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Challenges for building RFID tracking systems across the whole supply chain

Ville Hinkka*
Department of Industrial Engineering and Management, Aalto University, Espoo, Finland

Abstract. Even though numerous articles and real life cases have highlighted the benefits of radio frequency identification (RFID) tracking for supply chain management for almost a decade, companies are rather slow to implement the technology. This paper concentrates on researching the reasons for the slow adoption of RFID tracking in the supply chain management using literature review and multiple case studies as the research methodology. The literature review of the articles classifies different challenges for RFID tracking implementation and elicits the academic explanations for the slow acceptance of the technology. The conclusion of the literature review is that most of the published articles have been concentrating on presenting technological obstacles to RFID tracking implementation, while the problems nowadays are increasingly organizational or inter-organizational. Also companies usually settle for using RFID tracking to improve their operational processes instead of exploiting the full potential in the technology and the increased visibility for improving managerial processes of the company, or upgrading the efficiency of the whole supply chain. In addition to the literature review, five RFID tracking case surveys are presented to provide experience and insights into managerial decisions concerning supply chain-wide RFID tracking solutions. Followed by the literature review and case studies, this paper presents a framework, which suggests three levels, where different potential challenges to supply chain-wide RFID tracking system implementations should be handled: the supply chain, inside a company or inside a certain function.

Keywords: RFID, supply chain management, tracking, multiple case study, literature review

1. Introduction

Radio Frequency Identification (RFID) technology used for tracking purposes can improve the efficiency of the supply chains considerably. RFID tracking enables the automation of operational supply chain processes and creates possibilities to offer information to support managerial processes (Visich et al., 2009). There are several successful examples of RFID tracking implementations which have smoothened supply chain operations considerably and brought significant savings for the companies adopting the technology (Attaran, 2007; White et al., 2008). RFID tracking has also brought added value to many supply chain operations and even enabled new business opportunities (Martinez-Sala et al., 2009).

*Corresponding author: Ville Hinkka, Department of Industrial Engineering and Management, Aalto University, Espoo, Finland. E-mail: ville.hinkka@aalto.fi.

But the reality in RFID tracking adoption differs from expectations presented in literature. Even if RFID tracking has been in the spotlight for years, the adoption of the technology has taken place slower than estimated (Fish & Forrest, 2007). There are hundreds of reports, studies, papers etc. telling the benefits of RFID tracking for several supply chain operations, but still companies hesitate to invest in the technology. Numerous papers mention certain obstacles for RFID tracking system implementations, but there are only a few papers which concentrate on comparing and analysing different implementation challenges. To understand the reasons for the reluctance of the companies, this paper focuses on finding the reasons for the gap between the high expectations of the technology and the reality. To get a first-hand viewpoint from real life, the challenges found from the literature review are compared with the actual supply chain RFID tracking cases.

This paper is divided in the following sections: The introduction is followed by the methodology section describing the procedure of the literature data review and presenting the case studies. The third section presents the results of the literature review of obstacles and challenges in implementing RFID technology for tracking purposes, and the fourth section presents five different supply chain-wide RFID tracking implementation survey cases. The fifth section combines the findings of the literature review with the details of the cases, and finally the sixth section presents the conclusions.

2. Methodology

To illuminate the vast variety of possible different kinds of challenges for adopting RFID tracking reported in academic publications, the literature review of journal articles was conducted. The main survey method was a general search for articles published in 2010 or earlier and containing the search phrases *radio frequency identification* or *RFID* in the database called *ABI/Inform*. Over 50 000 documents were found as a result of this search. An initial step in analysing the literature found was to eliminate non-academic literature. This restricted the number of documents to 1675. The next step was to leave out articles not discussing any challenges or obstacles to RFID tracking system implementation. The challenges presented in the literature review section are taken from the remaining articles.

To summarize the literature review, 35 key articles, which present different kinds of the RFID tracking implementation challenges, are compared in the table summarizing the topics handled in the article. The table is formed by using the ideas of Webster and Watson (2002), where different concepts and literature handling these concepts, are presented in a matrix. The key articles are chosen to represent the variety of challenges for RFID tracking system implementation. Those articles, which fulfil the following two criteria, are presented in the table: (1) the article presents several issues or it concentrates on issues not presented in any other paper. (2) The article does not concentrate only on presenting the most common technological and cost-related challenges. The selection of the articles started by organizing the potential articles by date starting from the oldest, and those articles fulfilling the previous two

criteria were picked. As the number of potential articles was still rather high, even if those articles which did not fulfil the presented two criteria were omitted, those newer articles which do not present anything new compared to the older selected articles were left out from the literature review.

