necessary condition for restructuring the inventory management processes using just in time principles (ibid.). Thus, the benefits are dependent upon improving IQ as well as on the organization's ability and will to redesign processes and business models to make use of the information provided by the system. Discovering and exploiting such opportunities can evolve over a long time period (Orlikowski, 1996), and this lends further support to the requirement for longitudinal studies when researching system benefits.

Operational and strategic benefits: In addition to the operational benefits discussed above, followers obtain strategic benefits from increased trade with the initiator. These strategic benefits occur as increased trade in two distinguishable steps: first as a direct result of adopting and later when increased operational efficiency derived from the system makes it even more advantageous for the initiator to transfer business from non-followers to followers (Mukhopadhyay and Kekre, 2002). The stepwise realization of strategic benefits also endorses the long-term nature of benefit realization.

2.6.3 Expected impacts from RFID-based tracking systems

A number of reviews on the benefits of tracking systems have been summarized in Table 2-9.

Literature review	**Count and time period**	**Remarks**
Lee and Özer, 2007	1972–2006, n=42	Discuss 23 studies estimating the value of impacts from improving inventory management with RFID, seven models that could be used to make a better founded evaluation of the impacts of using RFID within a company and 12 studies discussing the value of receiving RFID-based data from upstream or downstream counterparts.
Sarac *et al*., 2010	1958–2009, n=142	Focus on impacts concerning inventory management, i.e. inventory inaccuracy, replenishment policies and the bullwhip effect.
Ilie-Zudor *et al*., 2011	1993–2010, n=84	Survey the RFID tracking system applications literature, including discussions on the obtainable benefits, tracking systems technologies and components and the requirements of logistics chains.

Table 2-9 Literature reviews on the benefits of tracking systems

A problem when summing up the possible benefits of product tracking systems reported in the literature is that different categorizations and levels of abstraction have been used. In the following sections, the benefits are categorized into two broad categories, where the first category covers benefits that come from the changeover from the manual identification of products to using automatic identification (AutoID), either to improve on manual processes or to support fully automated processes. The second category contains benefits that accrue from the collection of more complete and accurate information, making it possible to track and trace the product through the supply chain and production processes.

2.6.3.1 Benefits of AutoID

Product tracking systems can support process improvements by saving work, reducing errors and reducing the time taken when identifying products, as well as by providing visibility in terms of information on identity and location in real time (Saygin *et al.*, 2007). As a result, processes can be made quicker and more reliable and this results in improved flows of inventory (Sarac *et al.*, 2010; Ilie-Zudor *et al*., 2011) and information. Such benefits can lead to cost reductions (Lee and Özer,

2007) and can be found at any location where there is a need to identify product items, whether the identified products are raw materials, components or semi-finished or finished products.

In the sourcing process, having a digitally readable identity for parts can speed up and reduce the efforts and errors committed when ordering replacements for used up inventory (Ilie-Zudor *et al.*, 2011).

Transportation between actors can become more efficient and effective because AutoID can be used to speed up the loading and unloading processes and remove errors in those processes. It can furthermore make merge-in-transit more efficient. This results in fewer errors being present in the goods flow and in lower transportation costs. Tracking systems can also improve the management of unexpected variances in volume and destinations (Ilie-Zudor *et al.*, 2011).

The receiving process can be rendered more efficient by using AutoID and it can also become more effective in terms of discovering and handling transaction errors (Lee and Özer, 2007; Sarac *et al.*, 2010; Spekman and Sweeney, 2006), so the errors do not go undetected, thus causing inventory errors. AutoID can also be used to reduce errors in the put away process and thereby result in fewer misplaced items. AutoID can further be used to find and re-shelf misplaced items. Furthermore, inventory counting can be automated, making it feasible to perform frequent inventory counts, thereby reducing inventory errors (Lee and Özer, 2007; Sarac *et al.*, 2010).

Such systems can also reduce the overall lead time by cutting information lead time and by cutting the time necessary for inspection and clearance by customs and other relevant authorities (Lee and Özer, 2007; Ilie-Zudor *et al.*, 2011).

A manufacturing process can also be improved using AutoID (Lee and Özer, 2007), for example to support product variety, to reduce assembly errors by ensuring that the correct parts are being used according to customer specifications (Lee and Özer, 2007; Ilie-Zudor *et al.*, 2011) and by supporting improved quality control, both by ensuring that the correct components are used and by locating and weeding out faulty components. Tracking systems can also shorten the production cycle and thereby correct errors at an earlier stage. AutoID can further provide better control over the work in process inventory (Ilie-Zudor *et al.*, 2011).

At the delivering end, picking and placing products can be more accurate using AutoID, and quick identification can speed up the process (Ilie-Zudor *et al.*, 2011). Here, transaction errors can be eliminated before propagating to the next actor (Lee and Özer, 2007; Sarac *et al.*, 2010; Spekman and Sweeney, 2006).

Reducing or eliminating picking, loading and unloading errors also substantially reduces the potentially large efforts spent handling such errors by both counterparts in the corresponding transaction. Errors also slow down the economic settlement, so their elimination can contribute to improved cash flow. Reduced information lead times and reduced cycle times obtainable through AutoID also enhance cash flow (Spekman and Sweeney, 2006).

Theft is an important problem that can be alleviated by using RFID-based tracking systems. Furthermore, tracking systems can reduce shrinkage because of spoilage by supporting inventory management practices for perishable products (Spekman and Sweeney, 2006; Nicolai, 2011; Brown and Bakhru, 2007; Sarac *et al.*, 2010; Ilie-Zudor *et al.*, 2011). Shrinkage because of expired goods and theft represents both a costly waste in purchased goods that are not sold to paying customers and a lost opportunity for sale if the shrinkage results in stock outs. Tracking systems generally, especially those based on RFID, reduce shrinkage substantially (Lee and Özer, 2007; Spekman and Sweeney, 2006; Nicolai, 2011; Brown and Bakhru, 2007; Sarac *et al*., 2010; Ilie-Zudor *et al*., 2011).

Another source of errors in the inventory position is returns of products that can be sold directly or after refurbishment. Tracking systems can provide information about returns from downstream actors (Lee and Özer, 2007), thus making the handling of such returns more efficient and effective. Environmental aspects can also be improved using AutoID, for example by ensuring the correct handling of hazardous goods (Ilie-Zudor *et al*., 2011).

In returnable asset pools, AutoID can be used when screening contaminated or damaged containers (Ilie-Zudor *et al*., 2011) and to improve control over assets to reduce shrinkage (Brown and Bakhru, 2007).

2.6.3.2 Benefits of tracking systems

Product tracking systems can support track and trace functionality (Sarac *et al*., 2010) if they collect sufficient information to be able to document the history of a product and its constituent parts. Tracking systems can thereby support improvements in after sales service support by speeding up diagnosis, by supporting preventive maintenance and by supporting the correct disposal of the product and its components (Lee and Özer, 2007).

Product quality can also be improved by supporting the location of problems with the product (Brown and Bakhru, 2007) and by tracking down customers owning product items probably affected by the same problems in order to recall, repair or replace those products. This is especially important if the problems could have adverse safety or health effects.

Another possible benefit could be to enhance the product with information about its origin. This could be especially interesting for responsibly sourced products in terms of sustainability or fair trade.

Out of stocks can result in lost sales for a retailer. If out of stocks are not automatically detected because of the inventory record erroneously showing a positive inventory situation, the situation continues. Some causes for this issue could be undiscovered transaction errors or various forms of shrinkage, including theft, misplaced items and spoilage. As discussed in the previous sections, tracking systems can alleviate all the mentioned causes and thereby reduce out of stocks (Lee and Özer, 2007; Brown and Bakhru, 2007; Sarac *et al*., 2010).

However, there could be other reasons for stock outs, for example deficient planning because of faulty inventory policies or faulty demand forecasts. For a manufacturer, the demand forecast could be improved if data about actual demand are made available through tracking systems. Tracking systems could thus result in improved planning and management (Sarac *et al*., 2010; Ilie-Zudor *et al*., 2011).

Data from tracking systems can also be used to reduce the information asymmetry between counterparts and thereby provide credible information sharing without expensive contractual safeguards (Lee and Özer, 2007). Increased supply chain visibility could also be used to reduce supply chain instability, also known as the bullwhip effect (Sarac *et al*., 2010). From tracking systems extending upstream, information about supplies in the pipeline can be used to remediate supply uncertainty.

For the customer, value could be increased by improving customer service or by improved quality and safety. Tracking systems can take service, quality and safety to another level by providing better information on the status of ordered products, by supporting the efficient and effective recall, repair or replacement of products where problems have surfaced during or after distribution (Ilie-Zudor *et al.*, 2011) and by delivering information-enhanced products with credible environmental or fair trade properties (Bø, 2011; Smith, 2008).

Tracking systems can also be used to block counterfeit goods entering the supply chain. This is especially relevant for expensive fashion products, but even more so for possible a more life-threatening problem: counterfeit pharmaceuticals (Spekman and Sweeney, 2006). Another illegal product that could be barred from the market with the help of tracking systems is seafood coming from illegal, unreported or unregulated fisheries (Borit and Olsen, 2011).

As discussed in previous sections, tracking systems can reduce costs and improve many aspects of customer value, including increasing customer satisfaction (Elgarah *et al.*, 2005). Therefore, it seems that Spekman and Sweeney's (2006) statement that such systems could sustain a competitive advantage is justified. However, this is dependent upon adapting business processes. Tracking systems can also support more radical improvements in business processes and models (Sarac *et al.*, 2010).

The literature describes and makes plausible a large number of potential benefits from the implementation of tracking systems to supply chain stakeholders including customers. The impacts and their interdependency are summed up in Figure 2-13.

From the perspective of the greater society, tracking systems in the supply networks of food could also prove beneficial for alleviating the large number of food scares reported. Alleviation could come directly from the swift localization of the source of food illnesses and rapid removal of the affected products from the market. In the long-term, being able to pinpoint the culprit for hazardous food could lead to increased accountability and improved industry practices, thereby eliminating some of the too many food scares currently reported in the press.

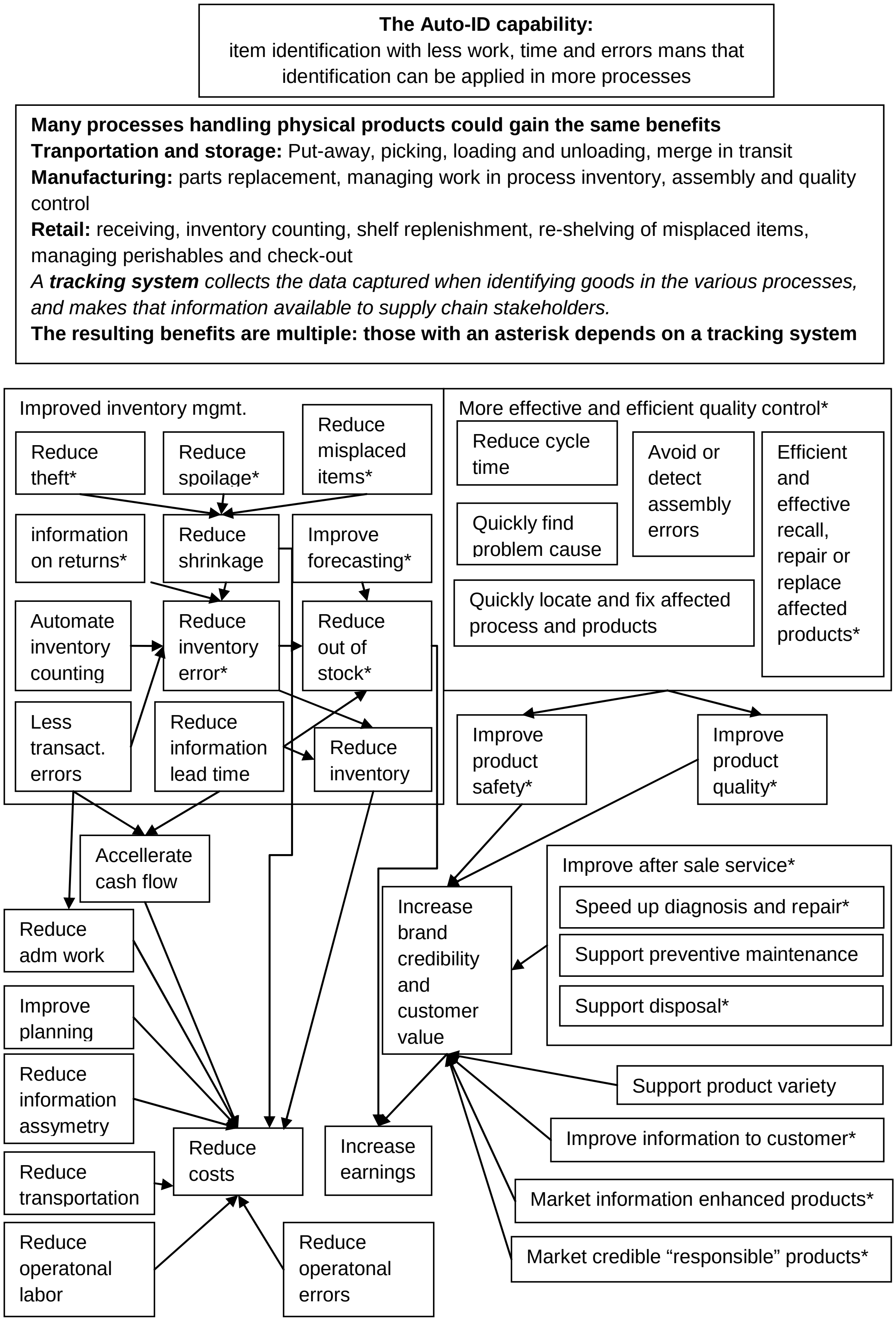

Figure 2-13 The impacts of tracking systems as discussed in the literature

2.6.4 Discussion and conclusion: A tentative impact framework

Figure 2-13 sums up the impacts of tracking systems as discussed in the SCM literature. A more high-level view can be developed by accepting Lee and Özer's (2007) assertion that the value of product tracking systems comes from the IQ provided by them. It also seems that the direct benefits of using automatic identification technologies such as RFID mainly accrue in processes handling physical products. The indirect benefits that result from the supply chain visibility provided by systems disseminating information captured from these physical product handling processes could be more beneficial for management processes. The resulting high-level impact framework is presented in Figure 2-14.

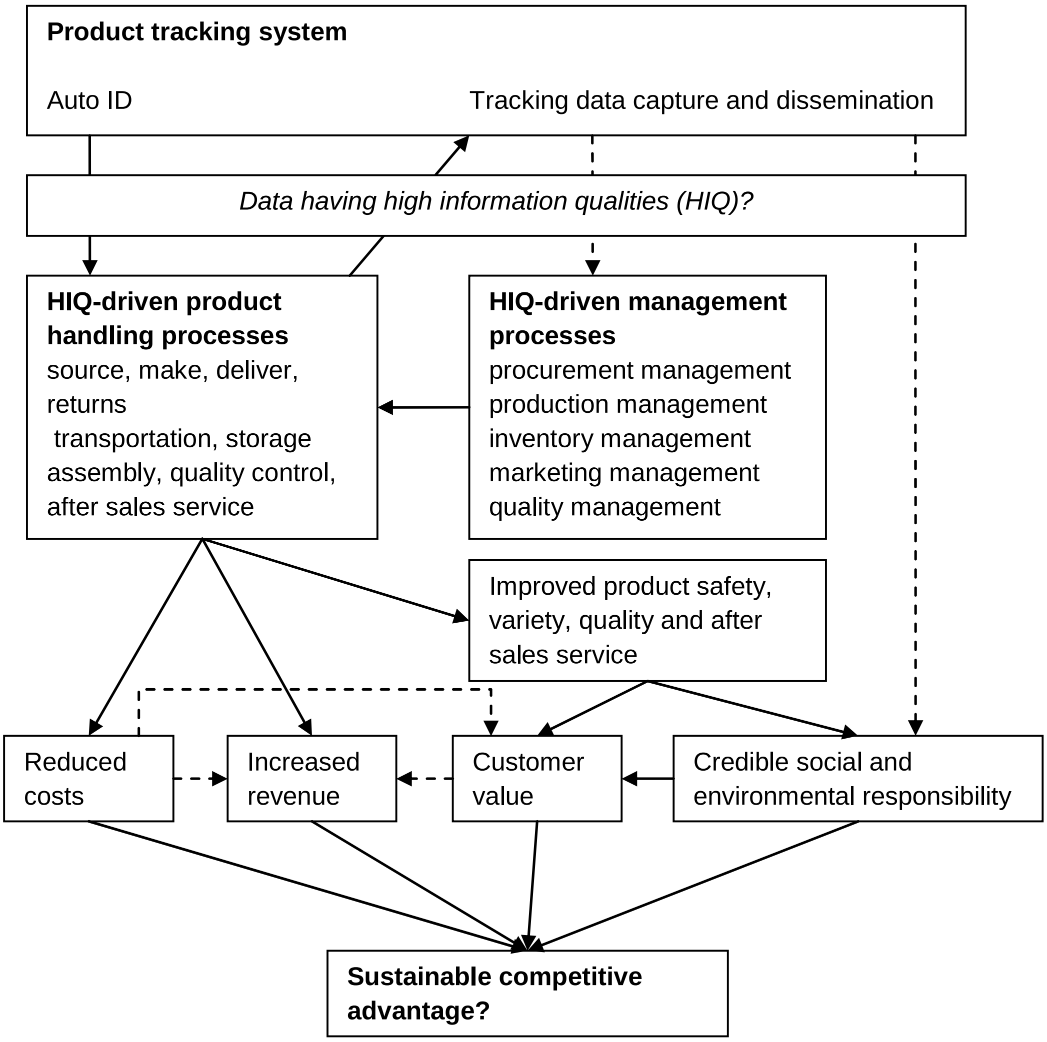

Figure 2-14 The tracking system impact framework (dashed arrows are long-term effects)

Some of the impacts are long-term and shown with dashed arrows in Figure 2-14. First, obtaining the necessary supply chain visibility for management processes depends both on the time-consuming process of system adoption and adaption in the supply network and on the time-consuming process of learning to interpret and use the resulting information. This unique and hard to acquire knowledge can also reduce the possibility for competitors to easily imitate the approach, meaning that competitive advantage could be sustainable in the long-term. Some of the effects on revenue are also strategic, i.e. long-term, because they depend on cost and quality improvements leading to a higher market share.

The long-term nature of a significant proportion of the benefits has serious implications on the methods for evaluating the benefits derived from tracking systems. Furthermore, similar, albeit less detailed and perhaps less accurate information, about goods flows is already being disseminated using EDI in many supply chains. This means that studies evaluating tracking system benefits should be longitudinal and should take the issue of the correct baseline seriously into consideration.

The figure also points to a problem with some of the existing literature; the taking for granted that product tracking systems do indeed provide a sufficient improvement in IQ to obtain all the touted benefits. As discussed in Section 2.4, IQ is a multidimensional concept where more qualities than accuracy and timeliness are essential to make beneficial use of the extra data.

Processing the enormous amount of detailed data on goods movement and handling events can be a challenge if the necessary data communication and processing infrastructure have not been developed (Saygin *et al.*, 2007). In addition, further challenges are lurking, for example the need to couple tracking data with data from a number of other heterogeneous systems to make them meaningful and consistent. It is further necessary to extract what is relevant for each user task and then to aggregate these data into a concise form containing the appropriate amount of data, which might be reintegrated with more contextual data from various systems in order to give a complete actionable picture of the part of reality the manager wants to optimize. This might seem an arduous task within a single company, but tracking systems can be inter-organizational systems covering a network of actors. And even though succeeding with the challenges mentioned above, the challenges of dirty data discussed by Wagner (2002) seem beyond the range of possible improvements even with tracking systems.

The strong belief in the perfection of RFID could be seriously misguided because its touted real time information visibility (Lee and Özer, 2007) supposes that counterparts are willing to share detailed sensitive internal information in real time and that it is possible to efficiently make sense of the immense amounts of information produced by systems with the necessary granularity, scope and extent to get a complete picture.

A possible conclusion is that IQ will always be more or less deficient in real world tracking systems, and therefore it might be a good idea to include various aspects of IQ explicitly when carrying out studies involving such systems in supply chains. A small contribution to such research is presented in Section 10, which discusses the completeness of information on the sustainability quality of seafood products that could be obtained using some of the tracking systems studied in this PhD project. Another is presented in Section 9, which discusses methods that could be applied to measure and map the IQ baseline of supply chains and to evaluate possible impacts on IQ when introducing a tracking system.

3 Methodology

This PhD project was conducted within a larger research project (BIP) in an industrial–academic partnership. This larger research project determined the primary research object of this study and effectively eliminated the possibility of carrying out a designed choice of research arena. The predetermined research object also implied that the detailed research questions and selection of corresponding complementary research sites had to be derived with the dual goal of carrying out research within the research project and simultaneously providing valid and relevant research contributions.

3.1 Research Design

As tracking systems have only recently started to appear in supply networks, empirical studies of the implementation and impacts of tracking systems in real supply chains are largely missing (Sarac *et al*., 2010, Whitaker *et al*., 2007). Even though there are theories from IS covering similar IS that can be tested on this new class of inter-organizational system, tracking systems are slightly different. In addition to the new technological challenges and cost structure (Whitaker *et al*., 2007), tracking systems imply higher risks by exposing more internal information to other players in the supply chain. These differences also imply that the theories developed by studying other systems might not apply, so more explorative research might be warranted. According to Yin (2003), a qualitative case study is the appropriate approach to such research.

Furthermore, there is a demand from the IS research community for more case research, especially for longitudinal research on IOS:

> “Most studies use the technological imperative to understand short-term benefits of data exchange, but impacts could certainly be long-term, requiring a change to the emergent perspective which sees the system impacts as the result of a process where effects emerge from the interaction between the technologies and the user organizations. From this perspective, longitudinal case studies adding richness of understanding will probably yield more insight than cross-sectional and short-term studies when elucidating how benefits accrue from the evolving implementation and use of the system.” (Elgarah *et al*., 2005)

Longitudinal studies of the implementation of inter-organizational systems are also necessary because of the prolonged implementation process involving decisions and implementation processes in the involved organizations (Gallivan, 2001; Brown and Bakhru, 2007). As tracking systems are networked and complex technologies, multiple units of analysis and multiple levels of theory are necessary to fully comprehend the diffusion of such systems (Damsgaard and Lyytinen, 1998).

