# RFID TECHNOLOGY INTRODUCTION AND IMPACTS ON SUPPLY CHAIN MANAGEMENT SYSTEMS

By

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# Abstract

Today's dynamic and competitive business environment puts an ever increasing pressure on companies to innovate, redesign processes, and leverage the potential of partnerships along the supply chain.

One of the technologies offering a solution is Radio Frequency Identification (RFID). RFID can be used to automate and thus streamline identification processes, which means that more checkpoints along the supply chain can be established at decreased costs. But additionally, the technology can provide further benefits which make it superior to the currently widespread automatic identification (Auto-ID) technology of the barcode. However, as RFID is only a way to collect the data at the lowest level, the technology must be integrated with the supply chain management systems of the companies. Also, the various information systems along the supply chain must be integrated to allow for exchange and in order to give a meaning to the data.

Even though RFID technology has initially been developed decades ago, the use of RFID in large-scale supply chain operations has until now been prohibited due to the relatively high costs compared to other Auto-ID solutions. Recent studies on the integration issues of the technology reveal that there are still several technical, as well as rather political, barriers to be solved before widespread RFID deployment in supply chain operations can take place.

Therefore, this dissertation deals with RFID technology introduction and impacts on supply chain management systems in order to give an insight into the current issues and status of the technology. It examines five RFID projects carried out by companies operating in different industries. The presentation and discussion of the results will help to better understand what RFID can deliver, what deficiencies companies reveal and where its application in supply chain operations is sensible and likely to occur.

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# Abbreviations

| | |
|---|---|
| APS | Advanced planning system |
| ATP | Available to promise |
| BOM | Bill of materials |
| CPFR | Collaborative Planning, Forecasting and Replenishment |
| DESADV | Despatch advice |
| EAN | European Article Numbering |
| EPC | Electronic Product Code |
| ERP | Enterprise Resource Planning |
| GHz | gigahertz |
| GTAG | Global Tag |
| IC | Integrated Circuit |
| IFF | Identification, friend or foe |
| ITU | International Telecommunication Union |
| kHz | kilohertz |
| MES | Manufacturing Execution System |
| MHz | megahertz |
| MPS | Master Production Schedule |
| MRP | Material Requirement Planning |
| MRP II | Manufacturing Resource Planning |
| ONS | Object name service |
| PML | Physical Mark-up Language |
| RFID | Radio Frequency Identification |
| SCM | Supply Chain Management |
| UCC | Uniform Code Council |
| VICS | Voluntary Interindustry Commerce Standards |
| WORM | Write once read many times |
| XML | eXtensible Mark-up Language |

# 1. Introduction

## *1.1. Scope and objectives of this dissertation*

Even though radio frequency identification (RFID) as a technology was developed during the 1940s, the first industry uses were occurring during the 1980s in tracking and access applications. Due to the relatively high costs of the RFID tags (> 50 US cents per tag) compared to widely used bar codes, the use of the technology was rather limited. Additionally, there was no unified standard, which resulted in incompatible vendor specific solutions. However, recent industry initiatives, e.g. by the world's biggest retail company WalMart, USA resulted in decreased production prices (~ 20 US cent per tag in orders of 1 million) and due to learning curve effects they are likely to decrease further. Thus, the use of RFID in supply chain operations becomes more attractive.

The market research firm IDC (Rockwell Automation, 2004) projects the spending on RFID in the US retail supply chain companies to exceed one billion US$ by 2007 (see appendix for an illustration). The increased use of this technology will have impacts on the supply management systems which must be accommodated to the new possibilities offered. New possibilities of RFID compared to the use of bar code systems include the automation of the scanning processes, the possibility to track location of items, and the storage, transmission, and use of more data about the item than just an identification number, e.g. temperature history, best-before-date.

As can be seen by the results of the EPC Forum Survey conducted by IBM business consulting services the majority of the participants plan to integrate RFID solutions with existing systems (Gramling, Bigornia, & Gilliam, 2003). With RFID the emergence of more data and the real time use of such data have impacts on the existing supply chain management systems. This dissertation examines the impacts of RFID introduction on supply chain management (SCM) systems by trying to answer the following research questions:

- How is RFID technology currently used in supply chain operations?
- How are supply chain management systems impacted by this use?