The author gained experience of five different RFID tracking cases during the TraSer EU research project in 2006–2009 (TraSer, 2011). In TraSer, the purpose was to introduce a software platform which could be used for tracking and tracing purposes in the supply chain. To understand the tracking and tracing requirements of the companies, the project participants arranged workshops, where the purpose was to research the possibilities to improve the visibility of the supply chains which the company belonged to. The results of these workshops were written down as tracking scenarios. Some of these scenarios were elaborated further and the author was involved in five of these elaborated scenarios where an RFID tracking technology was used. In this paper, the experiences of the cases are summarized and then analysed to get a first-hand viewpoint of the challenges occurring in RFID tracking implementation planning. This first-hand viewpoint was then analysed in order to fully understand the real cause and consequence relationships. The analysed case results are then compared with the issues found in the literature.

3. Literature review

3.1. RFID technology in tracking

RFID technology consists of two primary components – tags and readers. An RFID tag has a microchip and an antenna. The microchip stores object information (such as the serial number), while the antenna enables the microchip to transmit object information to the reader. The reader creates a magnetic field with the tag antenna, and the tag uses this magnetic field to transmit object information to the reader. An RFID system also has a third component – a computer that is used to interpret and store data, and perform required actions (Attaran, 2007).

An RFID tag can be used for the same purposes as a barcode, but an RFID tag has some extra features that traditional barcodes do not have: (i) An RFID reading does not require visual contact, (ii) the information of an RFID tag can be changed while reading, which also enables the reuse of RFID tags, (iii) several RFID tags can be read at a same time, (iv) the information capacity in RFID tags is bigger than in traditional barcodes, and (v) RFID tags are far more durable than barcodes (Wyld, 2006).

In supply chain management, RFID is mainly used for tracking and tracing purposes. Tracking systems are based on check-points that register the movements of tracked items (Loebbecke and Powell, 1998). The main function of tracking systems is that they connect physical material flow with information systems (Stefansson and Tilanus, 2001). The benefits of tracking are: real-time coordination of material flows and individual tracked items, such as merge-in-transit; providing an effective link

between physical reality and information systems, for example, improved inventory count and goods receipt transactions, improved logistics management metrics and analyses (Ala-Risku et al., 2003; Kärkkäinen & Holmström, 2002; Kärkkäinen et al., 2004).

3.2. Challenges for RFID tracking system implementation

Even though articles about RFID tracking in the supply chain field usually concentrate on explaining the solutions and opportunities of the technology for the supply chain management, most of the articles also mention the challenges and obstacles to adoption of RFID technology for this purpose. There are even articles, which concentrate on presenting certain challenges and different viewpoints around the topic or presenting a list of possible challenges or even obstacles. The rest of this subchapter discusses the challenges of RFID tracking adoption found from the literature.

3.2.1. Different standards and the insufficient technology

Deficient standards are commonly mentioned to be a problem, because globally agreed standards in RFID are a relatively new phenomenon (e.g. Ngai & Gunasekaran, 2009; Attaran, 2007). An issue somewhat related to standards is the differing frequencies which are used around the world (e.g. Wu et al., 2006; Moon & Ngai, 2008). Another technological challenge often mentioned is a tag reading problem. The poor reading can be caused by radio wave-absorbing materials (e.g. metal or water) around or under the tags (e.g. Li et al., 2006). The other reasons for poor reading can be the wrong position of antennas relative to the direction of the reader, or radio transmitting collisions caused by too many RFID tags, or just the varying quality of tags (e.g. Asif & Mandiviwalla, 2005).

3.2.2. Cost of the technology and technology adoption

The cost of the technology is also commonly mentioned as a major problem concerning RFID technology adoption. The cost of the tags is the most obvious expense, and even if the cost of RFID tags is decreasing all the time, the price is still at least 0.05–0.1 euro apiece (Bottani & Rizzi, 2008; RFID Journal, 2011). Also attaching the RFID tag might need special arrangements, which increases the cost directly related to tags (Brown & Russel 2007; Vijayaraman & Osyk, 2006; Li et al., 2006). However, before an RFID tracking system is implemented, there are also many other expenditure types. An RFID tracking system requires also other hardware than tags (e.g. readers, and RFID-enabled forklifts, conveyor belts and sorting machines). Software adjustment is usually needed when integrating RFID tracking system to the existing enterprise resource planning (ERP) and other systems even if most of the current systems on the market already have RFID connection capability. In addition to the system integration requirements, the amount of data that information systems handle increases significantly when RFID tracking is in use (e.g. Li et al., 2006; Ngai & Gunasekaran, 2009). Even if the magnitude of this challenge has recently been