When designing case studies, the following components are especially important (Yin, 2003):

1. The research questions
2. The research propositions
3. The units of analysis

3.1.1 Research questions

The research questions were developed in the introduction to this thesis by identifying empirical and theoretical gaps. The research questions are repeated below:

> *Q1: How can a player with low power use various strategies to succeed in implementing a tracking system in its supply chain, and why are those strategies effective*?
>
> *Q2: How could a tracking system initiator make technological choices to promote further enrollment into the system by its counterparts in the supply chain?*
>
> *Q3: How can the quality dynamics of information available to actors in a supply chain be we assessed and mapped?*
>
> *Q4: How well can information available from tracking systems in the upstream supply chain for wild caught seafood support strategies for sustainable SCM?*

3.1.2 Research propositions or purpose of exploration

When theory exists about the phenomenon under investigation, research propositions expressing the expected findings should be developed to direct the research activities. In the absence of theories when carrying out explorative studies, propositions can be replaced by a statement of the purpose and the success criteria of the research (Yin, 2003). Table 3-1 shows the propositions or the purpose and success criteria for each of the four research questions identified in the introduction.

Research question	**Research propositions or purpose of exploration and success criteria**
Q1	For each strategic advice X for supply chain system implementation from the SCM literature, and for inter-organizational system implementation from the IS literature, the proposition is that strategy X is effective. The success of the research can be measured in terms of how many strategies were tested in the implementation process studied and in the ability to distinguish between more or less effective strategies for the researched setting. Discovering effective strategies not discussed in the literature could be especially rewarding.
Q2	The goal of Q2 is to develop a tentative model that could support tracking system initiators when taking technological decisions during the construction of the system. The success of the research can be judged by whether a clear and succinct model was developed that supports decision making based on a systematic evaluation of the technological alternatives and thereby improves the resulting penetration of the tracking system in the supply chain.
Q3	The purpose of Q3 is to develop a research tool for investigating the processing and propagation of the information throughout the supply network and the resulting IQ available to supply chain players. Research can be deemed successful to the degree that the tool serves the purpose.
Q4	For each sustainable supply chain management (sSCM) strategy X identified in the sSCM literature that is relevant for wild caught seafood products, the proposition is that the tracking systems in that supply chain support strategy X at an acceptable cost. The research is successful if it can confirm or disconfirm the propositions. The research can be considered even more successful if it assesses to what degree a strategy enhanced by the tracking systems investigated could contribute to further improvements in the sustainability of the industry.

Table 3-1 Research propositions

3.1.3 Units of analysis

The unit of analysis is selected based on the primary research questions and constitutes a critical test of these questions. The units of analysis are shown in Table 3-2.

Research question	**Unit of analysis**
Q1	The implementation process of a tracking system in a supply network
Q2	Tracking system technological choices and implementations in supply chains
Q3	The information processing and quality dynamics in supply networks
Q4	Sustainable supply chain strategies implemented by the seafood industry in the UK and Scandinavia, related to the goals, scope and extent of upstream product tracking systems implemented in the same industry

Table 3-2 Units of analysis

3.1.4 Research designs

Table 3-3 shows the research design for each research question.

Research question	**Research design and rationale for selecting that design**
Q1	The main case is an SME. This can be considered to be a critical case because it seems to contradict widely held beliefs on the need for vast power and resources to succeed with implementing a tracking system in a supply chain. It also seems to contradict the well-supported results on the difficulty of enrolling SMEs in similar systems. A single qualitative case design is appropriate as a critical case. Qualitative case research is also especially adapted to answer how and why questions (Yin, 2003). A longitudinal study of the tracking system implementation processes was selected to chart the various strategies employed before and during implementation and their effectiveness. Furthermore, as the implementation of a tracking system throughout a supply chain is considered, a study with several research sites, also known as a single case-embedded research design, was selected.
Q2	Here, the inquiry covers how and why different technological choices during the initial construction of a tracking system influence the adoption of such systems throughout the supply chain. This type of question is amenable to research using a qualitative case study (Yin, 2003). Additional cases were selected using theoretical sampling to cover the range of technological choices available, and several sites were investigated in two of the cases, resulting in a multi-case, partly embedded research design.
Q3	The goal was to develop a measurement method, and notation for IQ in supply networks was pursued by iteratively designing and testing the qualitative research tool. To evaluate the tool at the supply network level, two of the three research cases used multi-site (embedded) designs.
Q4	To study how tracking systems can support strategies for sSCM, packaged seafood, the websites of actors in the seafood industry and environmental non-governmental organizations can be studied to discover how such strategies are implemented in the industry. A qualitative three-case study of the goals, scope and extent of the emerging tracking systems could then be used to ascertain the potential support for the different strategies pursued by industry.

Table 3-3 Research design for each research question

3.2 Instrument development and the selection of complementary research sites

The research instruments were not developed up front but were guided by the broad research questions, and an interview guide was prepared before each interview. This guide was adapted to the position of the informant and to the stage of the product tracking system implementation. As the research project and the literature reviews progressed, more adjustments were made to relate the research to the existing theory in order to build on earlier findings in the project and to catch all the informants' experiences during the implementation. In addition, the development of the research protocol was increasingly guided by validity concerns.

As discussed in Table 3-3, the need for supplementary research sites for conducting valid research was recognized. The research sites are shown in Table 3-4 with the main case in the first row.

Site, subsites	**Research activity**	**Used for**
BIP partners A reefer shipping company Three reefer vessels A multi-modal terminal Software supplier Fishermen's sales org.	total 23 interviews; 0.75–4 hours 109 hours observation >250 documents Four sessions of logistics training using problem based learning large amounts of tracking data	Q1–Q4
UK Fish Auction A fish auction A fish buyer	total 2 interviews; 1 and 3 hours 3 hours observation ~10 documents	Q3
UK Lobster Processor	1 interview; 0.5 hours >15 documents - news coverage and an evaluation report from an independent research agency no further access was granted	Q3, Q4
Danish Fish Box Pool* Thyborön Fish Auction	1 interview; 2 hours 2 hours observation ~10 documents	Q2, Q4
Norwegian Food Pallet and Box Pool* Pool main offices Software supplier	1 group interview, 3 participants, 2 hours 1 phone interview; 0.75 hours 19 documents	Q2
Norwegian national food tracking project	12 documents studied. Not approached for closer research.	(Q2, Q4)
11 retailer outlets in 2 countries	55 frozen seafood packages examined as documents.	Q4

Table 3-4 The research sites, research activities and corresponding research questions

Choosing to focus on one industry only eliminates industry-dependent variables. Furthermore, it was decided to look for actors implementing IOSs, in particular tracking systems within the industry in the North Sea region and nations where language barriers did not preclude case research. The concentration upon one industry also made the research more effective, because the necessary insights into the industrial context did not need to be reestablished for each case, but rather increased throughout the research process.

At the research sites marked with an asterisk, the companies were small, having a head count of two for the Danish case and approximately 10 for the Norwegian case. This means that even though the number of interviewees was small, the interviews still covered a significant proportion of the total staff.

3.3 Data collection

Data were collected using several methods, with interviews, observations and document studies the main methods. The extent of the research activity for the different types of data sources is shown in Table 3-4.

Each interview was prepared by developing an interview guide adapted to the position of the informant. When entering a new site, scoping information about the site from the web was used to inform the interview process and to show informants that the interviewer was interested and had some background knowledge. This enhanced trust and made informants quickly come to the core questions. The interviews were semi-structured, and all informants permitted recording. In three cases, the interview situation was not compatible with recording. Almost all recorded interviews were transcribed.

Observations were documented using note-taking and photography. Photography was essential both to capture fast-moving operations and to record details with sufficient speed to avoid making the observation impede operations. The observees often started to comment on the activities being performed and most observation sessions evolved into combined unstructured interviewing and observations. These interviews are not counted as interviews in Table 3-4.

Experience confirms the central role of interviews. However, Jick’s (1979) observation about how the combination of methods also leads to increasing the effectiveness of each method was confirmed. But the principal goal of using multiple methods was to ensure validity.

3.3.1 Validity and limitations

Validity is challenging and therefore important to consider when performing qualitative research. Here, the four types of validity most often considered are 1) *descriptive validity* i.e. whether the description holds true, 2) *interpretative validity* i.e. the degree to which the interpretation is correct, 3) *theoretical validity* i.e. how adequate the suggested theory/explanation is for what was observed and 4) *generalizable validity* i.e. whether the findings from the study can be generalized for other settings. A number of means have been suggested to ensure validity in qualitative research, including most notably triangulation i.e. studying the phenomenon using more than one source, method, researcher and/or theory. Triangulation can enhance the correctness and precision of the collected information, and also provide a more holistic, complete and contextual picture of the phenomenon under scrutiny (Ghauri and Grønhaug 2010).

In addition to using triangulation, descriptive and interpretive validity can be improved by using low inference descriptions in the sense of using the informants own words and by feeding field reports back to informants for validation. Theoretical validity can be enhanced by systematically looking for contrary evidence using negative case sampling and by consciously removing researcher bias through reflection over and handling of the possible biases of the researcher.

Table 3-5 shows how 11 approaches for ensuring validity proposed by Johnson (1997) were used in this research.

Approach for ensuring validity	**Use of the approach**
Fieldwork over extended period	Fieldwork in the main site was carried out for nearly three years. Research at the other sites does not fulfill this criterion.
Low inference descriptors	Direct citations from informants are used in the papers discussing findings from the study.
Data triangulation	Several informants in different positions were sampled. Information from different informants was compared to yield triangulation.
Methods triangulation	Information was gathered using a number of methods: interviews, observations and the analysis of different kinds of documents – operational, minutes from meetings, newspaper coverage, industrial actor's webpages and even information on frozen fish packages.
Investigator triangulation	The PhD supervisor was partly involved in the research and also reviewed a number of the reports resulting from the research, so there was a degree of investigator triangulation.
Theory triangulation	Mainly for research questions Q1, Q2 and Q4, different theories were consulted.
Feedback from participants	Some field reports were fed back to informants to get confirmation. This resulted in a low number of corrections. At the main research site, research ideas and results were presented at four sessions of logistics education involving partner personnel and management. Some of these presentations received substantial feedback, giving new insights.
Feedback from peer researchers	Papers from the research were sent to peer researchers for review.
Negative case sampling	This was conducted informally. Especially for research question Q1, the low power position postulated could need further substantiation.
Reflexivity	Reflections can be found in Section 3.3.4.
Pattern matching	Only research questions Q1 and Q2 were amenable to pattern matching. There was a partial match with existing theory.

Table 3-5 Approaches for ensuring validity (Johnson, 1997) and how they were applied

It can be argued that the systematic use of the approaches shown in Table 3-5 ensures the descriptive, interpretive, and theoretical validity of the research discussed in this thesis, while the fourth type of validity – generalizable validity needs further discussion.

IOPTSs represent a new phenomenon, where there are few instances available for research. Moreover, IOPTSs, the improvements in information quality they can support and the resulting beneficial effects are complex and multidimensional and also dependent on the complex supply chain context, as clearly documented in Table 2-1, Figure 2-9 and Figure 2-13. Also empirical research covering adoption, information quality improvements and beneficial effect of IOPTSs is largely missing to date, meaning that the research will have to be explorative. For these reasons, in addition to resource limitations and the nature of the research questions, case research with a limited number of research cites was selected as the research design.

Such research is not subject to statistical generalization. The support for the developed theory about how- and why- relationships rely on analytic generalization which is rendered possible by the close connection with the field and the resulting understanding of the mechanisms in play. Rather than aiming for context free theory, results from case research can be used through naturalistic generalization meaning that the relevance of the results depends on the similarity between the case described in the research and the case where the results could be applied. To support naturalistic generalization, it is however essential that the case is sufficiently well described. Thus, generalizability is obviously limited in studies where the IOPTSs studied and their context of implementation do not represent the full real world variability.

However, a higher degree of generalizable validity can be obtained at a later stage by aggregating of a number of existing case studies. Ostrom (1990) discusses how her award winning work is based upon aggregation of case studies from a number of research fields and how aggregation depends upon the quality of the case descriptions. The future will show if the case studies described in this thesis can contribute to research with higher generalizable validity through its incorporation into aggregated case studies.

For research question Q1, the goal was not to develop general theory, but to substantiate that contrary to widely held assumptions, it might be possible also for a low power SME transportation operator to successfully implement an IOPTS in the supply network it serves, and a further goal was to describe the strategies that resulted in the success. The study has a limited degree of generalizable validity even through naturalistic generalization because some of the crucial strategies depends heavily on the idiosyncratic features of the focal firm, while other important strategies discussed in the study are clearly more generally applicable.

Q2 aims at developing a support tool for IOPTS initiators facing the technological decisions of selecting system architecture and an Auto ID technology. The corresponding study builds on well substantiated theories of IOS adoption and conflict, but as IOS adoption researchers have failed to gain consensus on a single unified theory, and as IOPTSs are different from IOSs by potentially exposing more sensitive information to counterparts and competitors, the theoretical foundation of the study can be questioned. On the other hand, the theories for IOS adoption and conflict used in the study were selected because they took information risk into consideration, and the study is also supported by case research where the cases were selected by theoretical sampling to cover the different technological alternatives. But even if the study represents a best effort using the theory and case research results available, it is still difficult to claim generalizable validity for the tool without further research. The decision support tool should still be practically useful because it points to a number of possibly non-obvious factors that need to be taken into consideration when making the technological decisions. A follow-up project giving further opportunity to explore the role of information risk in IOPTS adoption has been approved for support by the Norwegian Research Council.

The IQ mapping tool developed as a response to Q3 is based on theories from information quality research and from research on information handling in supply chains. The mapping tool has generalizable validity to the degree that it supports mapping of information processing and information quality in a wide range of supply chains. Testing in three upstream supply networks for seafood seems to indicate that the tool is easily applicable to the different supply chains configurations tested within that industry, but the testing is still too limited to claim generalizable validity. The follow-up project mentioned in the previous paragraph also gives an opportunity for more extensive testing of the mapping tool in other supply chain contexts.

Q4 discusses the possible role of IOPTSs as a support technology for sustainable product strategies in the wild caught seafood industry and finds that two of the three systems studied could indeed support the strategies identified in the field and at a marginal extra cost. This contradicts the assumption that such systems could result in too high expenses. The study does not pretend to be generalizable, but points out that similar IOPTSs should become generally available in the future. The results might be applicable to industries with similar sustainable harvesting challenges and sustainable product strategies, e.g. the forestry industry, but might be less applicable to other industries having different types of sustainability challenges and hence different sustainable product strategies.

3.3.2 Researcher qualification

Negotiating access and performing observations, especially interviewing, require special skills. Some skills have already been acquired through education in qualitative methods and performing qualitative work at the MSc level. An additional course on research interviews at the PhD level was followed to hone interviewing skills. Qualitative research skills were further developed during my stay at the Transport Research Institute, Edinburgh Napier University, by mentoring from a merited senior researcher well versed in qualitative methods.

My background within software engineering and IS was also a substantial asset to the research work. This background made it possible to communicate effectively with software developers and come to terms with the software internals necessary for research questions Q2 and Q4. Software development skills were also essential to develop the necessary software for handling the operational data used in research question Q1. The modeling skills and IQ concepts used in software engineering were also used to develop research question Q3.

3.3.3 Role of the researcher

Walsham (2002) discusses the advantages of the different roles of the observer. An external observer can be perceived as neutral and can obtain relatively free-spoken responses from those observed or interviewed, whereas an involved researcher can get an insider’s view and thereby get access to more secret and sensitive material.

I did not try to become an insider, but observing charge and discharge operations on the reefer vessels, I appeared in the standard company overalls. On a couple of occasions, I was asked to stand in for company personnel registering cargo into the tracking system and running the cargo elevator. I did not refuse to help them.

Having a background in software engineering and requirements work, I also chose to assist in the development of specifications for an extension of the product tracking system to cold stores and to help the mariners express their requirements for improving the system. This probably helped the product tracking project move forward. However, it partially gave me an insider role, but simultaneously seemed to contribute to goodwill and subsequently increased opportunities for research.

It also paid to have good manners in the sense of taking a background role and of consciously moving to an unobtrusive position when observing. Also always asking for permission to ask questions, to take photos, to record and to look into documents seemed to be appreciated by the personnel being observed – and permission was granted except for some contract documents. I also consciously tried to be courteous to all personnel involved at each site. On subsequent visits to the same sites, I was increasingly well received.

3.3.4 Researcher bias

My background in software engineering could lead to bias. I am interested in making things work and could be biased towards neglecting problems in implementing the system being studied. This could be accentuated by my active but limited involvement in creating the software, giving me a stake in the system. On the other hand, debugging has been a substantial part of my former activity as a developer, so I am proficient at discovering errors and problems. To reduce possible biases here, I should be attentive to any symptoms of non-adoption or deficient functionality and immediately try to ascertain whether there are problems or not and also probe into the reasons for non-adoption (two interviews with non-adopters were planned, but cancelled when they turned into adopters). I should also be more skeptical to actors describing the beneficial effects of the system and require corroboration with more sources (triangulation) before accepting their claims.

Work within the IS field has also instilled in me a deep skepticism towards universal standardization. This means that I could have a tendency to overemphasize standardization problems, a bias that could be evident in the results from research question Q1. However, much of the discussion here is triangulated using theory.

3.4 Data Analysis

Data analysis has been a continuous and iterative process in connection with other research activities. Analysis has partly been carried out in combination with data collection in the form of write ups as suggested by Eisenhardt (1989). Many write ups are in the form of illustrated field reports. For the research questions handled using multiple case studies, the analysis has also involved a number of tabulations. The final stage of analysis actually happens when developing papers based on the research. Here, reflection on what is actually supported by the data collected and how to express this accurately is an integral part of the writing process.

4 Research paper overview

4.1 Paper 1: Against the odds: implementing goods tracking in a network of independent third party logistics providers

4.1.1 Outline

A product tracking system is being implemented in a network of third party logistics (TPL) providers, where adverse conditions makes succeeding difficult according to influential theories, and according to the experience of similar projects. The goal of the paper is to analyze the strategies that were employed by managers resulting in success against the odds.

The research project related to this paper was performed as a case study using interviews as the main source, but the findings are validated with data obtained from participant observations and from document studies.

The paper identifies the policies implemented and actions taken to align a critical mass of actors with the product tracking system and analyzes how these different means contributed to the final success of the project.

The research activity covers a single case, which makes the general nature of our findings hard to assess. However, a thorough case description should enable the reader to judge whether the results can be applied in other settings familiar to the reader. The relationship to existing knowledge is also discussed.

The SCM literature often suggests increasing supply chain transparency through the integration of IS across actors. In practice, such integration has proven difficult to accomplish, especially when actors are independent. This paper provides advice that could improve the chances of successful integration in similar cases.

4.1.2 Publication process

The paper was accepted for and presented at the 2011 NOFOMA conference in Harstad, Norway. Papers for the conference are subject to a peer review process. Accepted papers are published in the conference proceedings. The NOFOMA proceedings are accredited by the Norwegian University Authorities as a valid publication channel.

4.2 Paper 2: Product tracking systems in the supply chain for food – a support model for technology decisions

4.2.1 Outline

This paper proposes a model to support the crucial technological decisions taken by companies wishing to implement IOPTSs in their supply networks. IOPTSs can be beneficial for food safety and supply chain transparency.

The proposed model supports decisions on technologies for AutoID and on the architecture of the supporting information system when the goal is cross-actor supply chain visibility. There is already a relevant theoretical knowledge base on IOS adoption and RFID. This knowledge base is thus combined with empirical results from case research in four IOPTSs in the supply network for food in Scandinavia as a basis for the model.

4.2.2 Publication process

This paper was presented at the 2011 Nectar conference in Antwerp. The paper was further submitted to the International Journal of Information Systems and Supply Chain Management. According to reviewers, revisions are needed, but they do not agree on what revisions. A decision will be taken whether to continue the publication process in that journal or to submit the contribution somewhere else.

4.3 Paper 3: Supply chain information mapping notation

4.3.1 Outline

In SCM, a key idea is the tighter integration among the actors of supply chains, giving a higher degree of information transparency to support more holistic supply chain optimization. In many real world supply chains, however, information exchange among actors is performed with manual, expensive and error-prone processes leading to information with deficient quality, a situation that contributes significantly to increased operating costs. The Supply Chain Information Mapping Notation (SCIMN) presented in this paper could be used as a tool to analyze supply chain information flows. Another possible application is in supply chain integration projects to pinpoint problems and prioritize areas that could benefit from increased electronic information exchange and the use of automatic identification technologies.

The paper launches the SCIMN as a complementary tool to other mapping notations commonly used in such settings. The SCIMN could serve as a complement because of its unique features: its focus on the quality of the information elements supporting actors performing logistics activities, on goods identification and on the information carried by the logistics units, namely the boxes, pallets and containers moving through the supply chain.

IQ is an important research field, which has produced a rich variety of concepts and metrics. How those results are used for information mapping in a supply chain is elaborated upon, resulting in a simple four-level IQ hierarchy.

To describe the notation, a fragment of a real world supply chain is used. The processes are first described and illustrated using the popular Business Process Modeling Notation (BPMN). Then, the three elements of the SCIMN – the structure, notation for IQ and notation for information handling – are introduced before a SCIMN diagram for the partial supply chain is drawn and commented upon.

4.3.2 Publication process

The initial idea for the SCIMN was first discussed in a more comprehensive paper accepted and presented at the 2009 NOFOMA conference in Jönköping, Sweden. Here, the reviewers pointed out that the notation was the most interesting part of the paper. After further development and testing of the notation in two more supply chain settings, the notation was again presented at the 2010 NBB conference in Bodö, Norway. The resulting paper was submitted to the International Journal of Information Systems and Supply Chain Management, and it has been accepted for publication.

4.4 Paper 4: The potential of IOPTSs in a sustainable supply chain – observations from the wild seafood supply network

4.4.1 Outline

For industries using common pool natural resources, sustainable sourcing is crucial for long-term viability. Fisheries constitute a case in point as world catches peaked in the early nineties. Currently a change in behavior in the seafood industry in parts of the Western world can be observed, as the industry is implementing various sSCM strategies. This paper discusses the potential and limitations of electronic IOPTSs to support these changes. The discussion builds upon case research in the supply network for wild caught seafood in Northern Europe.

The paper initially looks into the sustainability problems of caught seafood. It then discusses various strategies for sSCM and identifies two alternative strategies that could be used for sustainable seafood products. Subsequently, it evaluates the characteristics and resulting IQ of three product tracking systems in the supply network for seafood against the requirements for following the identified strategies, and concludes that the tracking systems might indeed support the strategies. Two of the tracking systems are implemented for other purposes than sustainability, and using them to support the sustainability strategies could thus come out at a marginal and thereby acceptable cost.