## *1.2. Structure of this study*

The study is organized in two main parts, namely the first part which introduces the theoretical foundation drawing on secondary sources and the second part which contains case studies derived from empirical research.

The first part of this study commences with an introductory chapter providing an overview of the topic and this study. This is followed by an explanation and justification of the research method deployed. The third chapter gives an overview of SCM systems by explaining and justifying their emergence over time. An introduction to RFID technology, its history, components of a RFID system, differentiation features and standards precedes an investigation of the SAP Auto-ID infrastructure (AII), a solution for the integration of RFID technology with existing enterprise systems.

In the beginning of the second part of the study, examined cases of RFID pilot schemes within a supply chain context are first introduced and then analysed before the findings are discussed. Finally, conclusions are drawn.

## *1.3. Literature review*

In order to answer the above stated research questions, literature from the field of information systems in supply chain management as well as RFID-specific literature provide the basis which must be considered. Nevertheless, despite the topic's only recent popularity, there is already academic literature available which is also regarded in the light of this study.

According to Bowersox and Daugherty (1995) and Currie (1993), benefits of supply chain management can be reached by the use of "information technology and the construction of integrated supply chain information systems" (Narasimhan & Kim, 2001). Concerning the use of information systems (IS) to integrate business processes across the supply chain, various studies have shown that an internal integration should precede the external integration with suppliers and customers

(Narasimhan & Kim, 2001; Bowersox, 1989; Byrne & Markham, 1991; Hewitt, 1994).

Edwards, Peters, and Sharman (2001) found that among the companies which they researched, the ones exploiting technology to integrate trading partners and redesign business models were more successful than others.

Stadtler (2002) introduces the “House of SCM” in which the coordination of information in the supply chain is one of the building blocks. He states that information and communication technology is essential to efficiently automate processes and coordinate information flows along the supply chain.

Schlegel and Smith (2005) argue that technology is a key for the success of SCM systems and indicate that the successful supply chain integration positively influences the companies’ stock market performance. Nevertheless, they state that all projects which aim at enhancing the supply chain performance must be understood as part of the larger initiative of supply chain integration. Therefore, they introduce a model of the “Dynamic On-Demand Supply Chain” which among two other principles is based on technology integration.

An overview of the historical developments in supply chain management systems is given by Busch, Dangelmaier, Pape, and Rüther (2003). They outline the evolution of planning systems from the beginnings in the 1960s with the concept of Material Requirements Planning (MRP) and explain the development towards Enterprise Resource Planning (ERP) systems which are based mainly on the concept of Manufacturing Resource Planning (MRP II). Furthermore they introduce current functionalities and particularities of Advanced Planning and Scheduling (APS) systems and how these systems can be extended to collaborative supply chain management systems. Finally, they present the results of a market survey.

Gronau (2004) also describes the evolution of supply chain management systems. He bases the rational for APS systems and the coordination of information along the supply chain on the positive effects on the “bullwhip effect” which will be explained in chapter 3 of this dissertation.

Whereas Busch et al. (2002) and Gronau (2004) maintain a vendor-independent view, Mehlich (2005) demonstrates the latest developments in supply chain management systems on the basis of the mySAP SCM solution offered by SAP. She presents problems which often occur during integration of new SCM system modules and then gives recommendations on how to overcome these. Moreover, she points out certain limitations of mySAP SCM, for instance that a focus on specific industries is not yet realised and that for some customer requirements the computing power is not sufficient.

Finkenzeller (2003) gives a general introduction to RFID as an automated ID technology as well as sample applications such as Container Identification for the chemicals industry or in waste disposal and tool identification in industrial automation.

Hodges and Harrison (2003) provide an overview of the RFID components used in the EPC architecture framework of the Auto-ID Center. They cover the physics, different types of systems, and the standardisation issues at the time of writing (which are outdated by now).

The RFID technology used in supply chain operations is described by Sarma (2002). He not only illustrates the physical and technical principals but also outlines how current production techniques can be developed in order to produce transponders at very low costs (at around 5 US cents).

Sheffi (2004) states the RFID systems typically consist of the following four elements:

1. a unique standard identification number assigned to a particular item,
2. low cost identity tag which is attached to the item,
3. networked RFID readers and data processing systems, and
4. networked data bases that store the information and enable information exchange.