questioned (Ilic et al., 2010), this data processing may need additional investments in software, hardware and telecommunications. Implementation also requires the resources of technology experts, as well as resources for training of current employers to use the system and perhaps even for other new tasks, when the old duties are changed as a result of RFID-enabled automation (e.g. Asif & Mandiviwalla, 2005).

The different cost factors cause uncertainties when estimating the exact costs of RFID tracking adoption. As there are also doubts about the exact benefits that the transition to the RFID technology offers, several authors point out the difficulties of evaluating the usefulness of RFID tracking investment compared to the other potential development possibilities (e.g. Visich et al., 2009). The combination of the high implementation costs, along with unsecure payback time or conjectural return on investment (ROI) calculations, can also pose financing problems especially for smaller companies (e.g. Ngai & Gunasekaran, 2009; Pedroso et al., 2009). Li et al., (2010) also point out the worry of some companies that maintaining the RFID system can become too expensive. If the maintaining costs are considerable, simple ROI calculations are not enough for estimating the total economic effects of RFID implementation.

3.2.3. Ethics and privacy

Numerous articles concentrate on discussing the ethics and privacy questions related to the RFID technology (Visich et al., 2009). Some companies are afraid of the negative reaction of the consumers and consumers' organizations when implementing RFID technology for tracking purposes. One example of the power of public opinion is Benetton's RFID trial in 2003. The company ordered 15 million RFID tags for item-level tracking of pullovers, but the company never executed the pilot because the consumers started to boycott Benetton's stores, the customers being concerned about loss of privacy (Blanchard, 2003; McGinty, 2004).

3.2.4. Security and data sharing problems

A slightly related issue with privacy is the concern for security. If the tags contain considerable information about the product handling history, the other supply chain partners may obtain confidential information about competitors' supply chain practices, such as shares of different suppliers and delivery time of the product (Santos & Smith, 2007). In theory, it is possible that some outsider could break the code and read the information of the tag by using its own RFID reader and without authorized physical access to the item (Asif & Mandiviwalla, 2005). Another more severe fear is that someone could change the information of the RFID tag by using their own RFID reader (Li et al., 2006). To work effectively, a supply chain-wide RFID tracking system requires information sharing, which creates an indirect security concern when the companies might hesitate to share with other companies all the information needed to obtain the full benefits of supply chain visibility. But even if companies are willing to share all the information obtained by RFID-readers, Asif & Mandiviwalla (2005) also point out the reverse problem that too much information causes problems for the

information systems' handling and storing capacity, especially if the companies have not agreed common procedures to restrict the amount of data.

3.2.5. Decisions related to the RFID tracking adoption

Some authors highlight the common decisions included in RFID adoption as challenges. There are numerous possible alternatives to implementing RFID tracking in the companies and supply chains, but discovering the actual business case might be difficult (e.g. Attaran, 2007; Curtin et al., 2007). Regarding the variety of available technologies and the lack of standards, the selection of the technology provider is very important (e.g. Wu et al., 2006). Dozens of different manufacturers produce RFID tags, which are perhaps not compatible with competitors' tags. Also different reader manufacturers are used to build equipment, which may be compatible with only a single manufacturer's tags. Also patents can cause problems (Ngai and Gunasekaran, 2009; Wu et al., 2007). Therefore changing the technology supplier later could become rather expensive, if the company realizes that it has made a misguided decision. Another decision needed when planning an RFID system is the level of tagging: pallet, case or item-level (e.g. Bottani & Rizzi, 2008; Bradley & Guerrero, 2010). Partly as a result of expertise needed to decide between these technological alternatives, some authors consider generally the complexity of RFID technology to be an adoption obstacle (e.g. Brown & Russel, 2007; Russel et al., 2009). The uncertainty and lack of published research data about the effects of radio waves, e.g. to pharmaceutical products, could also be considered as a technology complexity problem (Matalka et al., 2010).