4.4.2 Publication process

This paper was submitted to the 2011 EUROMA conference in Cambridge, UK. Contributions to the conference are subject to a peer review process of the extended abstracts. The paper was presented at the conference. Presented full papers are published in the conference proceedings. The proceedings of the EUROMA conference are accredited by the Norwegian University Authorities as a valid publication channel.

5 Conclusion

This thesis discusses research on electronic IOPTSs. The research approaches several aspects of such systems, including their characterizations and possible improvements of IQ and the resulting benefits of such systems when used in supply chains. The study also scrutinizes the difficulty in implementing tracking systems across supply chain actors. The research combines theory from several relevant research areas, most notably the research streams on IQ and on the adoption of inter-organizational systems found within the field of IS, and in a large number of contributions discussing the possible benefits of tracking systems using RFID technology. The discussion is also based on rich empirical evidence that was collected using qualitative methods such as interviewing, observations and document studies to study some of the first electronic IOPTSs being implemented in the supply network for wild caught seafood in Northwestern Europe.

The first focal area is the adoption of tracking systems. The persisting low degree of tracking systems adoption in real supply chains seems to be a paradox when considering the large potential benefits that should make such systems a "technological imperative." In the '90s, a similar paradox was observed for EDI, a technology having many similarities with tracking systems, including high posited benefits and slow adoption. The adoption of EDI has been extensively studied over more than two decades using different theories, for example the TAM and DOI, but no commonly accepted theory has emerged. Finally, research covering several levels from the individual, via the organization to the industry and the national level indicates that all these levels contribute to explaining adoption. Early research on the adoption of tracking systems based on RFID seems to follow the pattern of early research on EDI by using the TAM, the DOI or similar theories and performing factor analyses at the individual level. This thesis follows an alternative approach by building on the results derived from the more mature part of research on EDI. This includes elements of TCE concerning transaction risks in the form of specific assets, asymmetric information and the risk of losing control over information. These risks are especially relevant when studying the adoption of tracking systems, which could be regarded as expensive relation-specific assets giving counterparts and competitors access to sensitive internal information.

The initiator is the actor taking the initiative to implement a tracking system in its supply chain. For the initiator, it is essential that other actors representing a substantial part of the product volume adopt the system to harvest the full benefits. We call these other actors followers. The adoption research presented here aims at obtaining actionable results by explicitly studying the actions that could be taken by a tracking system initiator to obtain the necessary adoption by followers.

A result from EDI research is that the initiator can use power to make followers adopt, and that follower adoption can be especially challenging when followers are SMEs. The results presented in the first paper (Section 7) indicates that even a less powerful company can obtain the necessary adoption in a supply network with many SMEs and points to a number of strategies that could be employed in similar situations, including two that have not been reported in the surveyed literature. The adoption theme is further elaborated in a second paper (Section 1), which presents a technological choice model to support decision making by initiators choosing technologies for a tracking system when the goal is to reach supply chain penetration. The model is based on results from research on EDI adoption and is supported by a four-case empirical study covering technological alternatives.

During recent years, a number of studies of the benefits of tracking systems have followed the call from Lee and Özer (2007) to go back to basics and use mathematical modeling of elementary processes to evaluate the possible benefits resulting from the improved IQ provided by tracking systems. However, unfortunately, the logistics and SCM research community has scarcely taken into consideration results from IQ research. This field in its own right has established IQ as a multidimensional concept and has developed methods for its assessment and improvement.

IQ is the second main theme of this thesis. Section 2.4 gives an overview of the IQ literature including some contributions relying on user centric methods to evaluate IQ in supply chains. Sections 2.4.5.1 to 2.4.5.3 combine theory from the IQ research stream with database theory to analyze the interdependent root causes of deficient IQ, especially in supply chains and extends the analysis to discuss how the important accuracy, completeness and timeliness dimensions of IQ can be substantially improved when introducing tracking systems.

The implicit baseline in the IQ research stream is computerized information. To cater for the lower baseline of IQ found in most supply chains Section 2.4.5.4 establishes and grades a new “digital representation” IQ dimension. A further contribution, discussed in Section 9 is the development of a supply chain information mapping tool. This tool uses a process-centric method to map information processing and IQ. Even though some mapping tools covering the information processing in supply chains already exist, the notation presented here is novel 1) by showing the IQ dynamics (the evolution of IQ over time) specific to each actor and each information element and 2) by having specific notations for the various methods for the identification of physical goods and transfer of information. When performed manually, such operations are ubiquitous sources of errors, incomplete information and costs in many current supply chains.

The impacts of tracking systems constitute the third theme covered by this thesis. There is already a rich research stream discussing the potential benefits of such systems based on RFID. In Section 2.6, that literature is summarized into a benefits framework by visualizing the relationships between the different benefits mainly as discussed in three extensive reviews of the literature. A higher-level framework is also presented, explicitly including IQ and tentatively classifying the resulting benefits according to being mainly because of the automatic identification of traceable items or being a consequence of disseminating the resulting information through a tracking system. The relationships are classified depending on the time horizons of their impacts.

This research project gave insights into the sSCM strategies pursued by the wild caught seafood industry. A contribution to tracking system benefits research based on this insight is presented in paper four (Section 10). The contribution is an evaluation of the degree to which the scope and extent of the tracking systems studied during the project provide sufficient IQ in terms of completeness and accuracy to support the sSCM strategies pursued by the industry. The paper thereby illustrates how the characterization of tracking systems and concepts from IQ can be used to discuss the potential benefits of such systems.

The literature study by Lee and Özer (2007) concludes that even though there are a number of impact studies making more or less informed guesses on the magnitude of impacts and a few making estimations based on findings from pilot implementations and from motion studies, there is a lack of published studies of the realized economic benefits from full-scale implementations. The scarcity of such research can be expected when taking into consideration that the full benefits of technologies needing protracted implementation processes in independent companies will only fully materialize after a prolonged time period. Such processes should therefore be studied in longitudinal research projects with a time frame from before starting until after completion, and with access to sufficient data both to capture the difference and to adjust for all disturbing factors. An exemplary 10-year EDI impact study in this category is Mukhopadhyay *et al*. (1995), but following their example is clearly beyond the time frame of a single PhD project.

However, the firms constituting the main arena for research in this study succeeded in implementing a tracking system in their supply chains. Since the study started, an increasing proportion of the supply chain players is participating both by providing goods that can be identified automatically and by capturing and transferring the corresponding information through tracking systems. The quality of goods identification has also improved considerably since the project started. The benefits have already started to accrue, and personnel in both focal companies have reported reduced errors and reduced claims. It also seems that their customers benefit from the increased IQ available from the tracking systems, and that this has resulted in demand for better information from competing actors and from the few actors in the supply chain not yet fully hooked up to the tracking system. Moreover, it seems that personnel turnover could be reduced because of the improved working conditions obtained through the decreasing number of complaints and the reduced efforts spent on mitigating errors.

6 References

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7 Paper 1:
Against the odds: implementing goods tracking in a network of independent third party logistics providers

7.1 Introduction

A salient idea in logistics and SCM is to improve supply chain efficiency and effectiveness by making information about the stream of goods electronically available from upstream and downstream actors. This is also called supply chain transparency. An early (‘80s and ‘90s) incarnation of that idea was to use EDI to establish links between supply chain actors, resulting in a loosely integrated IOS. However, the adoption of IOSs proved difficult, especially among SMEs. As a result, supply chains largely continue to be run using manual procedures for information interchange to this day (Nurmilaakso, 2008).

By the start of the new millennium, new hopes were raised by the promising RFID technology, making automatic goods identification (AutoID) a feasible proposition. RFID can be combined with an IOS to disseminate track and trace information to supply chain players. The combination between AutoID and an IOS can be dubbed an IOPTS, which could indeed provide the elusive supply chain transparency.

Despite reports from early successes obtained through mandates by powerful actors such as Wal-Mart and the US Department of Defense, we are still waiting for the widely heralded RFID revolution. Perhaps it is time to start research on how to increase IOPTS adoption in supply chains. This paper contributes to such research by reporting on a case study where a small TPL enterprise has successfully implemented an IOPTS in its supply chain against heavy odds. As other actors might wish to copy elements from the approach, the research question is “*what strategies were employed, and how and why did they result in success?*”

The next sections describe the TPL network, the IOPTS and the odds against the project, followed by a review of the theory and a description of the case study methods used in the research. The subsequent sections cover the strategies used in the integration project to align TPL actors with the system and a discussion on the theoretical implications. The conclusion sums up the results and their relationship to the existing knowledge.

7.2 The TPL network and product tracking systems

The TPL network lands fish frozen at sea in the North East Atlantic from deep sea fishing vessels, and transports it to the global market. Fish is typically landed at neutral cold stores along the Norwegian coast. These are neutral in the sense that they do not take title (ownership) of the goods. The goods are forwarded towards the processing industry in Europe and the Far East via reefer transportation. Regarded as a whole, the companies involved constitute a network of independent TPL providers. A number of these companies are small operations with a handful of employees, but they can still handle large amounts of merchandise by using effective equipment and by hiring additional manpower from stevedore organizations. Figure 7-1 shows an example of how the network operates, with separate chains of goods handling and title.

Goods typically change owner one or more times on the way, so the TPL network serves a network of customers – consecutive goods owners: fishing vessels, traders and firms in the processing industry. The customer and the TPL networks also have to cope with a large number of external actors such as stevedore unions, auctions and authorities in several nations.

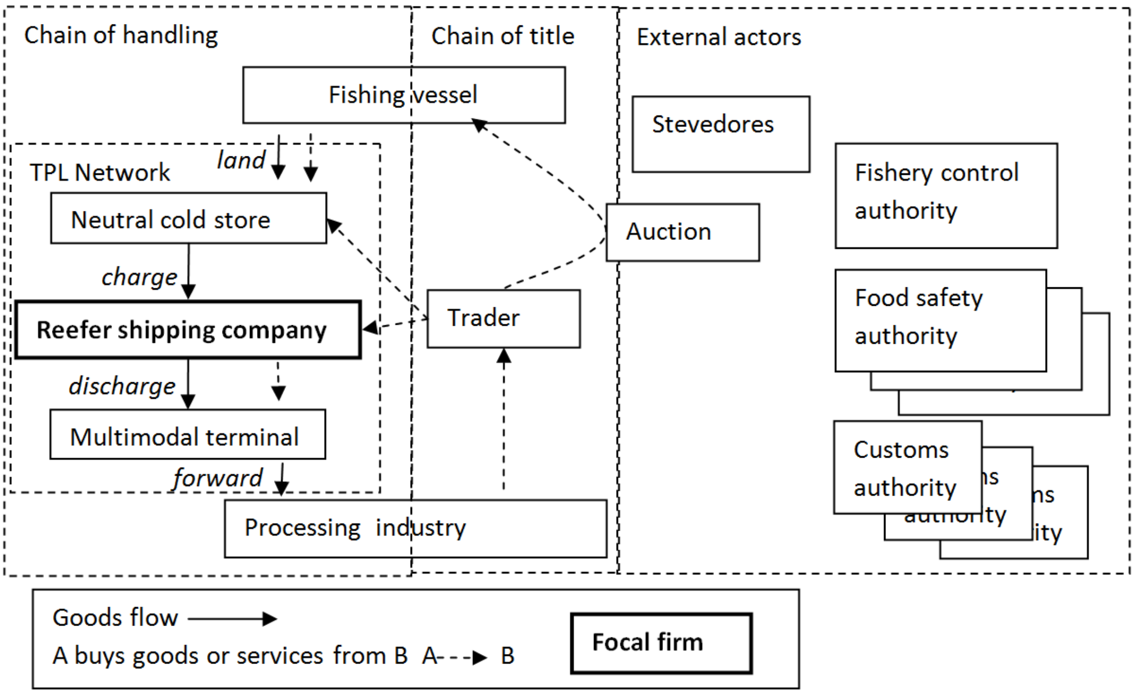

Figure 7-1 The TPL network in context. Handling operations are shown in italics. Buyer–seller relationships are shown with dashed arrows.

7.2.1 The product tracking system

To understand the remainder of the paper, we need to look closer at the functionality of an IOPTS and at how it can improve the efficiency and effectiveness of logistics. An IOPTS registers and distributes information about the item being tracked and about events related to that item. The handling operations shown in italics in this section and in Figure 7-1 are such events.

Onboard the fishing vessels, fish is usually packaged when caught and then placed unsorted into the bulk hold. When *landed*, these packages are sorted onto homogeneous pallets and data on the content of each pallet are captured in the IOPTS. These data are used when the fish is put up for sale at the auction. After having bought an auction lot, a trader places an order for the shipment of the pallets with the shipping company and also orders the release of the pallets at the neutral cold store. Then, an electronic list of the pallets is sent from the neutral cold store to the reefer shipping company. This is performed using EDI.

The electronic pallet list contains detailed up-front information that can be used to plan the following *charge* and *discharge* operations. Such planning improves vessel capacity utilization by predicting how much hold capacity will be used by each shipment. The vessel is the most capital-intensive asset in the network, so high capacity utilization is crucial for economic performance. The information also supports tally during cargo handling operations – with the goal of ensuring that all the correct pallets are *charged* and *discharged*. Correct tally mitigates a recurring problem in the trade where "frequent errors with subsequent claims undermine the profitability of many reefer transportation operations" (*Manager of Logistics Trade Organization*).

For the focal company, curbing claims expenses is the primary goal of the IOPTS. Providing exact and detailed information about the pallets handled in each operation is also perceived as an effective protection against downstream actors that might make fraudulent claims about missing pallets. Another aim of the system is to support improved precision in the registration of cargo damage, i.e. to be able to make the upstream terminals accountable for cargo damage occurring before the *charge* operation.

7.2.2 The TPL network – an adverse environment for system implementation

A number of factors can jeopardize IOPTS implementation in the TPL network:

1. **Asymmetric distribution of costs and benefits**: A crucial component of the IOPTS is tagging the goods for identification. This should be performed at the upstream neutral cold store where pallets are built, but will often need a change of routine. In addition, there may be costs for software, label printers, etc. Most of the benefits accrue to downstream actors in the form of error elimination, saved manual data entry and getting improved data for planning. Increased accountability for damaged goods could also lead to more claims hitting the upstream actors.
2. As shown in Figure 7-1, the focal company has **no direct or indirect buyer power** over the upstream cold stores.
3. The customers for the upstream actors are fishing vessels and traders. Those customers are **extremely cost conscious** and do not care about how their cost cutting affects the downstream actors (see Figure 7-2 for an illustration). This means that the terminals are engaged in cut-throat price competition for landing orders and that customers are not likely to exert pressure for IOPTS implementation.
4. Upstream terminals typically use skeleton crews working as supervisors controlling the manpower hired for each handling operation. This means that the terminals have **limited human resources**. Limited human resources are seen as an important barrier to EDI adoption in SMEs (Iacovou *et al*., 1995).
5. There is a culture of **trade secrecy** in the network. This is a characteristic of the seafood industry (Jacquet and Pauly, 2008), as confirmed by a number of interviews, for example: "We operate on a strictly need to know basis" (*Shipbroker, reefer shipping company*).
6. The various actors cooperating to fulfill customer requirements are, to some extent, **competitors**. For example, both the focal shipping company and a multimodal terminal run neutral cold stores.

Figure 7-2 Landing at a neutral terminal results in a pile of wrecked pallets (centre). The photo shows local cost saving on pallet quality of less than one ‰ of the pallet goods value. The bad pallets lead to expensive problems for downstream actors. (Photo: Ola Bø)

7.2.3 Success in an adverse environment

The implementation of the IOPTS depends upon two components: first, pallets have to be tagged with two readable identity tags and, second, electronic lists of the pallets to be charged should be received from the landing terminal before the reefer vessel arrives to pick them up. The first component makes it possible to register all pallets into the vessel and thereby to document the correct tally for each consignment, while the second supports controlling that the pallets charged or discharged are the correct ones.

The tracking project now seems to be a success. A gross estimate indicates that 70% of the pallets loaded from landing terminals carry the necessary identification tags. The focal firm is moving on from pilot testing to implementing the IOPTS on all their liner vessels.

Obtaining usable identity tagging by a large proportion of the players in what seems to be a loosely knit network of independent uncontrollable TPL providers with an asymmetric distribution of risks, costs and benefits and a culture for cost minimization and secrecy is an accomplishment that other actors in similar situations would wish to copy.

7.3 Theoretical perspectives

The goal of this paper is to report on the strategies used by an SME that result in supply chain integration through the successful implementation of an IOPTS. Because an IOPTS is an IOS, we could benefit from strategy advice offered in the large research stream on IOS adoption.

Starting from rationalizing early successes, the subsequent stagnation in EDI adoption leads IOS adoption research to enter a probing phase where factor analysis tested factors that could influence adoption. Factors were taken from case research or from theories, e.g. DOI, sociopolitical or critical mass theory. However, these efforts did not result in consensus on one common IOS adoption theory. In the third stage, recognizing the complexity of the relationship between IOS adoption and the organizational context, the research employed theories and methods that supported richer descriptive analysis (Somasundaram and Rose, 2003).

With no consensus on an IOS adoption theory, we select studies specifically concerning SMEs. A much cited study of SME EDI adoption is provided by Iacovou *et al.* (1995), which builds on 34 former studies and has since been further extended and substantiated by Chwelos *et al.* (2001), Mehrtens *et al.* (2001), Morrell and Ezingeard (2002) and Nagy (2007).

For SMEs, risk exposure can be especially critical, so Kumar and van Dissel's (1996) seminal treatment of risk mitigation in IOSs seems relevant, especially since it has a solid theoretical basis in TCE.

Another possible perspective could be SCM, but SCM performed by low power actors is in some way a paradox, and it seems to have raised scant interest and treatment in the SCM literature, with Harland *et al*. (2001) as a notable exception. SMEs are seldom in a position to impose standards, so papers discussing IOS standardization have also been included.

7.3.1 Strategies for IOS integration derived from the literature

Table 7-1 summarizes the strategic advice on IOS implementation derived from the literature. Only Harland *et al.* (2001) and Nagy (2007) specifically treat focal firms with low power. The section column refers to sections within this paper where the application of each piece of advice is discussed. A "no" in this column indicates that the advice was not implemented in the project studied.

Strategic advice	**Source(s)**	**Section(s)**
Aim for process and information processing improvements. Cope with the situation.	Harland *et al.*, 2001	7.5.1 7.5.7–7.5.9
Persuade the trading partner to use the system or change power balance. Increase benefits or lower the barriers of adoption (more effective).	Nagy, 2007	7.5.7 no 7.5.9 7.5.5
Plan the adoption of small partners from the beginning, assess their individual EDI preparedness and choose and implement an appropriate subsidy and influence strategy for each partner.	Iacovou *et al.*, 1995	not initially 7.5.5, 7.5.7
Comprehensive long-term leadership. Importance of change management. Handle specific asset risks. Exploit the installed base.	Bowersox *et al.,* 2000	yes 7.5.4 7.5.5, 7.5.6 7.5.3
For "long-linked supply chain systems," transaction risks can be mitigated by using the proper IT solutions, legal/contractual mechanisms and diplomacy.	Kumar and van Dissel, 1996	7.5.5-7.5.7
Exploit cheaper Internet technologies to reduce IOS cost.	Stefansson, 2002	7.5.5
Integrate databases along the supply chain. Use a common data model for the whole supply chain.	Lee and Billington, 1992 Gulledge, 2006	no no
Universal standardization is impossible. Idiosyncratic IT solutions might be superior. Differentiate integration solutions. Build bridges for SMEs. Support the varying business models of chain participants.	Bowker and Star, 00 Olsen and Sætre, '07 Harland *et al.,* 2007	 7.5.1 7.5.3 7.5.3 7.5.2

Table 7-1 Strategic advice from the literature

7.3.2 Low power SCM

SCM research and thinking has evolved from the study of how influential companies in stable situations can wield power in order to manage their suppliers (Cox, 1999, Harland *et al.*, 2001) to looking at strategies available to less influential actors in unstable situations (Harland *et al*., 2001).

Power relations seem to be a major factor in the adoption of technologies such as IOS and EDI (Iacovou *et al.*, 1995, Nagy, 2007). However, persuasive approaches can be more effective than can the coercive use of power for improving relationships and organizational coordination in an IOS context (Hart and Saunders, 1997).

7.3.3 Risk mitigation

Another perspective is that IOSs can be used to impose dominance, resulting in conflict and thus the possible demise of the IOS. To make a viable IOS, the risks have to be mitigated. Risks and the mitigation strategies can be discussed using TCE. The main transaction cost component for IOSs takes the form of exposure to a transaction risk that can be subdivided into asset specificity risk, information asymmetry and loss of resource control (Kumar and van Dissel, 1996).

Asset specificity means that an asset is acquired to serve a specific business relationship. The specific investment is lost if the relationship is lost, a fact that skews the power balance of the relationship. High investments in an IOS thus increase the risk of being dominated.

Loss of resource control means that the counterpart gains control over critical resources. When discussing IOSs, we talk about information resources. In the TPL network considered, the traders are important customers that are exposed to the risk of disintermediation if too much information is divulged to actors in the processing industry or to competing traders.

7.3.4 Imposing standardization or permitting idiosyncrasy?

The controversy between imposing standardization and permitting idiosyncrasy has been sparsely covered in the SCM discipline. Standardization towards a common universal standard is an enticing idea promising easy IOS integration – both Gulledge (2006) and Nagy (2007) discuss how the lack of standards makes integration difficult. The standardization idea comes in many flavors. For the single firm, ERP is the embodiment of standardization, where all data are stored in a common system according to a common data model and supporting “best practice business processes.” In the SCM literature, the integration of databases across the supply chain is suggested as a panacea by Lee and Billington (1992). Gulledge (2006) goes further by proposing a single common standardized data model for the whole supply network as proper integration and other forms of integration using interfacing between systems as inferior.

Bowker and Star (2000), discussing the standardization of classifications, which is necessary for creating data models, come to the opposite conclusion: “[The] permanent tension between attempts at universal standardization of lists and the local circumstances of those using them [..] should not and cannot be resolved by imposed standardization.” In addition, even though data are standardized, data from other firms can be misinterpreted because of missing contextual information (Jacobs, 2006). Gulledge (2006) also confirms the problems in supply chain-wide standardization when he goes on from lofty ideals to discuss real world examples, where standardization efforts drag on for years and where data consistency is a continuous struggle. Thus, real world IOSs often become more like the patchwork discussed in Nagy’s (2007) case research than a system built to a common standard. Harland *et al*. (2007) favors a differentiated contingency approach by the IOS initiator. For the individual firm, the standardization imposed when adopting ERP can make the company lose the competitive edge acquired using flexible idiosyncratic IT solutions (Olsen and Sætre, 2007).