Also, McFarlane and Sheffi (2003) list advantages of RFID systems over barcode systems in supply chain operations (pp. 4-5):

- Speed – many tags can be read simultaneously into a computer, rather than reading a single tag at a time.
- The content of various conveyances (such as trailers, cases, pallets, shopping carts) can be read automatically without opening and sorting the conveyance.
- Bar codes do not work well when exposed to weather elements, when dirty, or if damaged in a way that interferes with clear line-of-sight reading.
- Location – RFID readers can provide rough location information, particularly when the goods being scanned are moving relative to the reader.

By outlining a generic supply chain building block, they evaluate potential impact on supply chain operations. From the results they propose both short-term deployment and opportunities for re-engineering of supply chain processes with the use of RFID as automatic identification technology.

Regarding the benefits of RFID systems, Kambil and Brooks (2002) expect that early implementations will be likely to only hold proprietary benefits whereas the full potential lies in the collaborative use of open systems and applications.

Heinrich (2005) states that RFID systems will improve flows in supply chains. But he points out that the benefits are heavily dependent on the system integration and how the automatically collected data is used by the supply chain management systems. Furthermore he finds that before implementing RFID technology, a company must be aware of its business goals and then should map RFID technology onto these goals. To facilitate implementation success, top management commitment as well as a clearly defined scope are suggested.

As RFID technology introductions bear risks that the companies must be aware of, Kopalchick III and Monk (2005) identify four domains of risk, namely engineering/technical risks, business environment risks, process risks, and technology risks. With the intention of helping companies to anticipate these risks, they provide the following questions, an internal auditor of an RFID project should consider (p. 72):

- Have key business environment risks been identified in the organization's decision to implement RFID, including payback, supply chain capability, and customer capability?
- Have key risks regarding network security been identified?
- Have risks regarding data management and integrity been identified?
- Are organizational culture and change management risks understood and addressed effectively?
- Have business processes been identified and positioned for backup or exception process purposes?
- Will additional financial controls need to be in place for processing transactions directly to ledgers from networks or tags?
- Are current business processes mapped and understood prior to implementing any changes made possible by RFID?

Angeles (2005) presents cases of RFID applications and information which support the adoption of RFID rechnology. She states that RFID enables supply chain visibility but also states that further research should be undertaken to evaluate if the technology lives up to the high expectations and find out which factors make implementation strategies effective.

Because RFID provides benefits in logistics operations, impacts on supply chain facilities such as warehouses are foreseeable. Twist (2004) describes how the technology impacts facility operations and concludes that especially cross-docking warehouses will gain significance as products spend less time on shelves and loading and unloading processes are optimised.

As RFID technology might interfere with privacy rights of end customers, Flint (2005) reports on current legal issues discussed by a British working party established to address EU-conforming RFID privacy guidelines. He comes to the conclusion that informed consent for now is a practicable way for RFID applicationsbut that the privacy standards in the EU are far more developed than in other parts of the world where the customers may suffer from exploitation by the companies.

In addition to the above mentioned publications, there is also relevant research of the Auto-ID lab which is a federation of research universities and is developing an open standard architecture (Auto-ID labs, 2005).

Joshi (2000), for example proposes "a framework to achieve information visibility in the supply chain using radio frequency tags, tag readers, product identification codes, an object description language, and the internet". By evaluating the supply chain performance with simulations of different information visibility levels and forecasting functions, he proves that information sharing and information visibility increase supply chain performance and reduce costs across the entire supply chain. Based on these facts he then develops the RFID Auto-ID solution which can provide the necessary information visibility. Joshi's research represents a forerunner of the EPCGlobal Architecture framework which consists of several technologies around RFID Auto-ID solutions. The different parts of the EPCGlobal Architecture Framework have been developed initially by the members of the Auto-ID Center.

Brock (2001) describes the naming scheme for the individual identification of items along the supply chain, called Electronic Product Code, in 64 and 96 bit versions. Engels (2003), however, finds that these formats hold practical limitations and thus presents a 256 bit version of the Electronic Product Code which allows far greater numbers of "objects, services, assemblies, and groupings that may be uniquely identified" (p.1).

Because the EPC only contains the identification number of an item, the object name service (ONS) is used to connect the item with the corresponding information. The ONS "provides a lookup service to translate an EPC™ number into an internet address where the data can be accessed" (Harrison, Moran, Brusey, & McFarlane, 2003) and is described by Uo, Suzuki, Nakamura, and Murai (2004).