3.2.6. Organizational issues related to the RFID tracking adoption

Some authors point out the different roles in an organization as a challenge. As an extensive RFID tracking system is a big investment and requires changes inside organizations, considerable management commitment to system adoption is necessary (e.g. Lim & Koh, 2009; Brown & Russel, 2007). Asif & Mandiviwalla (2005) also point out that the biggest potential benefits of RFID tracking come when supply chain concepts are combined with customer strategies. Therefore they emphasize the involvement of marketing people in RFID system development, because supply chain management experts tend to concentrate on cost saving issues while marketing people attempt to find added value for a customer. However, combining marketing and supply chain management strategies is challenging. (Asif & Mandiviwalla 2005)

3.2.7. Inter-organizational issues related to the RFID tracking adoption

If the products are RFID tracked through all the supply chain, the tag should be attached at the earliest phase possible in the supply chain. This setting poses problems, as the common understanding is that it is the retailers who will get the biggest benefits when introducing an RFID tracking system (e.g. Vijayaraman & Osyk, 2006; Soon & Gutiérrez, 2008). Therefore the product manufacturers may

not be willing to pay the largest single cost of the system – the tags – while those downstream in the supply chain would get the biggest benefit (Dutta et al., 2007). This situation can advance to the free-rider problem (Whang, 2010), when the companies downstream in the supply chain wait for the RFID tracking decisions of upstream companies before planning their own tracking system, since joining the tracking system when a company upstream attaches RFID tags is cheaper if those downstream can use the existing tags attached by upstream supply chain members. After following the development of Wal-Mart's RFID system implementation, several authors also believe that RFID technology adoption will increase the power of large retailers relative to suppliers and smaller retailers (e.g. Soon & Gutiérrez, 2008; Rutner et al., 2004). Bradley & Guerrero (2010) suggest a similar example related to the U.S. pharmaceutical industry, where smaller secondary wholesalers may encounter huge problems if their larger competitors refuse to share electronic pedigree data related to RFID technology, or charge exorbitant fees for this data. Curtin et al., (2007) proposes that RFID tracking system adoption will lead to a situation that smaller companies have either to adopt the RFID tracking system or to lose out. This situation also increases resource dependences between supply chain companies (Cannon et al., 2008). Cannon et al., (2008) also evaluate the adoption of RFID technology through transaction cost economics theory, and propose that the threshold to adopt RFID tracking in a supply chain level is high, because the risks and uncertainty included in the adoption are great.

3.2.8. Dual tracking systems

RFID tracking is estimated to replace the old tracking systems in the long run. However, the barcode, which is the most common tracking technology used at the moment, cannot be replaced by RFID at once. This problem of dual tracking system situations is described in many articles (e.g. Ngai & Gunasekaran, 2009; Ross et al., 2009).

3.2.9. Lack of the information about existing RFID tracking implementations

Visich et al., (2009) pointed out that the information about the existing RFID tracking implementations is confusing. Technology providers usually have signed non-disclosure agreements with their customers, thereby preventing them from discussing these implementations. Lee & Özer (2007) highlight the fact that the best-known papers and reports about the benefits of RFID tracking have been written by technology consultants and other experts representing organizations which gain when RFID technology adoption increases. Therefore the information about unrealistically grand expectations of RFID tracking potential, combined with the lack of quantitative data from real cases, frustrates the executives who are responsible for decisions for implementation of RFID tracking (Lee & Özer, 2007; Visich et al., 2009).

3.3. Summary of the RFID tracking implementation challenges

In the reviewed articles, the viewpoint and the target group of the journal seem to have an effect on the topics considered as challenges or obstacles and the way they are classified. Different obstacles and challenges are also interrelated. For example most of the technological problems can be solved by purchasing more expensive technology and using the help of outside experts. Also the need for reorganizing the business processes to better exploit the possibilities of RFID tracking can be seen either as a cost problem or a question of management's capability for understanding the strategic opportunities of improved tracking.

The Fig. 1 summarizes the main challenges of RFID tracking adoption found from the literature, and presents which of the articles handle the challenge. In that figure, the challenges have been divided into the same main categories as the headlines in the subsection 3.2. To get a wider view for the challenges, most of the categories have been divided into subcategories presenting the different aspects of the challenge.