7.4 Researching strategies for IOS alignment

The IOPTS project is studied in its natural context, so there is no opportunity for control. Therefore, the options for research design are limited. As we are interested in how and why the focal firm succeeded in the IOPTS project, case research is a suitable method (Yin, 2003).

Because the project outcome seems to contradict the widely held assumptions about the need for long-term, trust-building relationships and/or power for a focal firm to successfully initiate IOS implementation, we can regard the project as a critical case. Thus, a single case design is appropriate (Yin, 2003). In case research, triangulation – the use of multiple data collection methods – provides a critical test for theories (Stuart *et al.*, 2002). Table 7-2 shows the methods applied. Data collection and analysis proceeded simultaneously as proposed by Eisenhardt (1989) through write-ups, here in the form of illustrated field reports.

Method and extent	**Who or what**	**Methodological details**
Interviews, 23 for 0.75 to 4 hours	Shipping, terminal and ITC personnel	Semi-structured, recorded and transcribed
Participant observation, 109 hours	Logistics operations, back offices, project and personnel meetings	Documented using photography and note-taking
Document studies, more than 200 documents	Freight documents, minutes from meetings	Using document database
IOPTS operational data	Data from logistics operations	Analysis of Serial Shipment Container Codes (SSCCs)
Data from problem-based practitioner training: 4 sessions	Terminal and shipping company personnel	Uses results from personnel analyzing problems in their own operations

Table 7-2 Data collection methods

7.5 Findings: strategies employed in the project

To overcome the numerous challenges discussed in Section 7.2.2, a number of different strategies and actions were necessary. Some of those were general long-term strategies in place before the project was conceived, while others were implemented to handle specific problems in the project.

7.5.1 IT strategy

The focal firm does not follow the trend of relying on commercial software and of outsourcing to the IT department. Its strategy can be summarized in the following points:

- Core operational activity is supported by a custom-built booking system. This strategy is followed in spite of considerable pressure from the parent company to implement SAP (an ERP system). The resulting SAP implementation was limited to functions such as accounting, but with the necessary integration with the booking system.
- Internal and external integrations are being implemented to speed up document handling and to remove expensive and error-prone manual re-keying operations.
- A small but effective IT department supports and develops systems and integration.

These strategies imply that the firm has personnel combining deep business and system knowledge, personnel that can also develop the necessary interfaces for the integration of the systems of the shipping company and the terminals.

7.5.2 Strategic involvement in neutral terminals – vertical integration

The focal company has historically been involved both in shipping and in a few neutral terminals, and it is still running one such terminal. This implies that the company has intimate knowledge on how upstream terminals are run and on their information processing routines. It also founded a software firm that served as an IT department when it developed a Warehouse Management System (WMS) for neutral terminals. The WMS software firm was sold off in 1999 and succeeded in the market, making the WMS product the preferred solution for the neutral cold stores in the network.

7.5.3 Exploiting de facto standardization

The large market share of the WMS among upstream terminals can be exploited by paying the software supplier for implementing the functionality for sending pallet lists to the focal company as a part of the WMS. This EDI functionality was made readily available on the screen used for selecting pallets for transportation along with the functionality for printing the necessary pallet lists for use when physically taking pallets out of storage. The scope of this effective strategy is somewhat limited because some upstream terminals use other WMSs, but a low cost solution to provide EDI functionality to such actors is planned.

7.5.4 Change management strategy

Safeguarding internal motivation was a major concern for company management. In addition to meetings with the personnel involved and taking their responses seriously, management had to keep up momentum, while not keeping personnel working with a dysfunctional system.

When testing the initial version of the IOPTS, the mariners were far from satisfied with the functionality or usability of the new system. Fixing problems and testing was time consuming, as the vessel used for pilot testing was in continuous service. To safeguard mariner motivation and support for the project, the company implemented two strategies. One was to enable quicker testing by setting up a complete in-house testing environment. The second was to stop pilot testing onboard until all changes requested by the mariners had been implemented and thoroughly tested in house. When finally installed, the mariners were delighted by a system well adapted to their requirements and felt ownership for it.

7.5.5 Counterpart cost minimization strategy and direct subsidy

The cost of joining the IOS for the terminals was minimized by the focal company paying much of the cost of developing the functionality for sending EDI pallet lists from the WMS using e-mail, and thereby made it available to the terminals at a negligible cost. In addition, the expenses involved in changing terminal routines were minimized by making the EDI functionality easily available on the same screen as that used in the standard procedure for taking out goods from storage.

This removed the crucial cost barrier for most terminals. Towards the end of the project, a policy of direct subsidies in order to eliminate even the negligible cost of joining was implemented. This made two large volume stragglers jump on the bandwagon.

7.5.6 Information ownership strategy

As discussed in Section 7.2.2, there is a norm for secrecy in a TPL network. However, the downstream actors need some information to complete their parts of the goods handling. Some of this information has traditionally been provided in the documents sent with the cargo by upstream actors. The new functionality gives upstream actors the opportunity to send the same information electronically by clicking a button. Hence, the terminal's information is still kept in the terminal's WMS, but the information necessary for downstream actors can be forwarded electronically under the control of terminal personnel.

7.5.7 Persuasion strategies

Implementing the tracking system involves changes at the upstream terminals by requiring that a valid SSCC is encoded in a barcode on the pallet label and that new pallet labeling routines are used to ensure the proper printing quality and placement of the labels. But how can the focal company influence the terminals to make those changes? Even though there is an ongoing relationship created by the necessary cooperation in order to coordinate the handling of shipments, the focal company has no buyer power over most upstream terminals. Our claim is thus that the focal company does not have the power to force upstream terminals to comply.

A subset of the terminals participates in closer collaboration with the focal company. The managers of these terminals meet with the shipping company once a year. These terminal meetings are used as a forum of influence. During pilot testing, a number of e-mails were also sent from the focal company to the terminals to make them start sending electronic lists and improve labeling practices. In addition, the WMS software provider arranges a yearly user conference for the terminals. The software provider invited a speaker from GS1, the company standardizing SSCC labeling, in order to inform terminal personnel of the benefits of registering with GS1 to obtain the necessary Global Location Number to make the SSCCs valid. The persuasion seemed to have little effect, as labeling quality remained low, and few electronic pallet lists were received by the focal company. There was a need for better incentives for the upstream terminals to try out the new functionality in the system.

As Christmas was approaching, a new initiative was taken in the form of an advent calendar lottery. Everyday a gift voucher for electronic products was awarded by drawing among the terminals that had used the EDI functionality that day. The result was above expectations and lead to a substantial adoption of the new functionality, and electronic lists continued to flow for a period. However, the pallet labeling quality remained far below that necessary. The sentiment among project participants at the time can be summarized in the following statement: “It will not get better before they start using barcodes for their own purposes” (*First mate reefer vessel, March 2009*).

Fortunately, in the same period, some terminals upgraded their WMSs to keep track of pallets internally using barcoded pallets and barcoded storage locations. This tendency gradually improved pallet labeling practices in the TPL network.

Effective persuasion could come from the master mariners and first mates of the vessel where pilot testing was carried out. These mariners use the system when charging or discharging at terminals, and can communicate with terminal personnel, both on labeling quality and on the presence of electronic lists. As they meet terminal personnel face to face at each call, they can influence terminal practices on behalf of the focal company: “We talk with them and it seems to improve practices” (*First mate, reefer vessel, November 2010*).

With the implementation of the system on all liner vessels, the terminals are probably subject to more face-to-face pressure to adopt the IOPTS because non-adoption implies slower charge and discharge operations and more work for their operational counterparts – the mariners.

7.5.8 Flexibility strategies

Even with the negligible costs for most terminals and several attempts at persuasion, different forums, a lottery and face-to-face mariner diplomacy, adoption was still patchy. This situation could have been expected both from the power relationships and from the scope limitations discussed in Section 7.5.3, and it can be expected to endure.

However, the project can still be declared a success because of the flexibility strategies developed to reap benefits from the level of compliance actually achieved for each shipment by carrying out extra re-labeling work or by sacrificing some of the potential functionality of the IOPTS. In all cases, these strategies retain the essential functionality for ensuring the correct tally and thereby fulfill the primary goal of the project – to contain claims expenses because of erroneous tallies.

The levels of shipment compliance to IOPTS requirements, the corresponding flexibility strategy and the resulting level of functionality are shown in Table 7-3.

Shipment’s level of IOPTS compliance	Flexibility strategy	Resulting functionality
4. Barcodes and pallet list ok	Not applicable	Full functionality
3. Invalid barcodes, pallet list ok	Use barcode as is	Full functionality*
2. Readable barcodes, but missing or wrong pallet list	Use barcode, drop pallet list	Tally only
1. No readable SSCC barcode	Re-label with barcode	Tally only

Table 7-3 Flexibility strategies

At the time of writing in January 2011, most shipments have compliance level 2 or 3. As a rough estimate, this indicates that approximately 70% of the pallets have readable barcodes, but most terminals have not complied with the requirement for GS1 registration, instead using a dummy number for the Global Location Number. Still, the barcodes can be used for pallet identification, as there is only a small chance of having to cope with different pallets with the same identity in the system. This potential problem with the full functionality is indicated with an asterisk in the table, but it will have to be handled even in the ideal situation of full compliance because occasionally terminals accidentally put the same SSCC on different pallets and because some pallets are transported several times by the TPL network.

The heterogeneous base data mentioned in Section 7.2.2 are not solved by standardization. Rather the product names used by the fishing vessels are passed on verbatim in the EDI messages. This flexible approach leads to some problems in goods categorization for downstream software, but for human users, understanding the different product names and correcting classification is a small problem.

7.5.9 Win–win strategies

The strategy that finally made terminals interested in sending pallet lists was the implementation of system functionality that could make terminals save time and cost: “Now they started to phone me when the functionality for sending pallet lists didn’t work. That had never occurred before” (*IT staff referring to the terminals*).

To curb claims expenses, the shipping company introduced a new document limiting their responsibility for cargo tally correctness. Initially, this “Mate’s receipt” document was printed onboard the reefer vessels after charging, forcing terminal personnel to wait while the document was produced. Waiting is both inconvenient and expensive as it often occurs out of office hours. The focal shipping company then introduced functionality for letting the terminals pre-print the Mate’s receipts based on the transmitted electronic pallet lists. This was probably the crucial move for making the sending of electronic pallet lists a standard operating procedure in some terminals.

7.6 Theoretical Implications

As we can see from Table 7-1 and the corresponding discussion in Section 7.5, most strategic advice encountered in the selected literature was put to use in the project in some form.

7.6.1 Low power SCM

A central idea in SCM is a powerful focal company being able to impose standards on other actors. The literature on the low power position is sparse. Harland *et al.* (2001) discuss SCM when the focal firm is in a low power position and points to “process and information processing improvements” and “coping with the situation” as the general strategies to follow, but also points out that lacking the necessary incentives can limit process improvements in such settings. The project under scrutiny is indeed an information processing improvement project, but this study could perhaps clarify what coping could involve.

Some of the strategies presented in Section 7.5 are good candidates for categories of coping strategies, going from the passive flexibility strategies (7.5.8), to increasingly active strategies trying to increase adoption by persuasion (7.5.7) or by developing effective incentives in the form of win–win strategies (7.5.9).

1. Flexibility strategies: These are strategies for obtaining as many benefits as possible from the level of implementation currently achieved, namely the current installed base. In addition to the

pragmatic dropping of requirements for compliance to standards and manual re-labeling, gateway technologies can be used to connect terminals using other WMSs.

2. Persuasion strategies: These are strategies for informing counterparts about the potential benefits of implementing the innovation and about how to implement it. Generally, this seems to have had a limited effect even though the focal firm and the software provider carried out several attempts. Interviews seem to indicate that the advent calendar and the repeated face-to-face comments on labeling quality from the mariners were among the more effective strategies in this category.

3. Win–win strategies: These are strategies where the focal firm seeks to locate potential actions that could improve the operational efficiency of the counterpart while simultaneously leading to an increased adoption of the innovation. The high impact functionality for pre-printing Mate's receipts based on EDI pallet lists sent from the terminals seems to be a case in point.

7.6.2 IOS risk mitigation strategies

As discussed by Kumar and van Dissel (1996), risk mitigation is essential for IOS viability. TCE discusses contracts to reduce such risks, while industrial network theory advocates long-term trust-building relationships and the careful consideration of the paradoxes of such networks when strategizing.

The focal company was able to reduce the specific asset risks for the terminals by making their implementation costs negligible (Section 7.5.5). The other counterpart risk elimination strategy was to adopt an IOS architecture where information ownership and control remains in the hands of the terminals (7.5.6). This observation could have implications for the architectural decisions in IOPTSs and in other IOSs, which could be implemented either as central information repositories or as internal systems under the control of each player, but interconnected through EDI. The information risks inherent in a central repository can be mitigated using information security mechanisms in the database management system (Kumar and van Dissel, 1996). However, a repository requires trust both in the technical safeguards and in the institution running it, while the semi-automatic EDI-linked system implemented in this project gives each player possession over proprietary data and control over when to exchange it. It might well be that the approach used in this project could be more acceptable to the counterpart than using a central repository.

7.6.3 Standardization vs. idiosyncrasy

The long-term strategy of keeping an idiosyncratic in-house booking system and the knowledge to support it and to develop further integration with other systems combined with deep inside knowledge on the internal operations of the counterpart terminals (Sections 7.5.1 and 7.5.2) were crucial to several of the other strategies. Both the solution for incorporating the EDI functionality in the standard workflow of terminals and inventing win–win strategies depended on deep knowledge of terminal operations and information processing.

As pointed out by Harland *et al.* (2001), information processing improvements might be the main strategy open to companies in a low power position trying to manage the supply chain. Such improvements could be far easier to accomplish if the company follows the flexibility enhancing strategy discussed by Olsen and Sætre (2007) of sticking to proprietary software for its core activities. Furthermore, ERP systems, such as SAP, are currently missing support for item-level track and trace (Rönkkö *et al*., 2007). Therefore, if the focal company had followed the alternative strategy of using standard ERP software, such integration would have proven difficult. Thus, the company benefited from following a non-standard practice internally.

Standardization in the terminal network is far from complete because many upstream actors do not follow the standards for using Global Location Numbers in the SSCC barcodes. This clearly shows that the low power focal firm has not been able to impose compliance to standards, but remains dependent on the de facto standardization provided by the installed base. However, the cost minimizing strategy involved implementing changes in the standard WMS and thereby the focal company was able to change the de facto standard from the inside. The limited level of standardization was handled successfully by the flexibility strategies described in Section 7.5.8, and win–win and persuasion strategies imply better compliance to standards in the future.

7.7 Conclusion: a panoply of strategies

A panoply of strategies were used. Many of these seem to be directly dependent upon each other or on the resources created by pursuing other strategies, as shown in Figure 7-3. When comparing with Table 7-1, it seems that most strategies discussed in the theory were pursued.

As far as we can see from the existing literature, the ideas of exploiting de facto standardization and using flexibility as strategies in the low power position have not been discussed before. The results also extend the discussion of Kumar and van Dissel (1997) by showing how specific asset risks can be eliminated by exploiting a de facto standard. The research also discusses the role of the intimate knowledge of the operation and information processing practices of the counterpart when pursuing win–win strategies and thus substantiates how such strategies can be effective for actors in low power positions.

Few firms are in a position to standardize an IOS and make all its counterparts adopt it by coercion, influence or persuasion. Patchy IOS implementation is thus probably more a rule than an exception. Flexibility strategies that are able to handle heterogeneity and low standards compliance could thus be important general strategies for reaping benefits from IOSs in real world supply chains. Such strategies could be easier to implement if the company enhances IT flexibility by using custom-built software solutions for its core activities.

Finally, it seems that implementing IOSs against the odds, even though feasible, is a demanding process, where success depends on a panoply of interdependent strategies that must be skillfully applied under long-term leadership.

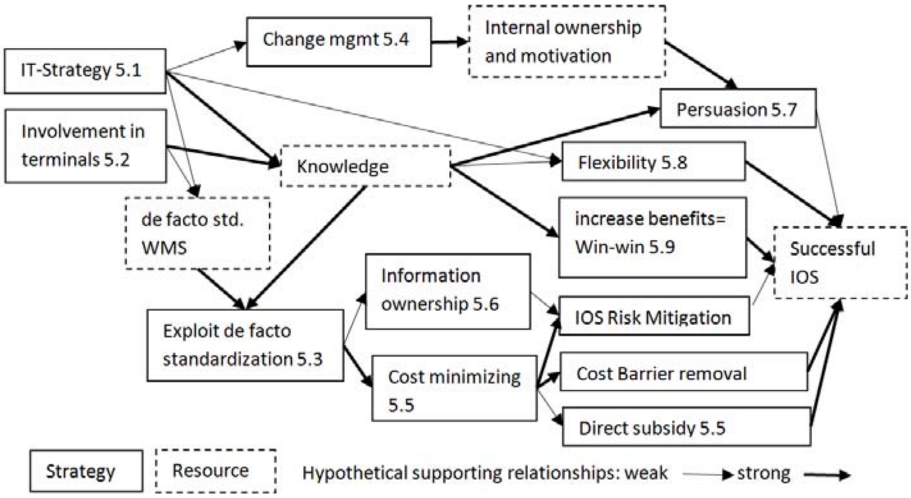

Figure 7-3 The panoply of strategies used and the relationships among them

7.8 Acknowledgments

This research was supported by the SMARTRANS program of the Norwegian Research Council. I also want to thank Jan Holmström, Bjørnar Aass and Kai A. Olsen who offered valuable comments on earlier versions of this manuscript.

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8 Paper 2: Product tracking systems in the supply chain for food – a support model for technology decisions

8.1 Introduction

IOPTS can be used to improve supply chain transparency and for a number of other purposes in supply chains generally (Holmström *et al*., 2010). In the supply network for food, such electronic systems can be beneficial when used to improve food safety, to curb food quality problems and to support different strategies for sSCM (Kumar *et al*., 2009; Bechini *et al*., 2005).

An IOPTS generally combines a technology for the automatic identification (AutoID) of tracked items with an IOS to collect and disseminate information about the tracked items to the players handling and transforming the items through the supply network.

There is much SCM literature on the potential of RFID for increasing supply chain transparency, but RFID is only an electable component in an IOPTS. Unfortunately, RFID has grabbed all the attention (Holmström *et al*., 2010), while the question of how to implement the necessary IOS backbone in the supply chain has been scantily treated (Ngai, 2009). The expected RFID revolution has failed to materialize so far (The Economist, 2007; Lee, 2007), and few supply chain RFID implementations have been covered in the literature (Sarac *et al*., 2010).

The SCM community should now refocus interest on *how* to succeed with implementing IOPTSs in real world supply chains. From IOS adoption research, we know that adoption has multiple aspects involving institutional, technological, socioeconomic and cultural factors (Damsgaard and Lyytinen, 1998).

This paper contributes to filling the technological aspect of the gaps identified above. It uses empirical results from case research in four food supply chain IOPTSs in Scandinavia to discuss the applicability of the results from the literatures on IOS adoption and on RFID in SCM. The result is an Inter-organizational Product Tracking Technology and Architecture Choice (IOPTTAC) model that informs both the technological decisions and the initiatives to increase IOPTS adoption among supply chain players.

The paper has five sections. Section 8.2 briefly presents existing research on IOS adoption and on AutoID. Section 8.3 covers the case research. Section 8.4 treats the model and discusses the theory versus the empirical findings of the technological properties used as inputs. Section 8.5 concludes and discusses the applicability of the model.

8.2 Implementing product tracking in a supply network – relevant theory

New technologies provide new opportunities for research, but one should always consider whether former research could be leveraged before starting new research (Stuart *et al*., 2002). For IOPTS adoption, we look at the comprehensive literature on the adoption of IOSs in supply networks that has accumulated since the 1980s. As every IOPTS needs an IOS backbone, IOS adoption research is clearly relevant.

8.2.1 IOS/EDI adoption research

IOS adoption research has focused on the adoption of EDI, and thus it can be divided into three overlapping stages. In the first rationalizing stage, early successes in industry were explained and further adoption taken for granted because of the competitive advantages offered by the technology. As adoption in industry stagnated, often at a fairly low level, research entered a probing stage, where positivistic methods using factor analysis tested factors that could influence adoption. Possible factors could come from case research or from theoretical perspectives such as DOI, sociopolitical or critical mass theory. Unfortunately, these efforts did not result in a universal consensus on one IOS adoption theory. In the third stage, recognizing the complex relationship between IOS adoption and the organizational context, research pursued theories and methods allowing a richer descriptive analysis (Somasundaram and Rose, 2003). Damsgaard and Lyytinen (1998) is an example of the richer approach. Their analyses use multiple theoretical accounts and conclude that the key factor to successful EDI diffusion is a mixture of institutional, technological, socioeconomic and cultural factors.

Lacking an accepted universal theory for IOS adoption and seeing the use of multiple theoretical lenses raise the question about which lenses to select. As the idea is to look at how technological choices affect willingness to adopt an IOPTS, we choose well-substantiated theories that have a bearing on the questions under discussion.

Iacovou *et al*.'s (1995) study of EDI adoption in SMEs is relevant for a discussion on current RFID adoption because of the similarities in terms of the high cost of, complexity of and knowledge scarcity about EDI and RFID. Iacovou *et al*. (1995) investigate why the penetration level of EDI among SMEs has been impeded by resistance. Building on a literature study including 34 preceding EDI and IOS studies, they develop a model with three major factors influencing EDI adoption decisions in SMEs: 1) the perceived benefits of adopting the technology, 2) the readiness of the organization to use the technology and 3) the external pressure from EDI initiators. The model proposed by Iacovou *et al*. (1995) was validated and extended by Chwelos *et al*. (2001). Nagy (2007) extends the model of Iacovou *et al*. (1995)/Chwelos *et al*. (2003) and adds perceived risk and switching cost. He also uses a finer grained treatment of power relations. He further regards low organizational readiness as a cost driver, thereby removing it as a primary factor. The resulting model is validated through case research.

The risks of conflict inherent in supply chain integration using IOSs and the strategies for mitigating those risks are treated in a seminal paper by Kumar and van Dissel (1996). They point out that the configuration of the IOS supporting the integration mirrors the interdependence between the players, and that the risk exposure, the types of risks and the corresponding mitigation strategies are dependent upon that interdependency. For IOPTSs two different types of configuration corresponding to two different IOPTS architectures seem to be possible (Table 8-1).