The actual information on an item, such as EPC-number, time stamp, barcode data or sensor data, is recorded using the Physical Markup Language (PML), which is based on XML and described by Brock, Milne, Kang, and Lewis (2001). However, they point out that the PML only records how the data is communicated. Harrison, Moran, Brusey, and McFarlane (2003) provide further information on PML server development.

Goyal (2003) introduces Savant, a hierarchical system in which lower level Savants "process, filter, and digest events" (p.4) and "To reduce network traffic, a Savant may just forward events of interest or event summaries to higher level Savants". The savants build the foundation for the exchange of data collected by the reading devices.

Regarding the problems in the standardisation for RFID applications, Edmonson (2005) reports on the current issues and attitudes of the two competing standardisation bodies, the EPCGlobal incorporation, an organisation formed by technology vendors as well as RFID-deploying companies, and the International Standards Organization (ISO). He concludes that both standardisation bodies are trying to reach a common goal but also that the users of the technology fear that the competition between the standardisation bodies may increase and ultimately result in two incompatible standards.

Gross and Lo (2003 provide the "Change Readiness Guide" for Auto-ID projects in order to assess impacts on the organisation, its processes, and employees. It provides project managers of Auto-ID projects with generic guidelines in order to assess which cross-organisational as well as cross-functional areas are impacted by Auto-ID applications. Serving as an introductory reading before RFID projects are started, the article provides useful information but the generic level prevents the expedient use in a concrete Auto-ID application which mostly contains various particularities which must be considered.

Morán, Ayub, and McFarlane (2003) examine the impacts of Auto-ID in a use-case approach in order to determine its impact on existing procedures and information systems in a retail company. They come to the conclusion that the impact on information systems is rather limited and that adoptions can be carried out incrementally as radical functionality changes are not needed “as long as early applications allow for extension and have strategic value”(p.36).

Nonetheless, the need to align the systems with the new technology is taken into account by Chang, McFarlane, Koh, Floerkmeier, and Putta (2002) who present methodologies for the integration in a manufacturing business context. Therefore, they identify three different business information systems and their integration, namely manufacturing execution systems, plant level supply chain management systems and enterprise resource planning systems. They develop example workflow cases to evaluate and show integration of the systems with Auto-ID technology. They conclude that effective use of Auto-ID data needs to be reflected in higher-level business information systems such as supply chain management and enterprise information systems which need to be modified and enhanced accordingly.

In another research paper Morán, McFarlane and Milne (2003) differentiate between process improvement use cases, business improvement use cases and Auto-ID implementation impacts with the intention of determining the impacts on business information systems. The authors conclude that “the implementation of Auto-ID requires significant modification of business information systems, which is frequently disregarded in most use cases” (p. 15). They also state that extensive research regarding integration models for Auto-ID and business information systems needs to be carried out.

Davenport and Brooks (2004) state that there are two factors which currently limit the use of RFID technology throughout supply chains, namely the price compared to bar codes and the incompatibility of RFID systems which means that companies across a supply chain cannot separately select a technology vendor. Additionally, they argue that “Software vendors must first create interfaces to access the distributed data network and will need to develop applications that can use the individual item data to its fullest potential”.

There is already an interface called Auto-ID Infrastructure “that integrates RFID technology with existing SAP logistics systems and delivers a generic infrastructure that enables integration with heterogeneous system landscapes" (SAP, 2005b). This interface is introduced more closely in chapter 5.

As can be seen, there are several issues related to RFID technology and SCM systems being discussed and almost daily new articles are being published. However, the discussion takes place rather on a theoretical level, not taking into account current issues experienced in practice. In order to close this missing link, this research will contribute to the discussion by providing knowledge about the current use of RFID technology and impacts of its introduction on existing supply chain management systems. Also, both fields which are considered lack a common understanding of terms and definitions adding to fuzziness of the topic. But especially the combination of these two fields makes it necessary to arrive at one common language. The experimental nature of the examined cases will also provide a critical view on the current status of the development of RFID technology and its performance in practice. Taking into account the user perspective will reveal current issues.

Having not only introduced the topic, the scope and objective of this dissertation, but also situated this study in the context of previous research, the next chapter provides an explanation and justification of the research method deployed.