	2010	2010	2010	2010	2010	2009	2009	2009	2009	2009	2008	2008	2008	2008	2008	2007	2007	2007	2007	2007	2007	2007	2006	2006	2006	2005	2005	2005	2005	2005	2004	2004	2003	2003
	Bradley and Guerrero	Li et al.	Matalka et al.	Neat et al.	Srivastava	Neat and Gunasekaran	Ross et al.	Pedroso et al.	Lim and Koh	Visich et al.	Chuang et al. Shaw	Soon and Gutiérrez	Bottani and Rizzi	Cannon et al.	Rundh	Curtin et al.	Attaran	Fish and Forrest	Brown and Russel	Delen et al.	Dutta et al.	Pillsson	Visscroman and Osyk	Wu et al.	Li et al.	Jones, M. et al.	Ameles	Asif and Mandviwalla	Twist	Jones, P. et al.	Lai et al.	Runner et al.	Wilding and Delgado	Kärkkäinen	McFarlane and Sheffi
1. Different standards and the insufficient technology																																		
Lack of Standards or different frequencies	X	X	X			X	X	X				X			X	X	X	X	X		X		X	X	X	X	X	X	X	X		X	X	
Tag reading problems or unreliable tags	X	X	X			X	X				X		X			X	X	X		X		X		X	X			X	X	X			X	
2. Cost of the technology and technology adoption																																		
Tag costs	X			X			X	X				X	X	X		X		X	X	X			X	X	X	X	X			X	X	X		X	
Tagging cost																			X				X		X									
Data Management	X	X			X	X	X					X	X				X		X	X			X		X			X	X	X	X		X	X	
Technology / hardware	X				X							X	X						X				X		X	X	X	X	X		X			
Software	X			X	X														X						X	X	X	X	X		X			
System integration	X	X		X	X							X					X		X				X		X	X	X	X	X	X		X		
Implementation (support, training, reorganization)				X	X	X	X		X			X					X		X		X		X	X	X			X	X	X	X			
Operational automation						X																									X			
Cost/benefits (poor ROI or unknown costs)	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X			X			X	X	X		X		X	X		X	X	
High capital costs and financing problems		X	X			X		X							X		X																	
3. Ethics and privacy																																		
Ethics and privacy	X	X	X			X					X		X			X			X				X			X			X	X	X	X	X		
4. Security and data sharing problems																																		
Security and data sharing problems	X	X	X			X					X								X		X	X			X				X	X		X			X
Information sharing and channel alignment																											X							
5. Decisions related to the adoption																																		
Difficult to develop the business case		X						X							X	X	X		X					X			X				X			
Choosing the right technology and provider					X	X										X								X		X								
Patents						X																		X										
Tagging strategy (pallet, case or item level)	X												X					X	X									X						
Complexity of technology or lack of knowledge		X	X					X	X									X										X					X	
Decision makers' uncertainty																X																		
6. Organizational issues related to the adoption																																		
Management commitment		X		X		X		X	X									X																
Different goals of SCM and marketing																												X						
7. Inter-organizational issues related to the adoption																																		
Increased power of large retailers / competitors	X											X				X									X						X		
Cost sharing mechanism (Free-rider problem)											X	X								X	X								X				X	X
Hook-up-or-lose-out proposition	X															X																		
Resource dependence														X																				
Transaction cost economics														X																				
8. Dual tracking systems																																		
Dual systems (both bar code and RFID needed)						X	X																X	X	X			X						
9. Lack of information about existing implementations																																		
Lack of information about existing implementations										X																								

Fig. 1. Summary of the challenges of RFID tracking adoption that different authors have discussed in their paper.

In most of the articles reviewed, the challenges have been presented similarly to Fig. 1, without trying to combine them into broader subcategories. Attaran (2007) has created one kind of categorization by dividing different challenges into (i) fundamental, (ii) technical and (iii) organizational. In his article, 'fundamental' includes the problems of high capital costs, deficient standards and the difficulty of finding a business case where good ROI can be found in advance of implementation. 'Technical' stands for cost and performance of hardware, software and information systems. 'Organizational' stands for the integration of the RFID tracking system into the other information systems and company practices, such as supply chain management, customer relationship management and enterprise resource planning (Attaran, 2007).

Ngai & Gunasekaran (2009) divide different obstacles into 'issues' and 'challenges' which face RFID tracking adoption. In their article, the issues are (i) the problem of a globally interoperable standardization, (ii) the environment, (iii) security and privacy, (iv) data management, (v) the rate of tag failure, (vi) quality assurance, and (vii) RFID expertise for deployment. They present 'challenges' including (i) management commitment, (ii) dual systems, (iii) cost challenges, (iv) legal and patent challenges, (v) operational automation, (vi) the selection of hardware and software, and (vii) technology support for adoption.