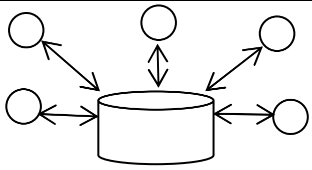
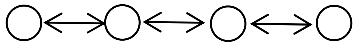
Architecture	Pooled	Long-linked
Configuration		
Implementation technology	Typically based on a relational database management system	Typically using some variant of EDI

Table 8-1 Product tracking IOS configurations (based on Kumar and van Dissel, 1996)

As we can see, the pooled architecture can be implemented as a shared database for players. This approach has been proposed as the ideal solution for IOSs in supply chains (Gulledge, 2006). Other "long-linked" architecture typically emerges when loosely integrating the systems of different actors along the supply chain using EDI. EDI could be heavily standardized Electronic Document Interchange or a more light weight Electronic Data Interchange solution.

Kumar and van Dissel (1996) treat the risks in the common pool architecture using the theory of common property resources (e.g. Hardin, 1968), and propose mitigating the risks by implementing technical safeguards using the standard security mechanisms available in database systems. The risks in the long-linked architectures are discussed using TCE, where the risks associated with specific assets, asymmetric information and the control over resources must be managed (Williamson, 1999). Investing in the necessary software, equipment and training to implement an IOS in a business relationship with another actor could indeed be a specific asset to that relationship, i.e. an investment that is lost if the business relationship ends. The investment in specific assets increases the risk of being dominated by the counterpart, a risk that can be mitigated by contractual safeguards. Losing control over information resources is another risk discussed by the authors in the long-linked setting.

8.2.2 Automatic identification (AutoID)

Even though there are other possibilities (Finkenzeller, 2003), barcodes and RFID currently seem to be the alternatives for AutoID in supply chain applications.

The first widespread supply chain application of barcodes was the UPC, which has been used since 1973 to identify products for fast and accurate grocery checkout (Garg *et al*., 1999). Barcodes are now ubiquitous, e.g. on cinema and airline tickets and on individual parts inside BMW engines (Mortimer, 2005). There is, however, a subtle difference between the UPC, where all instances of the same product have the same identity, and some of the current barcode applications where each item has a unique identifier. Thus, the good old barcode has quietly evolved into a technology that can be used to track individual logistics units. The UPC offered substantial benefits to the retail sector, but even though there is still huge untapped potential in the extended use of the UPC and its successors throughout the supply chain (Garg *et al*., 1999), there seems to be little interest in barcodes from the SCM community. It also seems that the barcode solutions described as inferior by Özer and Lee (2007) could be based on old UPC technology supporting only product but not item identification.

However, by promising real time supply chain transparency, RFID seems to have generated more interest. In RFID-based IOPTSs, each tracked item is equipped with one or more RFID tags or transponders, each containing a small microchip and an antenna. An item is identified when a reader device uses radiowaves to energize and interrogate the tag that responds with an identification number as well as other data that have been stored in the microchip (Finkenzeller, 2003).

The research on how RFID affects SCM can be classified according to the SCM problems being targeted, namely inventory accuracy, the bullwhip effect or replenishment policies, and according to how the estimation of benefits from solving them is addressed through analytical or simulation models or through case studies. Most studies assume that RFID offers perfect supply chain transparency. However, the decision about whether to adopt the technology should depend on a return on investment analysis (Sarac *et al.*, 2009).

The features of RFID and barcodes are summarized in Table 8-2. As we can see from the table, RFID supports high throughput reliable goods identification without needing to handle the goods manually. It can thus support a higher degree of automation and thereby reduce human work and errors, resulting in high quality supply chain transparency. Furthermore, the ability to collect sensory and location data can further provide real time information on goods' positions and states, thereby giving a more complete picture.

RFID	**Barcodes**
Not constrained by "line of sight." Hence, the location/orientation of the reader doesn't matter if the tags are within the range of the reader's signal	Requires line of sight
Simultaneous reading of multiple tags	One read at a time
Highly durable and difficult to damage, and thus useful in many potential applications	Low durability; subject to damage
Active tags have battery power and can deliver information about location. Some active tags can log sensor data, which subsequently can be transmitted to the reader for analysis.	Static label only
RFID tags can be written to repeatedly and they can serve as data bearers	Data on labels cannot be updated
Expensive compared with barcodes	More affordable than RFID tags are
Reading problems can be caused by liquids and metals	Performance unaffected by water or metal content
RFID tagging must be added to production processes or added to the unit before shipping	Can be printed before production and/or directly onto item

Table 8-2 RFID vs. barcodes (adapted from Delen et al., 2007)

8.3 Researching IOPTS implementation in the wild

Case research was selected because the implementation of IOPTSs is a contemporary phenomenon that must be studied in its natural context and where the research questions regard how and why technological choices affect the success of the implementation efforts. Case research is especially suited to answering "why" and "how" questions in such settings (Yin, 2003). The research sites and their positions in the supply network for food are shown in Figure 8-1.

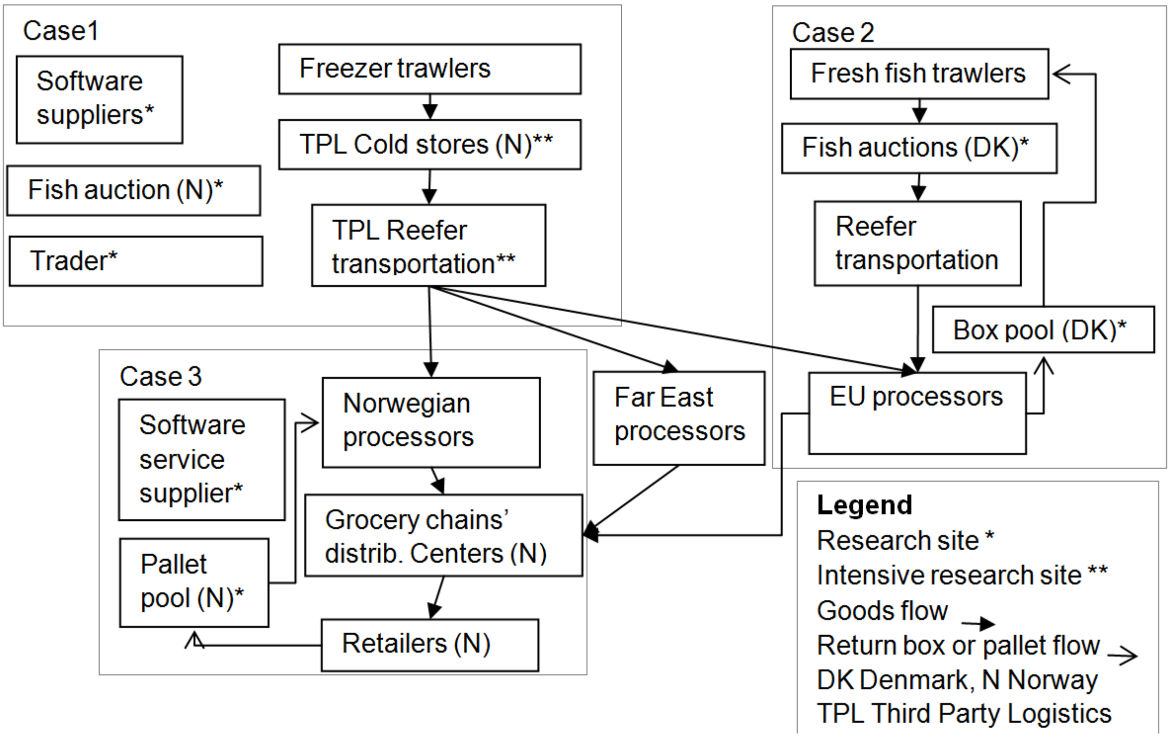


Figure 8-1 Research cases in the supply network for food

The cases covered by the case research are shown in Table 8-3. The first three cases have just started full-scale operation, but experience had started to accumulate through pilot testing. Case 1 is the primary case, which is an intensive longitudinal interpretative case study aiming at collecting cross-actor implementation experiences. Cases 2–4 are complementary cases brought in to cover alternative AutoID technologies and system architectures.

#	Case description	IOPTS architecture	AutoID technology
1	Pallet tracking in upstream supply network for frozen fish, Norway	Long-linked	Barcode
2	Box tracking in upstream supply network for fresh fish, Denmark (200,000 boxes) all major fishing ports	Information pool	RFID
3	Pallet and box tracking in downstream supply chain, Norway (1,000,000 pallets) top four grocery chains	Minimalistic info pool + Long-linked	RFID (+barcode on boxes)
4	National food tracking project, Norway	Information pool	RFID or barcode

Table 8-3 The four inter-organizational food supply chain product tracking cases used in this research

Table 8-4 shows the research activities used as a basis for this study. The main research method was semi-structured interviews, meaning that questions in the interview guides were supplied by follow-up questions when interesting topics emerged. Each interview guide was adapted to the function of the informant and to the state of the IOPTS project being studied. Before an interview in a new organization, documents were collected from the Internet. This documentation was shared with the informant at the start of the interview to show interest and to increase trust. The tactic seemed to work well in most cases, as we quickly came to the points of interest and seemed to get frank answers. Interviews were often complemented by further document studies and by observations, where further questions were asked to make sense of what was seen.

Case #	Research description
1	23 interviews covering management, operational personnel, software developers and auxiliary actors. 109 hours observation at a number of sites, >200 documents studied
2	1 interview 2 hours, observation 2 hours, ~10 documents: news coverage, web.
3	1 group interview 3 informants 2 hours, 1 phone interview 0.75 hours, 19 documents: mostly news coverage, marketing material and web.
4	Document study only, 12 documents – some of them comprehensive reports

Table 8-4 Research activities

Interviews were recorded with the permission of the informants, except for three interviews, where the circumstances were judged unfavorable for recording. The interviews were transcribed. Observations were documented using note-taking and photography.

Validity concerns should be handled systematically when performing case research (Stuart *et al.*, 2007). Validity in such research is obtained mainly through different types of triangulation, where inputs from different data sources, data collection methods, researchers and theories are used to alleviate single method weaknesses and to corroborate findings and explanations (Johnson, 1997). As can be seen in Table 8-4, both source and method triangulation were carried out, except for in Case 4. Furthermore, feedback from participants was solicited both on some field reports and when presenting results in meetings with participants in the primary case.

Analysis was carried out in two phases. First, analysis was combined with data collection using write ups as suggested by Eisenhardt (1989) – this resulted in a set of illustrated field reports. Final analysis was carried out while working out this paper by reflection over what is really implied by and supported by the empirical data.

8.4 The IOPTTAC model

The models discussed in the theory section can be combined into a unified IOPTTAC model for the IOPTS adoption shown in Figure 8-2. The model keeps the perceived risks, costs and benefits from Nagy (2007), but reintroduces organizational preparedness from Iacovou *et al.* (1995) as a prime factor to cater for the current scarcity of RFID implementation knowledge. Using RFID can also incur substantial running costs, so we should consider costs in general rather than discuss only the investment connected to switching to a new technology. Having both benefits and costs also supports return on investment considerations as proposed by Sarac *et al.* (2009). A number of other factors also influence the adoption decision (Damsgaard and Lyytinen, 1998). These factors are included as "other factors." The lower part of the model thereby covers the adoption decision, building on existing IOS adoption research. The upper part of the model covers how the properties of the technologies influence the costs, benefits, risks and organizational readiness. The discussion of these impacts uses results both from the literature and from the case research discussed in Section 8.3.

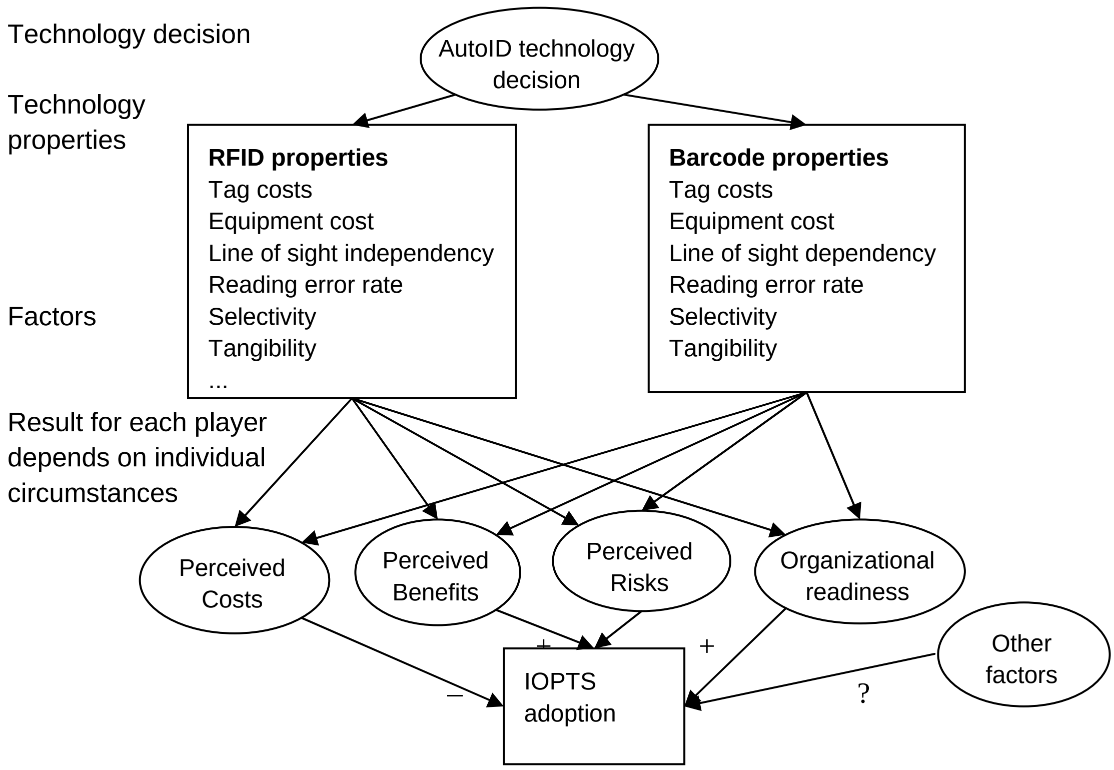


Figure 8-2 Outline of the IOPTTAC model used for selecting AutoID technology. A similar model can be drawn for the decision on the architecture.

The alternatives for AutoID technology are RFID and barcodes. For architectural choice, we have the pooled and long-linked architectures as discussed in Section 8.2. Some of the RFID literature proposes that information be transferred between players using the memory in the RFID tag as the data bearer (e.g. Lee and Özer, 2007). Using the tag to transfer information can be dubbed TDB (Tag as Data Bearer) and can be considered to be a variant of the long-linked architecture.

8.4.1 Using the IOPTTAC model

The model can be used to support cross-actor product tracking initiators when taking decisions on automatic identification technologies and on IOS architecture. After all, successful implementation depends upon enrolling the necessary players into the system. The model should support the initiator when evaluating the technologies for use both within its operation and in the rest of the supply chain.

This evaluation depends on the current state of technology, on the current prices for tags and equipment and on the installed base and handling processes at each player's facilities. Those are evolving and/or site-dependent targets.

The degree of IOPTS implementation can vary in several dimensions, e.g. whether to track at the pallet, box or item level, to track business events only or to aim for the real time tracking of each item's position (Grocery Manufacturers Association, 2004). Other dimensions regard how much of the supply chain should be covered and the extent of information being exchanged on each item. Yet another dimension is how much business processes will be changed. Obviously, the degree of IOPTS implementation has a profound impact on the possible benefits, costs and risks.

To support the evaluation, the following subsections discuss the different inputs to the model and describe how they depend on technological choices and local circumstances. Moreover, there is a large degree of interdependence between some of the inputs to the model. Such interdependencies are also discussed.

8.4.2 Cost generating properties

8.4.2.1 Running cost for tagging and waste

Compared with barcodes, which can be printed on labels and packaging already there for other purposes, RFID tags have orders of magnitude higher costs per unit and these constitute the main cost driver in RFID-based IOPTSs (Grocery Manufacturers Association, 2004). RFID tags can also imply higher costs when recycling used packaging because the materials used in the tags can break the recycling process adapted to standard packaging material and equipment (Kumar *et al*., 2009). Tags that have memory capacity to be used as data bearers can be more expensive than are simple tags. Tags that have sensors require sizeable memory and battery power, leading to higher costs and further recycling problems. In closed loop approaches, tags are reused multiple times, possibly reducing per-use tag costs to be comparable with those of barcodes. Closed loop approaches also reduce recycling costs and make tags equipped with temperature sensors a more viable option.

Cases 2 and 3 are box and pallet pools, where the boxes and pallets circulate in closed loops as shown in Figure 8-1. The RFID tags used on the returnable assets are thus available for other actors at no extra tagging cost. In Case 1, which is open ended because of the global nature of that supply chain, barcodes were selected as the AutoID technology.

8.4.2.2 Technical equipment cost

The costs of equipment for both AutoID technologies vary with equipment performance, and it seems that costs are currently comparable for equipment with similar degrees of automation. However, if there is an installed base of equipment for barcodes in the supply network, RFID is an extra cost. However, for such electronic products, costs can be expected to decrease.

In Case 2, the initiator saw high costs as a barrier for adoption, and it was looking for low cost RFID equipment that could be acceptable to fishing vessels. Here, low cost RFID equipment could be used to tie information on box content from the fishing vessel's information system to each box. The Case 3 initiator, seeing that portal solutions could be too expensive to some actors, put together a leased package for SMEs using lower cost equipment.

8.4.2.3 Changing work processes

In contrast to Lee (2007), who proposes that RFID initially replaces existing technology in existing processes, Ranky (2006) holds that ”work force transformation is a major challenge, because RFID projects force new practices.”

In Case 1, introducing barcodes and corresponding IS, barcode scanning was introduced into the current processes. Cases 2 and 3 using RFID introduced completely new processes and business models for handling empty boxes and pallets by the companies set up for the purpose of running the pools. At the fish auction (Case 2), the use of RFID was introduced into the current process for assigning fish boxes to buyers. In Case 3, hybrid tags combining RFID with barcodes were used on boxes to avoid breaking the business processes in the “barcode-oriented” parts of the supply chain.

Long-linked systems are constructed by linking together the systems of the players. This means that the current system is kept and it could thereby imply less change to work processes.

8.4.2.4 Integration cost

Item-level product tracking is incompatible with most ERP systems in operation (Rönkkö *et al*., 2007), and thus the integration costs of those systems could be significant regardless of the technology selected for AutoID. Barcodes can be easy to integrate because they can replace keyboard input directly.

An extra layer of middleware is generally required to extract information from the potentially enormous amount of data that can be generated by RFID readers (Ngai, 2009). This adds to the costs of systems building on RFID. However, reports from Case 3 indicate that the integration costs between players’ ERP systems and the Fosstrack Open Source EPCIS (electronic product code information services) IOPTS used in that project was affordable for most players.

There is also an integration cost inherent in choosing RFID tags and readers and in setting up and testing readers with the actual products handled. The necessity of testing is clearly illustrated by Poon *et al*. (2009). The same is confirmed by the case research: “I believed this was on-the-shelf standard products. – It was not!” (*Box pool manager, Case 2*).

8.4.3 Benefit generating properties

Benefits from IOPTSs can accrue through increased supply chain transparency in several ways: revenue can increase because of reduced stock-out rates, operating margin can improve through reduced shrinkage and capital efficiency can increase because of reduced stock and lead times. Operating margins can also improve through decreased labor costs because of automation and the elimination of mistakes and thus the costs of handling them (Grocery Manufacturers Association, 2004, Lee and Özer, 2007; Sarac *et al*., 2010).

For food chains in particular, benefits from IOPTS can be obtained through higher prices for products where the origin can be documented (Smith, 2008), through reduced spoilage by better control over expiration dates (Case 1, Case 3) and through increased food safety by the faster location of problems and the quicker and cheaper withdrawal of suspect products from the market (Kumar *et al*., 2009).

8.4.3.1 Readability/ tag integrity

There have been reports of high failure rates giving readability problems for RFID tags (Ngai, 2009), an experience also seen in Case 2. It seems that those were teething problems, which now seem to be solved (Case 2, Case 3). However, unfavorable tag antenna orientation could still result in readability problems, which can be solved by selecting another type of tag (Poon *et al*., 2009) or by moving or adding more reading antennas.

By contrast, the findings from Cases 1 and 2 confirm that barcodes in food chains are easily damaged because of humidity, resulting in a proportion of the barcodes being rendered unreadable. In Case 1, reading was in some cases impeded by shrink wrap obscuring or wrinkling the labels, requiring an extra manual operation to make the barcode readable.

These barcode readability problems can be reduced by higher quality label material and glue (Cases 1 and 3), but this increases barcode labeling costs. The high costs and resulting errors when manually handling reading problems seem to justify a conclusion that high RFID readability and tag integrity could save handling costs and improve IQ.

In Cases 2 and 3, RFID technology was used to enable innovative business models based on a hitherto unattainable precision on the movements of boxes and pallets. These models almost eliminated the shrinkage that had threatened pool viability. In both cases, work-intensive, error-prone manual box and pallet counting processes were replaced by accurate accounting based on RFID.

8.4.3.2 Independence from line of sight

Barcodes are read using reflected light. This often implies extra movement when the item or the reader must be moved to give line of sight between barcode and reader. Wasteful movement can be reduced using barcodes on more faces of the tracked item, but this increases labeling costs. In Case 1, even when using two barcode labels on opposite faces of each pallet, pallets typically weighing over 1000 kg often had to be turned to make labels accessible.

RFID is potentially independent from line of sight for reliable reading, but the orientation of the tag's antenna relative to the reader antenna is critical. In addition, some materials might be challenging to read through or on. Even the body of human operators might interfere with RFID systems (Ranky, 2006; Ngai, 2009; Poon *et al*., 2009; Roberts, 2006). The blocking of RFID signals is a potential problem in food supply chains handling products with high water content or with metal packaging (Kumar *et al*., 2009). However, such problems could be solved by using specially designed tags (Connolly, 2007) or by using more tags (Case 3 uses four RFID tags per pallet and Cases 2 and 3 use two RFID tags per box). One could also adopt ideas from sensor networks and ensure that tags cooperate to make the entire tag population on site accessible, but such solutions can require expensive battery-powered tags and result in site delimitation problems. The current conclusion is that independence from line of sight can be obtained in some RFID applications (Case 3), while in others RFID might not live up to the promise. Furthermore, experiments and experience might be necessary to decide whether independence from line of sight can be obtained in a particular application.