# 2. Methodology

## *2.1. Methodology/Research Method*

Due to the fact that the use of RFID technology in supply chain operations is a rather new application it became clear in the planning process that the research methodology must be suitable for the analysis of qualitative data as it could not be expected to find a representative sample of participants for a quantitative analysis. Therefore, a combination of secondary and primary sources provided qualitative data for this study. In a first step literature about supply chain management and supply chain management systems provided the basis for an introduction into the history, development and classification of supply chain management systems. The need for efficient data acquisition methods is elaborated and the fundamentals of RFID technology are introduced based on standards, company whitepapers and studies. Additionally, a description of an RFID integration solution with existing enterprise resource planning or supply chain management systems visualises the combination of both.

The case study methodology was used for the empirical part of this research project. Also, the nature of the research questions demanded that they were answered through multiple case studies in order to be more representative than one single detailed case study (Yin, 2003). Therefore, the goal was to find, analyse and compare current cases of RFID technology in several companies and to study the impacts on SCM systems. For this reason, a survey and interview were conducted and analysed by the means of descriptive statistics and especially thematic analysis. The following four steps were carried out for the case study (Harvey & Wensing, 2003):

- Select individual cases relevant to the issues to be studied.
- Collect data within individual sites using a range of quantitative and qualitative methods.

- Analyse the data within individual sites using appropriate quantitative and qualitative methods of analysis—for example, descriptive statistics, thematic analysis of qualitative data.
- Compare data analyses across sites to draw more general conclusions and/or generate hypotheses for further testing.

Additionally, findings from literature were used to compare the results with other research.

## *2.2. Justification of Choice of Methodology*

The interdisciplinary nature of the research topic brings with it two different backgrounds and languages which are to be combined. Therefore, it is necessary to provide a common language and to understand how these to fields are combined and how they interact. As the combination of RFID and SCM systems is still in its infancy it is vital to present the historical development as well as elaborate the standards and classifications of RFID technology. In this way RFID technology used in supply chain operations can be delineated from the general technology.

In order to achieve a higher accuracy of the gathered data, multiple data sources were used. This approach is also referred to as triangulation. According to Knight (2002), this strategy allows for a greater certainty of the accuracy of the data because it reduces the risks of individual bias and enables a validation through crosschecking the data.

For the second part of the project, the case study methodology "seeks to answer questions of how and why, instead of who, what, where, how much, and how many" (Brock, Kukulski, & Tanis, 2002, p. 1). Accordingly, most of the questions in the questionnaire and during the interview were of the nature of 'how' and 'why'. This approach allowed for the collection, analysis and interpretation of the sought data with regard to RFID technology introduction and its impacts on supply chain management systems.

The questionnaire and the interview questions and notes can be found in the appendix of this document. The use of a semi-structured interview provided direct answers in the nature of the research questions but also allowed for flexibility to ask subsequent questions to extend the view and understanding of the researcher by being responsive to the interviewee.

## *2.3. Data Collection*

As already stated above, the data used in this study was gathered through three sources, namely a review of secondary sources, a survey and a semi-structured interview.

The collection and evaluation of secondary sources was carried out over a period of two months, namely June and July 2005. In order to locate relevant literature, several internet databases were used. Among them were EBSCO and Emerald Insight. But to a greater degree, several libraries in the area of the researcher were visited and used. Among them was the 'Deutsche Bibliothek' in Frankfurt am Main which is "responsible for the collection, processing and bibliographic indexing of all German and German-language publications issued since 1913" (Die Deutsche Bibliothek, 2001). In order to include relevant English publications as well, the library of the European Business School in Oestrich-Winkel and the Supply Management Institute in Wiesbaden were also utilised. In case publications were not available in either of the libraries or via the databases, the document service of other libraries was used. Apart from the hardcopy version of books in libraries, also the electronic library services from Unitec provided access to several publications. Nevertheless, these sources where mainly used for information on supply chain management systems whereas the information on RFID technology found here was rather outdated. The technological advantages and creation of standards in recent years seem to outpace the publishing processes. But still, both German and international journals could be found which contained timely articles on RFID technology. However, especially on the website of EPCGlobal, a standardisation body which emanated from the Auto-ID centre at the Massachusetts Institute of Technology, several publications were identified and examined. The internet was also used to locate studies, governmental publications on RFID (regulations) and to research standardisation status.