Asif & Mandiviwalla (2005) list ten different challenges and write in the introduction of their article about business, technical and strategic challenges, but they do not tell which of these categories each of the listed challenges belongs to.

After an extensive literature review of RFID related articles, Ngai et al., (2008) noticed that about 80% of the RFID articles concentrate on RFID tag and antenna technology. They explain the discovery that the cost and the performance of the tags play such an important role in the RFID tracking system as a whole that many other issues are given only minor consideration. They conclude that in the future, when the technological problems are solved, the research can consider the business value of the technology and its impact on the inter-organizational relationships of companies. They also predict that the literature will concentrate more on the technologies' value for the whole value chain instead of concentrating on single company's operations. (Ngai et al., 2008) Therefore, in order to better take into the consideration the possible business challenges related to the adoption of RFID tracking, special attention needs to be paid to those articles which present other challenges than those that are purely technological or related to the cost of the technology.

4. RFID cases

The purpose of the TraSer project was to develop a software platform that would enable supply chain-wide tracking (Hinkka et al., 2009). In addition to the project participants' own tracking pilots, there was an attempt to get also users outside the original project consortium to test the software. Therefore the project participants presented tracking possibilities to several potential user companies, and started to

cooperate and research the prerequisites for supply chain-wide tracking systems with those companies interested in the TraSer software and tracking. Even if the tracking technology used did vary, depending on the supply chain case, RFID was selected as a target technology in five different cases. There was a large survey of the effects of RFID tracking for all of these case supply chains and three of these cases also included pilot installations. These cases offer real life understanding of the challenges in adopting supply chain-wide RFID tracking.

The first case was the survey for the Finnish Grocery Trade Association. The purpose of the survey was to define the costs and the benefits for the Finnish grocery trade of adopting RFID tracking. The second case was the survey for Finnish printing industry supply chain. In this case the purpose was to research the possibilities for introducing item-level tracking for the printed books by attaching an RFID tag already in the printing house for all the books published for Finnish markets. This survey included also laboratory tests, where the purpose was to research the performance of different available RFID tags and readers developed especially for the book retailing sector. The third case was hospital supplies tracking. The purpose of this case was to develop an RFID tracking solution which would offer continuous tracking of essential hospital equipment and supplies. This case included also two different pilots where two totally different technical solutions were tested and compared. The fourth case was a roll cage tracking pilot installation executed by a big logistics service provider (LSP) company. The purpose in this case was to decrease the shrinkage of roll cages by using RFID tracking. The fifth case continued the LSP's research and development work of an existing pilot installation, which was carried out together with one of its fashion company customers. The purpose of that case study was to design a configurable RFID tracking solution, which could fulfil the requirements of different types of fashion company customers. The presented cases are summarized in Table 1.

Although the results and the success of these cases varied considerably, the inside experiences of these cases helped to identify several obstacles which would hinder progression in the RFID tracking system design and implementation. In these cases the perceived obstacles postponed the leap to the next phase of the implementation plan for a shorter or longer time.

Hardware technology requirements were a challenge in two cases. The deficiencies of RFID tag and reader technology were a serious problem in the hospital equipment case, where the used technological solution was based on active tags, which offered continuous location information. The problem occurred when the power of the readers was taken off, which simulates the situation that the active tag cannot reach the reader. In that situation the active tags very quickly consumed their batteries. In the roll cage tracking pilot, the design and material of roll cages caused problems at first, but these problems were overcome through cooperation with the RFID tag provider.

The functionality of the software was an issue in several cases. Introducing item-level tracking increases the information handled in the system, which in several cases required in addition to more powerful computers also some development of the software structure. Especially in the hospital equipment case, where the system received

Table 1
The summary of RFID tracking cases executed in TraSer EU research project

Supply chain case	Short description	Technology testing
Grocery	Research the possibilities for the Finnish grocery trade to adopt RFID technology	No
Book	Introduce item-level RFID tagging from the printing houses to the retail stores	Functionality tests of tags and readers
Hospital equipment	Develop an RFID solution, which would offer continuous tracking of essential hospital equipment and supplies	Two different pilot installations
Roll cage tracking	To track roll cages handled by LSP in order to decrease shrinkage	Pilot installation
Clothes	To develop different item-level RFID tracking solutions for the fashion industry	Pilot installation

location information of the tagged equipment all the time, handling location information sometimes took too much time, which in production use would mean that the system suggested a place where the equipment was e.g. 20 seconds ago. It also seemed that the companies are rather hesitant when it comes to a question about making major improvements to their existing software systems, because the managers either have bad experiences of the software projects or they have heard stories about ERP updates where the deadlines have overrun and cost estimations been insufficient.