8.4.3.3 Reading speed – support for process automation

RFID tags can be read at high speeds (see Poon *et al.* (2009) for comprehensive tests) and reading can also be carried out without human assistance (Kumar *et al*., 2009). By supporting automation, RFID could thus prove a superior technology in high volume applications.

In Cases 2 and 3, this property was exploited to implement new automatic receiving and sending processes in the box and pallet pools. The costs of automation depend on the process in question. In Case 2 (box return process), tags were read by a single antenna installed by the conveyor belt in the box-washing machines, while in Case 3, a complex and expensive multiple antenna portal solution was installed reading up to 200 tags per second on boxes being trucked into or out of a loading port.

8.4.3.4 Selectivity and support for semi-manual operations

Both Case 1 and Case 2 have semi-manual operations, where new information is connected to the item being tracked. In Case 1, the number of boxes on each pallet and cargo damage is registered when inspecting pallets being charged onto reefer vessels. In Case 2, a new owner is bound to the box when acquired at a fish auction.

When using manual barcode readers, the barcode is selected by pointing a laser beam at the barcode. Using long-range scanners, the operator can precisely select the label to read at a 5 m distance. This *selectivity* stands in stark contrast to current handheld RFID equipment, which reads all tags within range, often requiring range adjustment and close distance reading to select the relevant tag in high tag density areas (see Figure 8-3for an example).

Figure 8-3 Using a handheld RFID reader to assign a fish box to a new owner. Low selectivity means that close range reading is necessary to select the right box (Case 2 fish auction). Photo: O. Bø

In Case 1, barcodes were used when receiving goods into a reefer vessel. Goods must be visually inspected anyhow to verify the count of boxes on each pallet and to discover possible damage. The barcode scanning did not seem to slow down the process even when handling the occasional reading problem, meaning that there was no extra personnel cost. Barcodes on the goods were scanned to identify each pallet, whereas barcodes fixed to the cargo elevator were scanned to input information about the number of boxes on each pallet and on the type of cargo damage when necessary. The shipping company reports a significant decrease in handling errors and subsequent claims after the introduction of barcode scanning. The cold store reports that barcodes for pallet and storage location identification have almost eliminated lost pallets. Barcodes thus might be a superior technology for supporting semi-manual operations in some applications, especially when binding information to particular items.

8.4.3.5 Support for sensor technology

The use of RFID tags with sensors, for example to document the integrity of the cold chain through temperature logging, has been touted as a major potential benefit of RFID in food supply chains (e.g. Kumar *et al.*, 2009). Even though dedicated temperature loggers have been used for decades in such applications (Case 2), RFID tags could promise a more fine meshed and comprehensive coverage of the chain by collecting temperature data through the IOPTS. However, the necessary batteries increase tagging, maintenance and waste handling costs. Furthermore, tag placement for readability might not be optimal for recording representative temperatures in the food. The Case 3 pallet pool is considering introducing a proportion of pallets with temperature sensing RFID tags.

8.4.3.6 Information availability

Improved planning and forecasting through improved supply chain transparency is one of the main advantages of product tracking systems. For the food supply network, another important consideration is reducing the impact of food crises.

Planning depends on information both on goods expected from upstream actors and on the flow of goods through the downstream parts of the supply chain. Here, the TDB architecture fails because the information being carried by the tag and updated while travelling through the supply network is only available to the actor in possession of the tagged unit, and thus it does not support improved planning. However, information in a TDB can be available without connecting to other IS, but with increasing mobile connectivity, this is a decreasing advantage.

In Cases 2 and 3, RFID has so far only been used for identification, while a large proportion of the barcodes in Case 1 also conveys box count, weight and expiration date.

Both Case 1 and Case 3 report that the supply chain transparency achieved through IOPTSs by data from upstream players is already being used by downstream players to plan the handling of goods in the pipeline, thus removing a number of telephone calls that were formerly used to obtain the necessary coordination.

Food safety authorities compare searching for the sources of food problems to finding a “needle in the haystack.” One method is to seek for the common supply chain denominator of the victims’ consumption patterns. Such queries are best supported using a common pool architecture, thereby giving instant access to all tracking information in the whole food supply network.

Case 4, which had food safety as its main goal, was implemented using a pooled architecture. However, long-linked architectures supported by effective query and data interchange technologies have also been suggested for IOPTSs for such purposes (Lo Bello *et al*., 2004).

8.4.4 Properties influencing organizational readiness

Barcodes have been with us since the 1970s and they are becoming steadily more ubiquitous in supply chains as well as in daily life. This means that organizational readiness for barcode solutions is probably high.

Organizational readiness for RFID is limited because the necessary competence is missing in many companies (Ngai, 2009). Interviews in Case 1 indicate that some of the informants have heard about RFID and have a strong belief in the wonders that could be accomplished by the technology. Even though RFID is gaining traction in toll road solutions, in car keys and in access control solutions, it could still be more difficult to understand than could barcodes because of the intangible and invisible nature of the technology, because of the erratic signal propagation and interference and because of integration complexity (Ngai, 2009).

In Case 3, the initiators have eased RFID enrollment among SMEs by leasing out an easily integrated base package and by offering education on the technology. These measures are in line with the advice from Iacovou *et al*. (1995) on how to alleviate low SME organizational readiness.

8.4.5 Risk generating properties

8.4.5.1 Asset specificity

Asset specificity in IOPTSs depends on the necessary investment for equipment and training to start participating as well as on the specificity, i.e. whether investments are lost if the business relationship ceases. Specificity increases if the initiator selects a technology that is incompatible with the installed base in the supply network. In many food supply networks, RFID is not a part of the installed base today, but this could change especially with the advent of supply chain pallet and box pools using RFID to keep track of their assets (Case 2, Case 3).

The EDI links in the long-linked architecture can be specific assets if they are especially adapted to a counterpart. EDI asset specificity can thus be reduced by using a common standard EDI profile (Damsgaard and Lyytinen, 1998). In Case 1, asset specificity was reduced when the initiator paid for an EDI module in the warehouse management software used by most of its counterparts.

For the pooled architecture, asset specificity is low if the pool constitutes a common standard for all players within a business sector.

8.4.5.2 Vulnerability to the loss of control over information resources

Contrary to the discussion on risks in Kumar and van Dissel (1995), it seems that the pooled information resource could constitute a more substantial risk for the loss of control over information compared with the long-linked type of system. This is both because it could contain a larger amount of information from many actors and because the other actors, some of them probably competitors and/or counterparts, could gain access to it in spite of technical safeguards. Another point is that the pool and its safeguards have to be controlled by someone, so the perceived risk to the information fundamentally depends upon the degree of trust each actor has in the organization running the shared resource.

It seems that information risk is indeed a barrier to adopting IOPTSs with common pool architectures: at least two prospective participants in the Case 4 common pool IOPTS have shown a reluctance to fully participate because of concerns about control over information in the pool.

A telling example of common pool information risk is the court case where the SAS aviation company received a heavy fine for industrial espionage by exploiting a competitor's information in the Amadeus common pool booking system to gain an unfair advantage (Nielsen, 2008).

Players participating in a long-linked architecture can reduce risk by sending information on a particular item only to the business partners handling that item and by reducing the extent of information: "We operate on a strictly need to know basis" (*Case 1 Shipbroker about information given to partners*). But this risk reduction could correspond to a reduction in information availability.

The alternative TDB architecture implies that information is accumulated on the tag. RFID-tagged goods containing sensitive internal information could then be vulnerable to industrial espionage using fast long-range readers.

8.4.5.3 Vulnerability to obsolescence and incompatibility

It seems as though some of the RFID standardization confusion (The Economist, 2007; Ngai, 2009) has been reduced by the advent of the EPC gen 2 tags used in Cases 2 and 3. In addition, the problem of region-specific standards for radio frequencies (Finkenzeller, 2003) can be handled using the multi-standard tags available today. For item identification, using identification numbers as standardized by GS1 is probably a good choice, since that standard has been widely embraced both for barcode and for RFID applications. However, the standardization of other information is still incomplete, meaning that applications using sensor technology or the TDB architecture might still imply a risk of obsolescence and incompatibility.

8.4.6 The adoption decision

We like to think that decisions are taken based on a thorough evaluation of the different options. However, as we can see from the preceding discussion, the decisions on technology and the resulting costs, benefits and risks are interdependent and uncertain. In reality, it seems as though the initiators of all four cases studied decided to implement an IOPTS to solve one problem that was crucial to the initiator. In Case 1, claims because of frequent goods handling errors threatened company profitability. In Cases 2 and 3, returnable asset shrinkage was considered to be the major problem, and in Case 4 the national food authorities had been seeking the reason why consumers were being hospitalized with food-induced illnesses.

8.4.7 The tabular IOPTTAC model

The tabular model is shown in Table 8-5. As discussed in the introduction to this section, the impacts depend on local and time-dependent circumstances as well as on the degree of implementation. Therefore, many entries in the model are interdependent or subject to discussion. Such entries are indicated with an asterisk, and when using the model to evaluate the situation for a particular player, those entries must be adjusted accordingly and if possible with exact amounts. The discussion in the preceding subsections might be of some help here.

	AutoID technology		Underlying IOS architecture		
Factors - Properties \ technological choices:	**Barcode**	**RFID**	**Pool**	**Long-linked**	**TDB**
Costs					
running cost tagging and waste	low*	high*			
investment in technical equipment	medium	high*			
investment in changing work processes	medium	high*	medium	low	medium
integration costs	medium	high*	med*	medium	medium
Benefits					
readability/tag integrity	medium*	high			
independent from line of sight	no	yes*			
reading speed/support for process automation	medium	high	high	high	medium
selectivity/support for semi-manual operations	high*	medium*			
supports sensor technology	no	yes*			
information availability	medium*	high*	high*	medium*	low*
Organizational readiness	high	low*	medium	high	low
Risks					
asset specificity	low	medium*	low*	high*	medium*
lost control over information	low	medium*	high*	medium*	high*
obsolescence and incompatibility	low	medium*	low*	high*	medium*

Table 8-5 The tabular IOPTTAC model. Context-dependent or interdependent impacts are marked with an asterisk.

8.5 Conclusion

There is a large span in the degree of IOPTS implementation and in the corresponding supply chain visibility. Cross-actor visibility is dependent on the penetration of the underlying IOS in the supply chain, but except for coercion through famous RFID mandates from seemingly omnipotent players such as Wal-Mart and the US Department of Defense, the SCM literature to date largely seems to ignore the crucial issue of how to obtain the necessary IOS adoption.

The proposed IOPTTAC model attempts to fill some of these gaps with a structured overview of how the properties of the different technologies and architectures influence the factors determining the adoption decisions taken by supply chain actors. The factors and the connection between them and the adoption decision come from well-substantiated theories on IOS adoption built on factor analyses and on a theory on risk handling in supply chain integration developed from common property resource theory and TCE.

For each factor in the model, we have discussed the impacts of the properties of the different technologies for AutoID and of the architectures for IOPTSs. The discussion compares hypotheses and findings on the technologies from the literature with findings from a case study, including *selectivity* as a salient property for barcodes. The discussion further seeks to show the interdependencies between choices and explain how these choices played out in the four cases. The model and structured discussion could inform similar decisions in other supply networks.

In fact, it seems as though in some cases the initiators' choices of technology could be more influenced by the initiators' own requirements to solve imminent internal problems than a careful consideration of what could be beneficial for supply chain-wide adoption. However, the discussion on the case studies shows that supply chain adoption becomes an ongoing concern for initiators, and that many of the measures they use to promote adoption could be described in terms of the IOPTTAC model. An improved adoption rate in similar projects might be obtained by using the IOPTTAC model normatively to inform technology decisions up front.

For further research, we propose the following. Most SCM research on RFID benefits today posits perfect supply chain transparency (Lee and Özer, 2007). For a number of reasons, full transparency seems an unobtainable target. Is it possible to develop theory that could guide decisions on what degree of transparency to aim for?

8.6 Acknowledgments

This research was funded by the Norwegian Research Council. I also want to thank the case research sites for providing access for interviews and observations. The SCM and IS group at Molde Specialized University of Logistics, in particular Bjørnar Aass, Berit Helgheim and Ketil Danielsen, also provided valuable input to the paper.

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9 Paper 3: Supply chain information mapping notation

9.1 Introduction

One response to increased competition and globalization is SCM, where the goal is the holistic optimization of a supply chain to reduce the cost of getting the right product to the right place at the right time. To reach that goal, SCM combines the principles from lean manufacturing with a tighter integration of the supply chain (Burgess, 1998). Here, integration does not necessarily mean to take ownership of the supply chain actors, but rather to foster cooperation and partnership and thereby improve information interchange between actors in the supply chain. The resulting improvement in the quality of the information available to stakeholders in the supply chain is an important goal in SCM. The focus of SCM so far has been on the downstream part of the chain with efforts to reduce product and order cycle time, optimize inventories and reduce the Forrester effect (Forrester, 1961; Lee, 2004) through initiatives such as Efficient Consumer Response and Vendor Managed Inventory.

However, for many if not most real world supply chains there are still considerable gaps between the ideal of full electronic information transparency throughout the supply chain using EDI or supply chain IS and the everyday realities of missing, untimely or uncertain information handled using largely manual, expensive and error-prone processes. In addition to inefficient and ineffective manual information handling, the work to correct errors and the expenses of settling claims are probably in many cases among the major cost drivers for the logistics parts of supply chains.

Evaluating the impact of poor data quality is a challenge, but three proprietary studies indicate that the cost of poor data quality can be estimated to 8–12% of the revenue in the typical enterprise. A more informal evaluation indicates that “40-60% of a service organization’s expense may be consumed as a result of poor data quality” (Redman, 1998 p. 80). It seems probable that a significant proportion of those expensive data quality problems can be attributed to deficient information handling in the supply chain.

When carrying out research or IQ improvement projects in supply chain settings there is clearly a need for a tool to provide an overview of the information handling activities and the resulting quality of the information available to the personnel performing the logistics activities. The SCIMN presented in this paper has been developed specifically for such mapping.

A number of mapping notations and tools for business processes and value chain improvements as well as the construction of the corresponding software have been described, for example Hines and Rich (1997) describe seven different value chain mapping tools, which were later extended to 11 mapping tools in Hines *et al*. (1998). The value stream mapping tool is discussed by Lasa *et al.* (2008). Larman (2005) describes activity diagrams, which are a part of the Unified Modeling Language, and finally Wohed *et al*. (2006) cover the BPMN.

The SCIMN is complementary to the established notations for three reasons: first, by explicitly including IQ as seen by the different actors; second, by including the identification of the goods; and, third, by including information carried by the goods itself. This last point means that the SCIMN includes the logistics unit (box, pallet or container) as an actor with its own information content. Including the logistics unit as an information carrier also means that the notation could be an especially useful tool in projects where the potential of RFID tags as data carriers is being considered.

The SCIMN was originally developed to illustrate findings when researching quality problems in the information used for the operational coordination of upstream fish logistics. The case research revealed a complex supply network with many stakeholders, intricate information exchange patterns and considerable potentials for reducing errors and costs by making better quality information available to stakeholders and on logistics units. For the extreme case of the fresh fish supply chain, the combination of perishable goods and high supply uncertainty leads to inherent quality problems in several information elements, and using the notation makes it possible to document how those IQ problems were handled in the business processes of the supply chain.

The next two sections discuss the concepts of IQ and information handling, respectively. In Section 9.4, a fragment of the fish supply chain, an electronic fresh fish auction, is described and modeled using the current standard modeling tool, the BPMN. Then, the SCIMN is thoroughly presented using the same fresh fish auction. The subsequent sections cover the testing of the SCIMN and BPMN in supply chain research settings before concluding and presenting opportunities for further research.

9.2 IQ

Information and data quality are synonyms in the literature on IQ dimensions, IQ assessment and IQ improvement, mostly from the perspective of the users of IS, databases or data warehouses. A recent review of the field can be found in Batini *et al*. (2009).

There has been some confusion in the field of IQ with different researchers using different terminologies; it is not within the scope of this paper to enter into that debate but rather to discuss findings that could be relevant when developing a mapping notation.

A seminal IQ paper by Wang and Strong (1996) builds upon an elaborate two-stage survey on data quality as seen by data consumers and results in a taxonomy containing four quality categories with 15 different quality dimensions. This seems to indicate that data quality is not a simple concept, and that quality assessment might prove a difficult challenge.

A particularly interesting approach is that of Price and Shanks (2005), who first pointed to the correspondence between components of semiotics and components of IS and then used semiotics as a theoretical basis to distinguish between syntactic, semantic and pragmatic as the three main categories for data quality. Here, syntactic means that the data is according to the database constraints of the IS storing them, semantic means that they constitute a correct and complete representation of the real entities the database contains information on and pragmatic means that the information serves the real requirements of users.

Compared with most studies of IQ, the focus when carrying out IQ research in supply chains is both narrower because it is limited to the context of supply chain activities and wider because many actors in most cases have different IS including manual procedures. This means that “syntactic” IQ assessments cannot be based upon compliance with a single well-defined information system. Furthermore, the goods are transformed and transported several times on the way from the source of raw materials to the market. This means that that the real entities to compare the information with may be uncertain and changing, and so “semantic” IQ will be hard to evaluate and time-dependent.

However, the importance of different elements of information and dimensions of IQ for a particular user and a particular task obviously must be different for each user and each task (Salaün and Flores, 2001). Therefore, we need to closely examine each user task to carry out a meaningful assessment of the quality of the information used to support the task in question. This assessment can best be performed qualitatively by observing and interviewing users to discern the information processing being carried out, the information being used and the problems users encounter when working to complete their tasks. Rather than measuring the data quality directly, Redman (1998 p. 80) suggests that “showing how poor data quality contributes to better-known problems [..] is often more effective than estimating error rates in the data [and the resulting] consequences.”

From a mapping point of view, it is impractical both for map readability and for mapping cost reasons to operate with too many quality dimensions and too fine-grained measurement of each of them. Thus, to make quality mapping a feasible proposition, we need to simplify rather than diversify the notion of IQ. Furthermore, the data quality dimensions are not at all orthogonal because, if data are not accessible, accuracy cannot be evaluated, and if data are inaccurate, they might not be interesting to process in an information system. Therefore, for a SCIMN, the many dimensions and sophisticated data quality metrics could be replaced by a coarse IQ hierarchy shown in Figure 9-1, a hierarchy in the spirit of Maslow’s hierarchy of needs (Maslow, 1943).

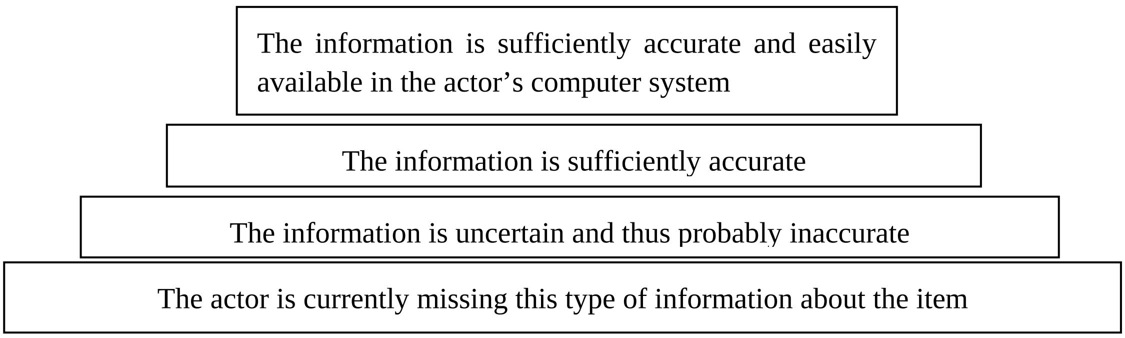

Figure 9-1 The IQ hierarchy

In the context of the mapping notation, the level in the information need hierarchy indicates the quality of a specified information element from the perspective of a supply chain stakeholder carrying out a definite task at a definite time. Surprisingly, a closer examination shows that 13 of the 15 IQ dimensions from Wang and Strong (1996) could be projected onto the IQ hierarchy when used in the SCIMN. Because it seems obvious that believability, objectivity and reputation can only be based on a track record of the accuracy of the data source in question, those dimensions could be included in the accuracy dimension.

IQ dimensions from Wang and Strong (1996)	Projection of IQ dimensions onto the IQ hierarchy
Intrinsic data quality	
-believability	included in accuracy
-accuracy	used as a main criterion
-objectivity	included in accuracy
-reputation	included in accuracy
Contextual data quality	
-value added	not covered
-relevancy	only relevant information is shown in the SCIMN diagram
-timeliness	missing or uncertain information at task time is shown as such
-completeness	missing information shown as missing
-appropriate amount	included in easily available
Representational data quality	
-interpretability	included in easily available
-ease of understanding	included in easily available
-representational consistency	included in easily available
-concise representation	included in easily available
Accessibility data quality	
-accessibility	opposite of missing
-access security	not covered

Table 9-1 Correspondence between data quality dimensions from Wang and Strong (1996) and the information need hierarchy

Another simplified description of data quality can be found in Watson (2004), who discusses information accuracy and reliability on a scale of hardness from 1: soft–rumors and gossip to 10: hard–stock exchange data.

For mapping purposes, it seems a practicable approach to use the four-level IQ hierarchy and to adapt the concept of hardness from Watson (2004), resulting in the following four levels of information hardness used within the SCIMN.

0. None – The information is missing
1. Soft – The information is inaccurate
2. Medium – The information is sufficiently accurate
3. Hard – The information is sufficiently accurate and easily accessible in the actor's computer system

9.3 Information handling

Logistics is "the coordination of material and information flows across the supply chain" (Harrison and van Hoek, 2008). Information handling is thus a central activity in logistics, and logistics effectiveness and efficiency can be improved by changing the way information handling is carried out.

Harrison and van Hoek (2008 p. 238) use the following three categories of electronic integration in supply chains:

- transactional: the electronic execution of transactions

- information sharing: the electronic sharing or exchange of information
- collaborative planning: enables trading partners to work together closely to align their organization's plans

The same categorization could be used to classify the corresponding manual information interchanges. To complete the list we should also include the identification of logistics units, because correct identification is crucial to avoid expensive goods handling mistakes.

Changing information handling can imply substituting the labor-intensive and error-prone manual information handling with suitable ICTs as shown in Table 9-2. Even more substantial improvements might be obtained by also changing the communication *pattern* by giving more actors access to the information or by providing the information at an earlier stage.