As already stated above, the data for the case study was collected by a questionnaire containing 23 questions and a semi-structured interview with one of the survey participants. The questionnaire was sent out via email and collected either by email as well or by fax. The questions of the survey were primarily aimed at answering the research questions but additionally, basic demographic information of the participants was collected as well.

The questionnaire needed to be sent to companies which had already completed an RFID technology introduction project or were doing so during the time of this study. Therefore, it was initially planned to identify such participants by having access to companies associated with the Supply Management Institute, an international research and training centre for purchasing, logistics and supply chain management. With the aim of getting a better understanding of current issues of RFID deployment in supply chain operations and to identify potential research participants, the researcher attended a workshop, organised by DHL Express for key customers in the electronics industry (Customer Advisory Board RFID) in Frankfurt in late June. The workshop was moderated by Jun.-Prof. Dr. Darkow of the Supply Management Institute. In this workshop, requirements of RFID deployment in the supply chain were discussed among 14 key customers, and RFID pilot studies and their results were introduced by DHL and Infineon. During the workshop it became clear that most of the attending customer companies had not started RFID projects and two stated that under the current status of the technology they were not considering the implementation in foreseeable future at all. However, three potential participants could be identified and were approached. Because it was not likely that all three of them would actually participate in the study, the researcher identified more potential participants with RFID project experience. They were identified through the internet, either directly on the company websites which contained information about the RFID projects or by the use of the internet community openBC (www.openbc.com, open business club), and by going through publications on logistics trends and news. . The role of the participants in their companies had in common that they were responsible for the RFID projects but interestingly their actual job positions differed.

In total, 10 questionnaires were sent out by email in early July to decision makers and project managers involved in RFID technology introduction. The email contained an introduction to the study in either German or English depending on the participant. Along with the questionnaire, an Informed Consent form was sent which can be found in the appendix.

After ten days only one questionnaire was returned. Therefore, telephone calls were made in order to establish rapport and remind of the study. During these telephone calls it became clear that the popularity of the topic among market research firms and academic researchers caused an overflow of survey requests and resulted in a negative attitude of potential participants towards this study. Even the prospect of receiving the results of this study once finished did not result in a higher interest. Yet, two more questionnaires were returned within a week of these follow-up telephone calls.

Additionally, 10 more potential participants could be identified through a more thorough research on the internet and in recent logistics publications. Of these 10 participants nine could be reached by telephone and 6 of them directly said they would not participate in the study. The others said they would first take a look on the questionnaire and then if possible would answer it and send it back. The result was one more questionnaire.

As the timeframe for this study was limited, the time for the data gathering process was planned to end in the middle of August. Consequently, the remaining potential participants were reminded again via email resulting in one more returned questionnaire. With these five questionnaires the planned sample size was reached.
Additionally to the questionnaire, the researcher took notes after telephone calls with the participants to gather information about their attitudes and perceptions in order to better interpret the data.

After a thematic analysis of the available responses, the participants were asked to partake in the planned semi-structured interview. Unfortunately, the short time frame for the study incidentally fell in the German summer holiday season so that only three participants could be reached and only one of them was available for an interview. Because of the long distance between the researcher and the interviewee, it was agreed to conduct the interview via telephone conference. When asked if the interview could be taped, the interviewee declined because he feared to distribute sensitive commercial information or to be quoted. Therefore, the researcher took notes during the interview and expanded these directly afterwards. This procedure guaranteed for not letting any interruption occur between the interview and the note taking, thus, resulting in the most objective way to transcribe the data without recording.

Additionally to the data gathered through the questionnaires and the interview, publications of the companies, such as published annual reports, project presentations available on corporate websites, where available were used as well.

## *2.4. Ethical Considerations*

Due to the fact that this research involved the collection of business information about the introduction of a new technology and the strategic character of such projects, the data needed to be treated accordingly. Prior to the collection of data, the researcher examined the Policies and Procedures of the Research Ethics Committee as well as the NZ Privacy Act 1993 "which, amongst other things, requires that data can only be collected for the purpose for which it is stated, must be kept securely, must only be kept for as long as is necessary, and must be destroyed at the end of the project"(Coard, 2004). The form 'Is Ethical Approval Needed for my Research; Checklist and Declaration' which is contained in the appendix was completed and approved by Unitec's Research Ethics Committee for non-contentious student-led research.