The attitude towards the money and investments that RFID technology implementation requires varied. In all these cases, the companies received public support for the survey and the pilot so that their own share was a maximum 50% of the total costs. Some companies were ready to invest considerable sums of money in RFID surveys and pilots, while for some companies even a contribution of a few thousand euro was too big.

It seemed that the question of money in these cases was a reflection of the management's understanding about the importance of RFID tracking for their company. As the companies have several on-going development projects and plans, managers need to somehow rank the possible development projects and decide the number of the realizable projects. In the grocery and book supply chain cases, some companies' management's low valuation of the RFID tracking project was witnessed in their unwillingness to participate in project meetings.

There were also inter-organizational problems, which troubled the negotiations about the system development. The power balance between a retailer and its suppliers seemed to be rather sensitive in the cases followed. Even if the position in the supply

chain of the main initiator varied case by case, the balance of power caused a problem anyway. In two cases, where the retailers actively supported the research project, the suppliers withdrew from the project because they were afraid of becoming the payer for the proposed tracking system. In another case, the LSP was an initiator for the development efforts. The LSP suggested that they would make investments to the technology, and the retailers could pay LSP for this service if the technology offered savings for the customer users. However, in that case the retailers hesitated to continue the project in that form, because they were afraid of losing market power to the LSP. Instead they wanted at first to study their own options for building and controlling an RFID tracking system.

5. Analysis of the challenges

Numerous possible obstacles and challenges for adopting RFID tracking system were mentioned in the literature review section. When discussing the relevance of these challenges for a certain proposed system, it is useful to define the objectives of the system in question. Visich et al. (2009) have created a framework where the benefits of the RFID tracking systems have been divided by their association with either operational or managerial processes. They found that most of the reported benefits are operational, which indicates that the current RFID tracking systems are implemented mainly as a limited stage in a supply chain, and the system is used to automate certain tasks (Visich et al., 2009). If the target for a proposed RFID tracking system is to improve the performance of one supply chain activity, the relevant challenges for that kind of system are more limited compared to the system which is planned to have an effect on the whole supply chain. Pålsson (2007) handles this topic by writing about closed-loop and open tracking systems. He brings out the point that open systems have more technological and cost-related challenges than closed-loop systems. He also highlights the inter-organizational barriers which are specific challenges that an RFID tracking system implementation faces, if the system will be used by several actors (Pålsson, 2007). The conclusion based on these ideas is that the challenges vary at different levels of the supply chain-wide RFID tracking system – some common challenges belong to the whole supply chain, while others may be more company or certain operation specific.

Attaran (2007), and Ngai & Gunasekaran (2009) highlight the fact that some challenges are so fundamental that they become obstacles for adopting RFID tracking if they are not solved, while other challenges only decrease the benefits of the planned system. However, regarding the experiences of actual supply chain cases in the TraSer project, dividing challenges into more or less important is problematic. For example, technology providers may be willing to use their resources to be the first to solve their customers' technical problems, which Attaran (2007) designated as being fundamental. Alternatively, an inter-organizational challenge which may sound rather easy to solve by inter-company negotiation might become an insuperable obstacle. This obstacle might be a reflection of some other reasons why companies are not

willing to make any kind of agreement which would satisfy all the partners. Ngai et al. (2008) speak out on this topic by stating that when technological issues can be solved in the near future, more attention should be paid to business and inter-organizational issues.

The common view considering the benefits of RFID tracking is that the wider the RFID technology used, the bigger are the benefits (Spekman & Sweeney, 2006; Wyld, 2006). In this context, RFID technology is usually compared with barcodes, which are commonly used in all kinds of supply chains; without common standards and widely spread use, the benefits would be small compared to the benefits of current supply chain-wide use. Still, the adoption of RFID tracking usually starts from applications which improve only certain operations (Visich et al., 2009). However, as seen during the past ten years, when RFID tracking implementations have spread, this approach seldom leads to supply chain-wide RFID tracking implementations. Wal-Mart's initiative started by forcing its suppliers to attach pallet tags and later tags to cases, but has not yet led to supply chain-wide use of item-level RFID tracking as planned. Therefore, one problem considering the adoption of supply chain-wide RFID tracking systems seems to be that the aims of tracking and obstacles are discussed in the wrong context. As in those TraSer cases, where the problems culminate in inter-organizational challenges, the companies tend to focus on their own premises and details concerning their own operations, when the purpose was to discuss the benefits that improved tracking would bring to the whole supply chain.