Information exchange	**ICT opportunities**	**ICT cost/benefit profile**
informing	e-mail, web, EDI, web service (WS)	medium cost/high benefit
transactional	web application, EDI or WS	high cost/high benefit
collaborative planning	low bandwidth: phone e-mail, instant messaging, high bandwidth: videoconferencing, collaborative software	low cost/medium benefit high cost/medium benefit?
identification	AutoID using barcodes AutoID using RFID	medium cost/high benefit high cost/high benefit

Table 9-2 Information exchange categories and ICT opportunities for improvement

As collaborative planning is often used in situations where partners negotiate based on knowledge not available to each other or in situations with considerable uncertainty, the application of higher bandwidth technologies for collaborative planning might prove beneficial, but low cost technologies such as phone or instant messaging might also be sufficient.

9.4 The Fresh Fish Auction presented in the BPMN

The Fresh Fish Auction presented here is one among several fresh fish auctions in the UK. It is an electronic auction, selling fish to buyers situated at the auction. Those buyers are agents for their customers, mainly the fish processing industry and chains of supermarkets in the UK and France. The following text describes the typical processes and information flows and Figure 9-2 is a BPMN diagram for the same processes and flows. The bracketed numbers for information flows in the text correspond to the numbers on the BPMN diagram, and the same numbers will be used again later when mapping the IQ dynamics using the SCIMN in Figure 9-8.

The fishing vessel catches the fish and grades and sorts it into boxes while at sea. On the way to the auction, the fishing vessel sends an early landing notice [1] stating species and quantities to the auction, who publishes the landing info on the auction webpages [2]. During the night, the fish is landed at the auction, and auction personnel place the boxes on the auction floor. Box position indicates both the fishing vessel and how old the fish is. As some of the fish lose weight during storage, some of the more valuable species are re-graded by auction personnel, who also group and register boxes into auction lots resulting in an auction list [4].

In the morning, fish buyers come to inspect the quality of the lots and then make agreements with their remote customers, mainly fish processors, on what to buy and at what price [6, 7]. The market operates a Dutch auction meaning that the price for a lot starts at a high price and then falls until a buyer presses his/her bid button [9], and then the fish is sold to that buyer. In some cases, the buyer, seeing higher prices than those expected, contacts his/her customers again to get a revised order [8].

After the auction, the buyer tells the auction personnel what fish should go to what address [13], so the fish can be correctly loaded into the cold trailer. He/she then contacts his/her customers to get confirmations [14,15] and finally sends consignment documents [16] to the trucking companies involved in forwarding.

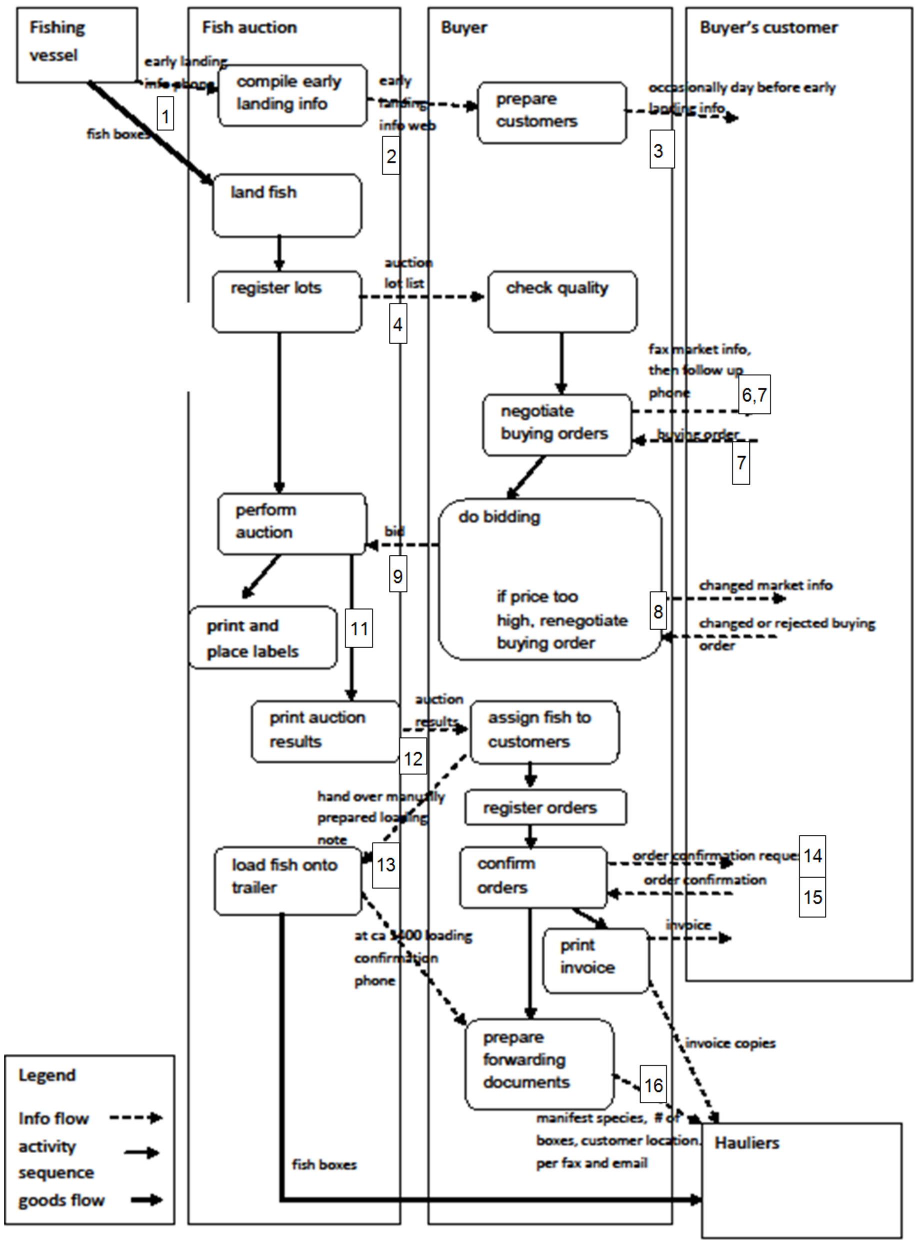

Figure 9-2 BPMN diagram for the Fresh Fish Auction

As can be seen from the BPMN diagram in Figure 9-2, the BPMN notation is straightforward to read and this is also used when discussing business processes with stakeholders. In the next section, we discuss a complementary notation to the BPMN, the SCIMN.

9.5 The SCIMN

A map is an abstraction in the sense that it cannot and should not show all details, but rather present a simplified picture of reality, a picture to serve a certain goal. Maps for car drivers are thus different from maps for inland waterway skippers. As the goal of the SCIMN is to show the dynamics of data exchange and data quality for the different actors of a supply chain, the mapping notation is adapted to that purpose.

9.5.1 SCIMN structure

The basic structure of the SCIMN is shown in Figure 9-3 using a horizontal operations axis, where the different logistics operations are placed sequentially, meaning that the operation axis is also a time axis.

- A vertical actor axis where the top actor is the logistics unit, namely the goods in the form of a box, pallet or container. Under the logistics unit, the actors of the supply chain are listed.
- For each actor, the table is subdivided into rows for each of the main information elements about the goods that are relevant to that actor. When applied to Figure 9-3, this means that the relevant information elements for auction personnel are the Logistics Unit Identification (LUI), the quantity and quality of the fish in each box, the price for the box and the address they will later forward the box to.
- For the logistics unit, the information shown could, for example, be printed on a box label or stored in an attached RFID tag.
- A special data element is the LUI, information used to identify a particular logistics unit. The LUI is necessary for the accurate identification of the goods and thereby crucial to avoid handling mistakes.

We can see that the SCIMN supports mapping the same information element several times in the table, thereby making it possible to map the well-known fact that in a supply chain different actors might have different data quality for the same data element.

actor	info element	catch	land/ regrade	quality control	pre auction	auction
logistics unit	LUI quantity quality address					
fishing vessel	LUI quantity quality price					
fish auction	LUI quantity quality price address					

Figure 9-3 An example showing the SCIMN structure

9.5.2 SCIMN for IQ

The IQ is coarsely classified into four quality categories corresponding to the four levels of the IQ need hierarchy depicted in Figure 9-1. The levels are shown by the different degrees of colored hatching from no pattern meaning no information available via red thin “soft” uncertain and inaccurate, brown “medium” sufficient accuracy quality to heavy green hatching “hard” computerized, accurate and easily available information, as shown in Figure 9-4.

Figure 9-4 The four levels of IQ

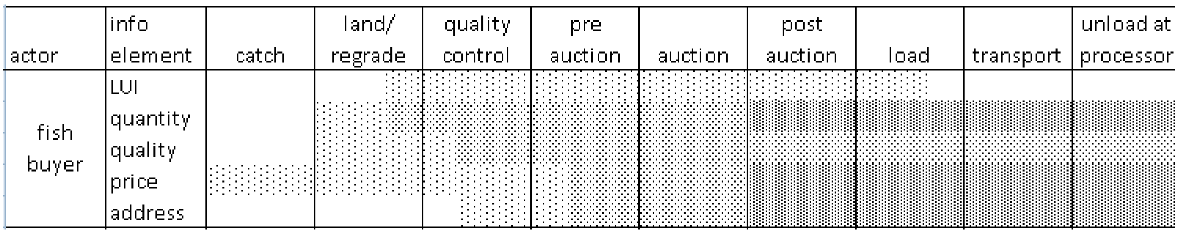

Figure 9-5 IQ dynamics for a fish buyer

As an example, Figure 9-5 shows how the notation can be used to describe the information quality dynamics for a fish buyer. In the catch phase, 24 hours before the auction, he does not know anything about what will be coming in, but he has soft information from experience about the current price levels. Just before landing, the buyer can fetch early landing information on the auction web-site to get low precision information about the expected quantity of each species from each of the fishing vessels on the way in to land their catch. Knowing the fishing vessel this also is an indication of the expected qualities available, hence information on fish quality is now described as soft. Early in the morning, the buyer then controls the quality of the fish landed and gets a firmer idea on the quality (see Figure 9-6).

Figure 9-6 Fish buyer evaluating whether a box of perishable monkfish can be expected to arrive in France two days later with a quality still fit for sale. (Photo: O. Bø)

The quality inspection increases the IQ of fish quality from soft to medium but not to hard, because there is still some uncertainty as to the quality of the fish when delivered to the end customer. In addition, the fish quality information is handled manually. The price and address for the fish is still uncertain (i.e. soft), but in the pre auction phase, the fish buyer contacts possible customers informing them of the market conditions and negotiating a buying order at a certain price limit. This increases the buyer's address and price IQ from soft to medium. The final price is decided when bidding, and being accounting information in the electronic auction system, this information is now top quality hard information. The buyer performs the final allocation of fish to his/her customers in the post-auction phase, entering the information into a computer system and confirming with his/her buyer, thereby turning the address of the fish into hard high quality information as well. Fish quality information remains medium quality through the following stages, because quality can change more than expected on the way to the customer leaving a degree of uncertainty. The quality of LUI remains low because this is based on the fish box position on the auction floor, making mix-ups possible.

To sum up the example, for some information elements, IQ starting low is improved by information exchange and by operations, thus creating new or more accurate information. For some information elements, IQ is limited by inherent uncertainties that might be difficult to reduce even with the best of technologies. For other information elements, IQ can be substantially improved by introducing ICTs such as AutoID and EDI. The SCIMN in all cases helps pinpoint IQ problems.

9.5.3 SCIMN for information handling

The notation for information handling, as shown in Figure 9-7, uses the four categories of information exchange presented in Table 9-2 and this shows to what degree the information exchanged is represented in a digital format, i.e. to what degree the handling is supported by ICT. Furthermore, because re-entering the same information into one or more systems for each new actor is a frequent and wasteful activity in supply chains, such operations are explicitly represented in the notation. The notation also makes it possible to express another common phenomenon, namely the manual handling of output from ICT systems.

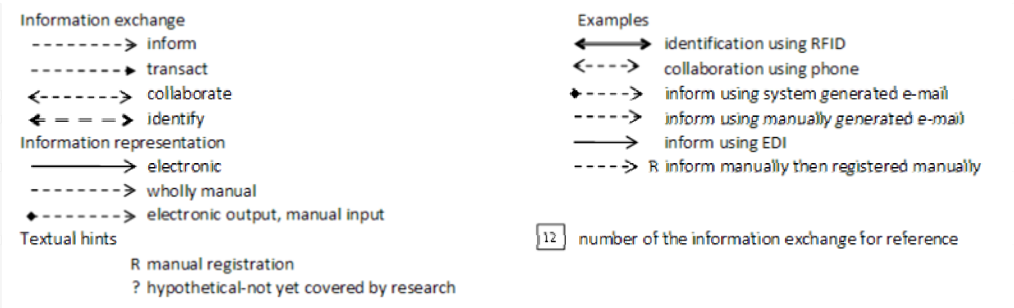

Figure 9-7 Notation for information handling

Now, all the required components of the notation have been described and we can thus present a complete example.

9.5.4 Complete SCIMN diagram

An example SCIMN diagram complete with structure, IQ and information handling notations is displayed in Figure 9-8. The diagram corresponds to the BPMN diagram in Figure 9-2, and the information flows are numbered in the same way. The textual description in Section 9.4 can also be read with this diagram to enhance understanding. The observant reader will see that more information streams appear in the SCIMN diagram compared with in the BPMN diagram. These flows are mainly for goods identification. The IQ dynamics and amount of communication and the proportion of manual labor expended to support the information propagation throughout this part of the supply chain should also be clearly visible on the diagram.

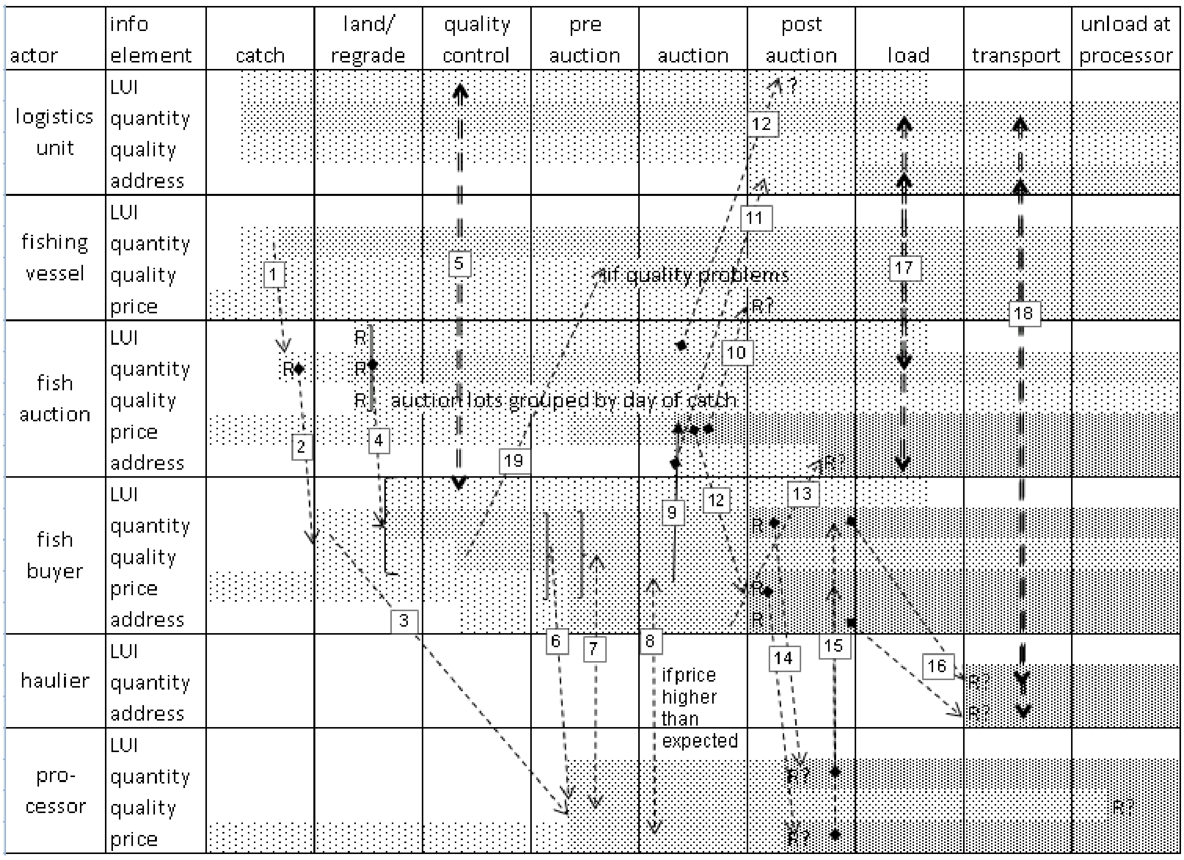

Figure 9-8 A complete SCIMN diagram for the fresh fish auction (numbers refer to bracketed numbers in the text)

9.5.5 Some findings from the SCIMN diagram

- One of the main results of the business processes is creating better quality information. Price and quantity and quality information are initially unknown or uncertain for all actors. The business processes remove much of the uncertainty and spreads information to several actors.
- Even though an electronic auction is a central business process and some of the actors are using IS to format the data sent to other actors, all information exchange except [9] is

handled manually, leading to the same information being manually registered over and over again by different actors.

- Fish quality is an uncertain factor that is handled both in quality control and in the pre- and post-auction business processes when the fish buyer assesses which fish has the right quality and price for transportation to and use by which customer. This assessment is one of the main functions of the fish buyer, and many of the information exchanges shown in the diagram are handling information resulting from these assessments and the corresponding business transactions.
- Logistics units are identified manually both by the fish buyer and later by auction personnel handling the loading of refrigerated trucks as well as by the hauliers in subsequent stages. At the auction, goods are roughly identified by position on the auction floor. After each sale, a label showing buyer is added as a first step towards an address. After the auction, the buyer informs the auction personnel of the addressees of the fish boxes. For the haulier, LUI information is missing, so address and quantity are used as substitute means of identification in the later cross-docking steps [17,18]. Reports on the weekly problems of faulty deliveries should perhaps not come as a surprise because of the weak quality of the goods identification methods used throughout the part of the supply chain described in the diagram.

9.6 Test of the Notation

The notation has so far been tested in research settings including in three case studies in the upstream supply network for seafood:

Norwegian coast frozen palletized white fish, with several primary buyers using reefer vessel transportation. The SCIMN was developed and used to pinpoint waste caused by IQ problems. Benefit: a systematic walk through of the importance of the different information elements for the different actors and the corresponding quality problems.

UK, fresh-boxed white fish auction with several primary buyers using road haulage transportation. The SCIMN was used after BPMN modeling and revealed a number of areas that had not been covered by the interviews. Here, the BPMN was tested with a fish buyer and this gave a clearer understanding during discussions on the business processes with the practitioner.

UK, fresh lobster, one primary buyer using road haulage transportation. Here, the IQ diagram was tentatively drawn before starting interviews. This was possible because the supply chain in question had been subject to some media interest and to a review process for sustainable fishing, resulting in more than 15 documents on the supply chain being publicly available. The diagram effectively showed what actors and processes were covered by the documents and where more questions had to be asked.

In all cases, drawing the SCIMN diagrams proved crucial to getting and giving an overview of the IQ dynamics for the supply chain being researched. Every time the diagram was drawn, the drawing revealed several aspects of the information handling that were not sufficiently covered by the research.

9.7 BPMN versus SCIMN

The two notations used in this paper have some similarities. They can both map business processes involving several actors and can show the information exchanged between those actors, but there are also several differences.

The BPMN is a standardized and popular notation, showing a clear sequence of actions performed by the actors. The notation uses symbols that can be placed where it suits the draftsperson, and comments to give more profound explanations can easily be added. The BPMN has proven itself as an easy and intuitive tool for communication between the personnel involved in the business processes and experts involved in improving the same processes.

The goal of the SCIMN is to discover and describe IQ problems in supply chains. Its tabular format forces the draftsperson to consider the IQ available to each actor at each stage of the business process for each element of information relevant to that actor. The main strengths of the SCIMN are the ability to outline the information handled throughout a supply network and to show areas with missing or low quality information and the corresponding information asymmetry between the actors involved, as well as showing the information carried by goods and to show a variety of automatic or manual information handling processes including cooperative planning, goods identification and wasteful manual re-entry of information. The weaknesses of the SCIMN are that the format makes it challenging to include comments directly in the diagram and that the number of information exchanges depicted can make the diagram overcrowded and hard to read.

9.8 Conclusion and further research opportunities

The paper presents a new notation supporting the mapping of IQ in supply chains. Testing seems to indicate that the notation is conducive to the development of a detailed and comprehensive overview of information exchanges and resulting IQ in the multi-actor business processes common in supply chains. The notation is based upon a coarse four-level hierarchy of IQ needs that can be seen as a supply chain operations projection of 13 of the 15 IQ dimensions proposed by Wang and Strong (1996).

Because failures due to deficient goods identification are reported to be a major cost driver in transportation activities, information carried by the logistics units and the corresponding information available to actors to correctly identify logistics units has been included in the notation.

Compared with the BPMN currently used in some supply chain improvement projects, the SCIMN might seem to be slightly less readable, but it could still prove beneficial as a supplementary tool to document IQ problems, and thereby support and direct work to improve information flow in supply chains through the implementation of ICTs such as EDI, supply chain IS and AutoID.

The SCIMN could be a useful tool, but more research is needed to evaluate its suitability as a tool for:

- other parts of the supply chain or other commodity or service supply chains
- communication with practitioners
- prioritizing between areas of improvement
- analyzing the direct and indirect effects of such improvements.

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10 Paper 4: The potential of IOPTSs in a sustainable supply chain – observations from the wild seafood supply network

10.1 Introduction

The operations management literature sees the tracking of products both as a practical problem and as a potential tool for improving inventory management and operations performance. Currently, leading industrial actors are introducing product tracking to improve their supply chains (Holmström *et al*., 2010). Electronic IOPTSs can also play a supporting role in sSCM. In the supply network for food, which is subject to legal requirements for traceability to ensure food safety, IOPTSs are known as supply chain traceability systems (Moe, 1998). We have chosen to use the term IOPTS, henceforth called tracking system, to emphasize that these systems are not necessarily made with food traceability as their main goal. This and the inter-organizational nature of the tracking systems have deep implications for the costs and the extent of traceability that can be achieved using them. The aim of this paper is to clarify aspects of how upstream tracking systems can be used to support sSCM.

”Sustainability” is a vague concept (Marshall and Toffel, 2005), and the field of sSCM thereby covers a number of issues (Linton *et al*., 2007). However, for industries using common pool natural resources, sustainable sourcing is crucial for the long-term viability of the industries in question. Fisheries, the livelihood for 8% of the global population and an important dietary resource for many more, constitute a case in point as world catches peaked in the early 1990s (UNEP, 2010). For seafood, sustainable harvesting can thus be seen as the main sustainability concern.