In order to ensure that the participants where informed about the purpose of the study and that their participation was voluntarily they received a cover letter as an email and an Informed Consent Form which was sent along with the email containing the questionnaire.

The collected data has been stored securely with password protection and encryption during the entire project. Therefore, only the researcher can identify the participants and the gathered data is presented anonymously. As soon as this master's dissertation is examined, the data identifying the participants will be destroyed.

## *2.5. Data Management, Processing and Analysis*

Creswell's (2003) six step method was used to guide the data management, processing and analysis:

**Data organisation and preparation**

The collected data from the questionnaire was copied directly from email answers into a Microsoft Excel spreadsheet and answers from questionnaires sent by fax were typewritten to allow for an equalised view. The notes from the interview were also included in the spreadsheet but marked with a different colour.

**Developing an overall picture**

With the harmonised display of the answers to allow for the development of an overall picture the questionnaire and interview answers were read several times to code for emergent themes. Trace (2001) states: "This approach ensures that any unanticipated themes are given the opportunity to emerge from the data and that no undue weight is given *a priori* to any preconceived themes."

**Data analysis**

Emergent themes were then highlighted and categorized. Different phraseologies of the same themes were examined for different meanings. This was necessary as the answers differed in length and circumstantialities. Nevertheless, all participants answered in uncompleted phrases throughout the questionnaire. This provided data which was rich in content and information but also difficult to interpret.

**Description and categorisation of the collected data**

In order to classify the emerging and identified themes, the themes were examined again, notes were taken, and similarities as well as differences were highlighted. The examined RFID projects took place in different industries, namely in logistics, consumer packaged goods, fashion and lifestyle, electronics, and semiconductors and were examined individually as well as in comparison to each other.

**Representation of the collected data**

The collected data is mainly presented in a condensed form of case studies in chapter 6 Results. This allows for a unified view of the different RFID projects yet leaves enough room to present unique features and requirements in order to dwell on the richness of the collected qualitative data. The analysis of the gathered information is presented in chapter 7 and presents the different themes and classifications discovered in the data.

**Data interpretation**

After the thematic analysis and presentation, the data was further examined in view of the research questions. It was interpreted and parallels as well as variations in comparison to findings from the literature were elaborated upon. The interpretation and discussion of the results can be found in chapter 7.

## *2.6. Bias*

Even though careful preparations were taken in order to minimise sources for bias, some possible sources should be taken into consideration. Because the research questions look at a new technology as well as at the topic of supply chain management in which terms are not ultimately defined and interpreted in the same way it is possible that the participants have a different understanding of certain terms than the researcher has. Also, the subjectivity of the researcher which can lead to a better interpretation of the data by including surrounding factors for instance recognising the tone of the participant’s voice during an interview can mislead the interpretation because the researcher and the interviewee do not share the same perception. Another possible source for misinterpretation is simply the different understanding of terms and definitions of the participant and the researcher. As the research was conducted in Germany using questionnaires in English it was possible that the participants, even though English is the corporate language in most companies operating in an international context, did not have the language capability needed to produce correct and understandable answers. This was not the case but if that had happened, the researcher would have provided the questionnaire in German and translated the answers back to English, which would have represented another source for bias.

The interview and the quality of note taking during its conducting are heavily dependent on the researcher's abilities to simultaneously understand what the interviewee is saying, take notes, follow the interviewee and also ask further questions. As the researcher is used to taking notes in a lecture setting and asking questions in between, the possible influence on the correctness of the gathered data should be minimal.

As the above explanations regarding the methodology of this study have shown, the chosen qualitative research approach is suitable under the given circumstances. The researcher has utilised various sources of information for the data collection bearing in mind ethical considerations. By following a structured and well documented procedure, bias is likely to be reduced to the remaining factors which are mentioned. The following chapter is the first part of the theoretical foundation for the empirical study and introduces the fundamentals of supply chain management and supply chain management systems.

# 3. SCM systems

The advances both in supply chain management activities and in information technology to support these activities are closely intertwined. Therefore, the history of applied SCM can be illustrated by the developments in enterprise information systems. But because supply chain management is the conceptual basis for SCM systems, in the first part of this chapter, the understanding of SCM used for this dissertation is given and the need for information visibility among the supply chain is demonstrated through a presentation of the bull-whip effect. Then, the emergence of present-day SCM systems is classified in the context of the history of enterprise information systems. In a third part, data acquisition techniques which feed the SCM systems with data are introduced and discussed.