To analyse in the right context those different challenges presented in section 3, the author proposes the framework presented in Table 2. The idea of the framework is that different challenges for implementing RFID tracking are relevant at different levels of supply chains. The task specific issues should be handled at the operational level, while managerial issues should be handled at the company level. The issues where several members of supply chains are involved should be mainly handled at the supply chain level, although the companies make the final decisions themselves. The actual classification of the challenges is done by considering the effect of the issue. If the same issue is topical for all supply chain members, it needs to be discussed at the supply chain level. Company specific issues can be dropped to the company level and some task specific issues to the operation level. For most of the challenges, there is a certain level where that problem should be handled. However, some challenges have different aspects at two or all three levels and therefore they have to be handled at several levels.

6. Conclusions

The reasons why promising ideas and plans for RFID tracking system implementations remain unrealized seem to vary case by case. The literature review and Fig. 1 indicate that the technological problems and cost of the technology are the most often mentioned challenges. This is somehow understandable, because RFID technology is still constrained in some environments and so the final costs can be bigger

Table 2
Different challenges of implementing RFID technology for tracking purposes in the supply chain divided by the level where these issues should be handled

	Operation	Company	Supply chain
Challenges relevant for all levels	Developing the business case	Developing the business case	Developing the business case
	Complexity of technology	Complexity of technology	Complexity of technology
	Lack of information about existing systems	Lack of information about existing systems	Lack of information about existing systems
Challenges relevant for two levels	Operational automation	Operational automation security	Security
Challenges relevant for one level	Tag reading problems	Software	Standards
		System integration	Tag design
		Implementation issues	Costs
		Management commitment	Patents
		Ethics and privacy	Different goal of SCM and marketing
			Increased power of large retailers
			Resource dependence
			Cost sharing mechanism
			Tagging strategy
			Dual systems
			Choosing the right technology
			Information sharing

or smaller. However, an increasing number of recent articles discuss cost issues in the form of inter-organizational and business challenges for RFID tracking system implementation. In the RFID tracking implementation case studies, it seemed that the question about the division of the costs and the benefits was the most difficult problem to be solved. The research phase itself already requires resources. If the successfully conducted project will lead to RFID tracking system deployment where some of the participants companies may think they are likely to be the payer of the system or otherwise lose their power in the supply chain, then it is difficult to motivate these companies to support the RFID tracking research and implementation projects. Therefore the problem is no more whether RFID tracking will work properly with affordable costs, but how to implement the technology without disturbing the dynamics of the current supply chain too much. This problem was especially recognized in the arrangements of the fourth case: instead of trying to improve the visibility of

the customers' products that the company handles, the LSP prefers to track the assets where the products are carried, because roll cage tracking can be realized without involvement of other companies in the supply chain.

One problem in designing and implementing supply chain-wide RFID tracking systems seems to be that the targets and realization of RFID tracking systems are not aligned. The companies may consider RFID tracking as a technology which improves the management of the whole supply chain, but still they concentrate on the operational benefits of the technology for some specific tasks in the supply chain. The same applies for the challenges of the RFID tracking implementation. By analysing the challenges at the level where the issues should be handled, different actors have the chance to concentrate on the challenges relevant to them. The supply chain level covers the main technical decisions, the evaluation of costs and the benefits, their realistic separation and other inter-organizational issues. For a company level, the main challenge is to implement the system and integrate it to become a part of the processes of the company. However, it is up to the company's management to commit to the RFID tracking development project. It is also important that the ethics and privacy questions should be handled mainly at the company level, because different supply chain members are perhaps working in different market areas and have different public images depending on their position in the supply chain. As a consequence companies will suffer differentially from any poor decisions regarding ethical questions. The challenge at the operational level is to ensure that the operation works as planned and tags are read correctly. The common challenges at every level are that the technology can be used correctly and the right business cases for every level are found. Also up-to-date information about the existing systems would help the implementation process.

Future research in this area could focus on defining the importance of different challenges and try to improve classifying them as the most and the least important for different kinds of RFID tracking systems. It would also be beneficial to research how the RFID technology development has affected the importance of different challenges. However, the most important area for future research is still to find good solutions for the challenges presented in this paper.

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