Currently, one can observe a change in behavior in parts of the Western world, where voluntary market-based measures seem to be changing the seafood industry and the retail industry selling its products, towards marketing “sustainable seafood,” meaning that the seafood is sustainably harvested. A central actor in this picture is the Marine Stewardship Council (MSC) whose high quality sustainability certification scheme (Accenture, 2009; Nick, 2006) is becoming the baseline standard for seafood sold through the leading retailers in Northwestern Europe (van Waarden, 2010).

Figure 10-1 Poster at Marks & Spencer, Ayr, Scotland, March 2010. (Photo O. Bø)

"Sustainable products" can be seen as one of the two main strategies for sSCM (Seuring and Müller, 2008). In the food supply chain, two strategies for sustainable products can be discerned: 1) the implementation of improved baseline standards for commodity foods and 2) the marketing of identity-preserved food (Smith, 2008). If MSC-certified food can be seen as the baseline standard, identity-preserved food could be used to market seafood harvested to even higher standards, but as Smith (2008) points out, identity-preserved food could be too expensive to be competitive.

How and to what degree a tracking system could support and speed up the change towards more sustainable products in the seafood industry can be operationalized into the following three propositions:

- P1: Tracking systems can lower the cost of implementing MSC certification in the supply chain.
- P2: Tracking systems can lower the cost of implementing identity preserving supply chains.
- P3: Tracking systems can let consumers locate the most sustainably harvested products among the offerings on the fish counter

10.2 IOPTSs

Kim *et al*. (1995) provide a theoretical treatment of the ontology of traceability. They point to the tracing of resources and the discrete activities performed on them as the core functionality of a traceability system (Moe, 1998). Traceability depends on the unique identification of tracked resource units (Bechini *et al*., 2005). Tracking systems typically use AutoID technologies to obtain reliable identification of tracked resource units. The activities representing the movement or handling of a unit are recorded as a sequence of dated discrete events. The recorded information is captured and disseminated to other players using an IOS, which can have either a centralized or a distributed architecture (Bechini *et al*., 2005).

Tracking systems can vary along several dimensions. Three dimensions seem relevant for answering the research questions. First, the *granularity* of the system concerns the size of the tracked resource unit, which could theoretically range from a single fish to a one-day production batch in the processing industry. Second, the *scope* of the system describes the set of supply chain actors covered by the tracking system. The scope of most tracking systems is limited to a few actors (Bechini *et al*., 2005). Third, the *extent* characterizes the set of information elements recorded in the tracking system. The extent is also in most cases small (Moe, 1998). To use existing tracking systems to support sSCM, these systems might need to encompass additional supply chain players and additional information. However, the current complete lack of standards for information exchange about transformation activities (Donnelly *et al*., 2009) could be a barrier to increasing the scope and extent of the systems.

10.3 Sustainable seafood harvesting

Despite several periods where fishery science asserted that seafood resources were inexhaustible (Gordon, 1954), it now seems proved that the global seafood resource depletion is mainly caused by its overexploitation. The consequences of this are threatening human survival on a large scale, firmly placing the sustainability of fish harvesting at the first priority level of the sustainability hierarchy described by Marshall and Toffel (2005). For the players in the fish industry, resource depletion also poses a threat to their long-term commercial survival (Smith, 2008).

The problem of overexploitation is multifaceted and treated in a substantial literature. As a basis for discussing proposition 3, Table 10-1 shows the salient facets of unsustainable wild seafood harvesting and some causes, interrelations and references. From the table it seems clear that the problem is complex.

Problem facet	**Causes and interrelations**	**Discussed by**
Root cause: Overfishing is an instance of the tragedy of the commons	Fish as a common pool resource	Warming (1911), Gordon (1954), Hardin (1968), Ostrom (1990)
Illegal, unregulated or unreported fisheries claimed to approach 30% of global catch	Partial or no enforcement of regulations. Missing industry responsibility and accountability	van Waarden (2010), Marshall and Toffel (2005), Borit and Olsen (2011), Alder and Lugten (2002)
Uncertainty in fishery science regarding what is a sustainable total allowable catch for a fishery	Partly caused by illegal, unregulated or unreported fisheries and the deficient reporting of discards	Marshall and Toffel (2005), Bates (2010), van Waarden (2010)
Regulation deficiency: quotas are often set beyond what is scientifically justifiable	Industry lobbying, the short time span of the political outlook and the uncertainty in fishery science	Clover and Murray (2009), Marshall and Toffel (2005), del Valle and Astorkiza (2007), Hardin (1968), Alder and Lugten (2002)
Large quantities of fish are discarded because of missing quota for the species or unselective gear catching unmarketable species or sizes (juveniles)	Partly caused by regulation policies. The EU Common Fisheries Policy implies compulsory discards of fish over the quota	Catchpole *et al*. (2005), Clover and Murray (2009), Davies *et al*. (2009)
Marine habitat destruction by fishing gear	Static gear e.g. traps and long lines could be less destructive	Clover and Murray (2009), van Waarden (2010)
Ecosystem breakdown because of the extinction of species	Typically caused by overexploitation	Clover and Murray (2009), Marshall and Toffel (2005)
Missing industry transparency	Connected to illegal and unethical practices	Jacquet and Pauly (2008)

Table 10-1 Facets of the unsustainable fish harvesting problem

10.4 Researching tracking systems in the wild

Tracking systems are contemporary phenomena to be studied in their natural contexts. The research questions cover how and why such systems support the two strategies for sustainable food products. Case research was selected because it is suitable for treating "how" and "why" questions in such settings (Yin, 2003). In a first explorative phase, a single multi-site longitudinal intensive case research design was used to study the introduction of a tracking system in a TPL-driven supply chain for frozen fish. Then, two more research cases were introduced to cover a broader variety of tracking systems in the supply network for seafood. The research sites and their positions in the supply network are shown in Figure 10-2, and a textual description of the respective supply chains follows in the next section.

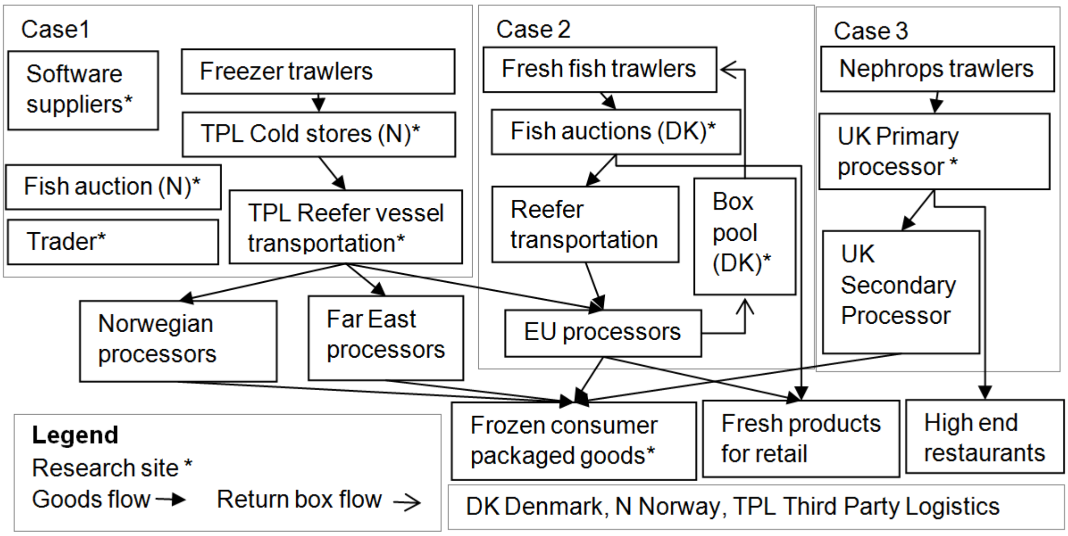

Figure 10-2 Research cases and sites in the supply network for caught seafood

Table 10-2 shows the research activities. Interviews and document studies were the main research methods. Interviews were semi-structured, meaning that in addition to the questions in the interview guides, follow-up questions were used when interesting topics emerged. Interview guides were developed to fit the function of the informant and the state of the project being studied. Before entering an organization, scoping was used to collect relevant documents from the Internet. The documentation was shared with the informants at the start of the interviews to show interest and to increase trust. With this tactic, we quickly came to the core of the matter and seemed to get frank answers. Interviews were often complemented by observations, where more questions were asked to make sense of what had been seen.

Case	**Research description**
1	22 interviews covering management, operational personnel, software developers and auxiliary actors. 109 hours observation at a number of sites, >250 documents studied
2	1 interview 2 hours, observation 2 hours, ~10 documents: news coverage, web.
3	1 interview 15 minutes, 15 documents – some of them comprehensive reports
CPG	Studied as documents in 6 UK and 5 Norwegian retailer outlets. 55 products covered.

Table 10-2 Research activities (CPG refers to Consumer Packaged Goods)

Interviews were recorded with the permission of the informants and transcribed. In four interviews, circumstances were unfavorable for recording, so note-taking was used for documentation. Observations were documented with photography and note-taking.

In case research, validity should be handled systematically (Stuart *et al*., 2007). Validity in such research is obtained through different types of triangulation, where inputs from different data sources, data collection methods, researchers and theories are used to alleviate single method weaknesses and to corroborate findings and explanations (Johnson, 1997). As can be seen from Table 10-2, both source and method triangulation were carried out. Furthermore, feedback from participants was solicited both on write-ups and when presenting results in meetings with participants in Case 1.

Analysis was carried out in two phases. First, analysis was combined with data collection using write ups as suggested by Eisenhardt (1989) – this resulted in a set of illustrated field reports. Final analysis was carried out while preparing this paper by careful consideration of what is really implied by and supported by the empirical data.

10.5 Supply chains

Table 10-3 shows the locations, supply chain contexts and technologies used in each of the systems. The tracking projects studied are situated between the producers of raw materials, namely the fishing vessels, and the processors, that is the industry turning raw materials into more or less finished products. In the supply network, landing refers to taking the catch on shore from the producer.

Case	**Supply chain types (Smith, 2008)**	**Supply chain structure**
#1 North and West Norwegian coast frozen demersal fish pallets	commodity/ manufactured or commodity/ conserved	Independent producers, neutral cold stores, neutral transportation. Several intermediaries. Chain of title and chain of handling separate from landing to primary processor
#2 Danish fresh demersal fish boxes	local, conserved, commodity/ manufactured	Independent producers, fish auctions, processors. Chain of handling and chain of title separate from landing to primary processor
#3 UK Nephrops boxes, fresh and frozen	manufactured or conserved	Producers under contract, common chain of title and handling from landing to finished product

Table 10-3 Supply chains

The Norwegian coast supply chain lands considerable quantities of fish that have been caught in the Northeast Atlantic and Barents Sea by fishing vessels from a number of nations. Those are locations far from the markets and require fish to be conserved, for example by being frozen at sea. The frozen fish is palletized upon landing at neutral cold stores. After forwarding to cold stores in Western Norway and the EU, a proportion of the fish is stuffed into reefer containers and transported to the Far East for low cost processing before being transported back again to the Western world as manufactured product. The product can thus be seen as a commodity resource for food manufacturers making readymade frozen dishes. Alternatively, the raw material is forwarded directly to processors in the EU or conserved by drying in Western Norway. The supply chain is complex with many actors and intermediaries using TPL for the handling and transportation of the goods. This means that the chain of title (ownership) is separate from the chain of handling.

The Danish supply chain mainly uses fish caught in the areas around Denmark by independent producers, and it has short transportation routes to continental Europe. The fresh fish is landed at 10 fishing ports operating fish auctions connected to the Pan European Fish Auction network (see Collins (2002) for a description). The catch is sold to processors mainly in Denmark and the Netherlands.

The UK supply chain handles nephrops that are caught by producers under contract with a substantial player in the seafood industry. The large nephrops are chilled for live transportation as “langoustine” to restaurants mainly in continental Europe, while the lower grade fraction is partly processed at the landing plant before being transported to a secondary processor where they are turned into readymade frozen dishes for distribution through the grocery retailers.

10.6 Findings

10.6.1 The goals of tracking systems

Table 10-4 shows the sponsors for each system and their motivations for implementing the system. It also shows that in all cases, the sponsors propose to use the systems to supply downstream actors with more accurate information about the provenance of the products as one of the goals.

Case	System project sponsor	Stated primary goals	Stated secondary goals
#1 North and West Norwegian coast frozen demersal fish	Shipping company providing transportation between landing terminals and terminals for containerization or for processing industry.	Improve control over goods movement to reduce errors, shrinkage and subsequent claims. Increase upstream actor accountability for goods damage.	Become preferred transportation company by being able to provide information about food origin to downstream actors.
#2 Danish fresh demersal fish	Company running the box pool of the supply chain. Box pool owned by the producers' organizations and a private investor.	Improve control over box movement to reduce box shrinkage and to collect box rent.	Provide detailed information about food origin to downstream actors. Provide proof of legal and registered catch to downstream actors. Turn gains from information into better product prices for producers.
#3 UK Nephrops, fresh and frozen	Seafood landing and processing plant, part of leading international fish processor.	Obtain MSC certification by providing information on sustainable catch management.	Provide detailed information about food origin to downstream actors in the high price segment (restaurants).

Table 10-4 Tracking system project sponsors and their motivations for implementing the systems

A surprising fact is that two of the three systems do not have sSCM or food safety concerns as their primary goals. This means that the costs of these systems are completely or partly justified by other applications in the supply chain.

10.6.2 The characterization of tracking systems

The technical feasibility of using an existing tracking system for sustainable products depends on the characteristics of the system, as shown in Table 10-5. The scope is the set of supply chain actors covered by the system. Actors marked with an asterisk are not currently participating in the system, but these are covered in the sense that the goods they handle have the necessary AutoID tagging. The extent describes what information is made available through the system. Limited information availability limits the potential of a tracking system to support sustainable products.

Case	**Technology**	**Tracked resource unit**	**Scope**	**Extent**
#1 North and West Norwegian coast frozen demersal fish	Barcodes, distributed systems, EDI	pallet ~1000 kg	Neutral cold store to reefer vessel to processing industry*	Box ID, box movement through supply chain including producer.
#2 Danish fresh demersal fish	RFID, central database	box ~40 kg	Producer*, to auction to processing industry*	Producer, species, grading, quality, weight, and pallet movement
#3 UK Nephrops, fresh and frozen	Barcodes, central database	box	Catch to primary processing	Not available because of divergent empirical evidence

Table 10-5 Tracking system characteristics

10.7 Discussion

Because the cost of implementing the systems is justified by other goals, as discussed in the goals of tracking systems section, the systems can be used to support sSCM at a low or negligible marginal cost, meaning that using them for sSCM purposes is economically feasible. Depending upon which one of Smith's (2008) strategies for sustainable products we consider, there are different requirements for the systems to support the strategy.

A common trait of the systems studied is their limited scopes and extents; they typically only cover a part of their supply networks and few information elements. To support sSCM, the system can be extended to cover the part of the supply network required for the sSCM strategy selected. Widening the extent could also be considered, but this might be complicated by the number of players already using the system, making it a hard to change infrastructure.

Can tracking systems lower the cost of implementing MSC certification in the supply chain?

If we follow the alternative of an increased baseline standard through MSC certification, tracking systems could just be used as an effective and efficient way to meet the MSC chain of custody requirements by distinguishing MSC from non-MSC goods in those parts of the supply network handling both categories. If the supply network handles MSC-certified seafood only, there is no need to invest in a tracking system for chain of custody purposes.

As we can see from Table 10-5, the systems studied cover the supply chain from the producer of raw material to the processing industry. In the case of an MSC-based strategy, this might be sufficient to cover the requirements for chain of custody certification without further expensive changes, such as separate physical storage and transportation. These tracking systems could thereby almost remove the cost of implementing an MSC-based strategy for the part of the supply chains covered by the system in Cases 1 and 2.

Can tracking systems lower the cost of implementing identity preserving supply chains?

If an identity-preserved strategy is followed, then the system must be extended to cover the supply chain from fishing vessels to the fresh fish counters or to the finished products in a package carrying the necessary information.

As fishing vessels are currently being equipped with an electronic log integrated with electronic weighing systems, which effectively constitute an onboard tracking system (Fishing News, 2010), the upstream extension thus simply means integrating input from the fishing vessels into the systems studied in Cases 1 and 2. In fact, the sponsors of Case 2 are looking into how fish box RFID identity can be connected to the catch data at the catching stage by providing the fishing vessels with RFID readers connected to the onboard weighing system.

In the fish processing industry, product transformation operations lead to more complex and thereby expensive internal traceability systems (Donnelly *et al*., 2009). Interviews with software developers targeting the processing industry indicate an increasing demand for internal traceability solutions with several ongoing projects initiated by major actors.

Integrating the fishing vessels' and processing industry's internal traceability systems with the existing low use cost tracking systems covering the actors between them (Cases 1 and 2) could thus support a reduced cost and complete end-to-end tracking system supporting identity-preserved products. However, the information available to make the products distinctive is limited by the extent of the tracking systems.

Can tracking systems let consumers find the most sustainable products on the fish counter?

Most fishing vessels are specialized in the sense of being equipped for fisheries using one or a limited variety of fishing gear. Thus, in many cases the gear type and thereby the order of magnitude of discards and damage to the marine habitat can be partly indicated by the identity of the producer. As can be seen from the extent column in Table 10-5, the producer's identity is registered by the systems covered by this research, and thereby consumers could be informed about this aspect of sustainability. Observations of freezer counters in Norway and the UK seem to indicate that this information is seldom forwarded to consumers. Among the 55 instances of consumer-packaged frozen seafood examined, only one instance was found indicating the fishing vessel, the accurate fishing ground and that the fish was caught using a long line (static gear). It was not established whether this fish had a higher price tag than the nonspecific competition or whether consumers have the necessary background knowledge to see the difference.

As for information about discards or the destruction of the marine habitat, this information is not registered in the systems studied, except perhaps for Case 3, where sustainable catch management is the main purpose of the system. However, the company involved does not seem to provide such information on their packaged products.

Thus, for proposition 3, it would be possible to give some information to the consumer about the sustainability superiority of products from vessels using fishing gear with fewer side effects. However, detailed quantitative information about the side effects of harvesting is not covered by the systems used between the producer and the processor in Cases 1 and 2 and thereby cannot be transported through those systems. As seen from Table 10-1, comparing the relative sustainability merits of caught seafood products is a hard and complex problem even for experts that have the best information available. Thus, it seems safe to conclude that even with tracking systems that have considerable extents and scopes, consumers will not be able to discern the most sustainably harvested product on the fish counter.

10.8 Conclusion

We have seen how tracking systems that have been installed to solve other problems can be used to support sSCM in the seafood industry. In particular, we have examined how both the strategies for more sustainable food products proposed by Smith (2008) can be enabled by the systems studied.

The degree to which a tracking system can be used to support an sSCM strategy for sustainable products depends on the scope in terms of the supply chain players participating and on the extent in terms of the information recorded in the system; however, it also depends on the strategy selected.

Providing more information to consumers about the relative environmental side effects of different products could allow for a price premium for products caught using less efficient albeit more environmentally friendly static gear.

This study is limited to three tracking system projects in the caught seafood industry in Northwestern Europe. The applicability of these results to other parts of the world and to other supply networks using common pool resources certainly depends on the degree of similarity with the industry studied.

The systems studied are in different stages of implementation, and thus they might not all be adopted by a sufficient number of supply chain actors to make them enduring realities. That said, they represent a trend that should lead to the widespread availability of such systems in the near future. The increased availability of tracking systems might make the implementation of sSCM strategies less costly and thus increase the credibility and value of sustainable products. Tracking systems can also lead to an increased positive impact from those strategies on the environment, and that is the ultimate goal of sSCM, isn’t it?

10.9 Acknowledgments

This research was generously supported by the SMARTRANS project of the Norwegian Research Council. Research in the UK was facilitated by a half-year stay and support from Professor Margaret Grieco at the Transport Research Institute of the Edinburgh Napier University. The paper has also benefited from comments by Harald M. Hjelle and Kai A. Olsen of the Molde University College.

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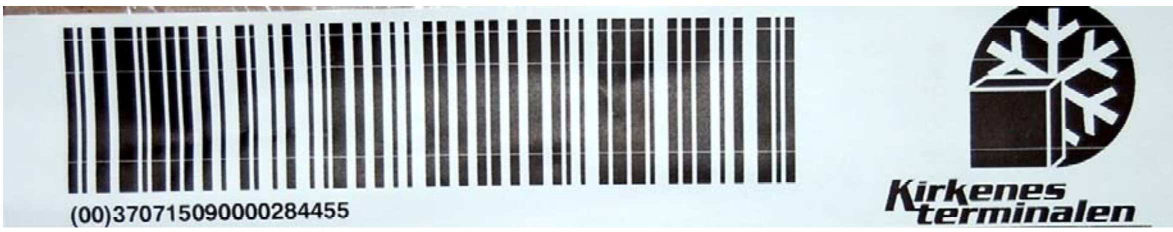
11 Appendix 1 AutoID technologies

Currently, the two main technologies for the automatic identification of product items are barcodes and RFID (Table 11-1). A precursor to RFID was conceived in both Germany and the UK before World War II as a means to identify friend and foe aircraft using radio signals. The fast development within the field of microelectronics after the War made it possible to reduce the size and cost of such equipment to a degree that it is now feasible to apply to many types of goods. Well-known barcodes were developed in the early 1970s as a technology to identify *product types* and it has been used since 1973 to speed up the checkout of many types of goods, most notably groceries. Towards 2000, barcode technology had reached a sophistication that made it possible to uniquely identify single *product items*, and standards were developed by GS1 for the identification of logistics units using a SSCC and for the identification of reusable boxes and pallets using a Global Returnable Asset Identifier. These standards are compatible with both RFID tags and barcodes, i.e. with both automatic identification technologies. The bottom AutoID tag of Table 11-1 contains the same Global Returnable Asset Identifier code encoded in both the barcode and in the RFID tag hidden underneath the barcode.


RFID tag used on Danish fish boxes to make each box identifiable. The little black dot under the bright yellow blot of glue contains the electronics. The surrounding pattern is the antenna

An SSCC barcode uniquely identifying a pallet. From a freezer terminal in Northern Norway.

Hybrid tag with both AutoID technologies: On the surface - A Global Returnable Asset Identifier barcode. As indicated on the upper left side, there is an RFID tag underneath. Used in the Norwegian grocery box pool.

Table 11-1 The two most common AutoID technologies used today

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ISBN: 978-82-7962-137-9
ISSN: 0809-9588