## *3.1. SCM*

### 3.1.1. SCM definition

There are two major understandings of SCM. One sees SCM as a logistics-oriented concept which comprises inter-company logistics (Weber, 2002, Göpfert, 2001) and the other understanding is SCM as holistic concept which spans across further business functions (Tan, 2001). Cooper, Lambert and Pagh (1997) state “there is definitely a need for the integration of business operations that goes beyond logistics […] The integration of business processes across the supply chain is what we call supply chain management”. Therefore, SCM aims for improvement of all material, informational and financial flows both within the internal supply chain and the extended supply chain from the original supplier to the end customer.

As this research project deals with the impacts of RFID technology introduction on SCM systems and thus, not only focuses on functions and processes of logistics the latter understanding of SCM will be used as definition throughout this study.
Supply chains vary in terms of length, meaning the number of supply chain members involved from the raw materials producer to the end customer of a product,

and in complexity, referring to the interdependencies between different supply chain members.

The activities of each member of a supply chain are typically plan, source, make, deliver, and in some supply chains also return. All of these activities are supported by information systems enabling visibility of products, processes and progress. The need for such information visibility can be demonstrated by the impact of it on the so called bullwhip effect which was first mentioned by Forrester in 1958 (1961) and revisited with regard to supply chain management by Lee, Padmanabhan, and Whang in 1997.

### 3.1.2. The bullwhip effect

In a supply chain where the demand information flow between chain members is not enabled, such as in the popular ‘beer game’ simulation, small changes in demand amplify orders at each stage in the upstream supply chain.

In the ‘beer game’ simulation participants play the roles of supply chain members of a simplified but realistic supply chain in the beer industry. Retailer, wholesaler, distributor and manufacturer are not allowed to communicate and order decisions are only based on the downstream orders. Each week the customer places demand with the wholesaler who fulfils the order from his inventory. The wholesaler requests an order from the distributor who gets his supply from the manufacturer who brews the beer. Thus, the flow of information from the customer to the manufacturer takes three weeks and is filtered and altered by the supply chain members. The flow of materials in the beer game version mentioned in Richter, Rochel, Samans, and Schäfer (2004) is even slower. The beer passes the stages ‘incoming’, ‘in transit’, and ‘inventory’ at each supply chain member and the transfer from one stage to the next takes one week. Costs occur for inventory and in case orders cannot be fulfilled, backlog costs accrue. As backlog costs are twice as high as inventory costs, safety stock is build up by the individual supply chain members and the variance in order quantities increases from customer to manufacturer.

According to Lee et al.(1997), four distinct causes lead to information distortion and result in the bullwhip effect:

- Demand Signalling
- Order Batching
- Fluctuating Prices
- Shortage Game

All four causes are based on behaviour of supply chain members trying to maximise profit individually rather than maximising the entire supply chain's profit. The overall costs of the supply chain are higher, resulting from higher inventory levels, unavailability of products, irregular orders, unused overcapacities and higher logistical efforts (Richter et al., 2004; Gronau, 2004). Simulations of information sharing along the supply chain indicate that the magnitude of the bullwhip effect can be reduced (Joshi, 2000).

Enterprise systems enable the flow of information within both the intra-company supply chain and the extended inter-company supply chain thus being a key component in SCM efforts.

## *3.2. History of enterprise information systems*

In the course of first commercial uses of data processing, material requirements planning (MRP) automated the processes of inventory and production planning in the early 1970s (Joshi, 2000). Because the used data is limited and the manufacturing system is not integrated with the firm's financial system, the concept of MRP was extended. MRP II, standing for manufacturing resource planning, additionally included the functions purchasing and capacity planning (Gronau, 2004; Wöhe, 2002). During the 1980s it became apparent that the information and information systems used within firms were much like the organisational structure, rather functional and disconnected. The need to integrate information across more units of the firm led to the appearance of enterprise resource planning (ERP) systems. And the integration of internal systems and information drives increased competition resulting in the next development of enterprise information systems. The boundaries of the firm are crossed with the advent of advanced planning systems (APS) and collaborative planning, forecast and replenishment (CPFR) systems. These systems allow for planning across the entire supply chain, with extensive information exchange in order to match supply with demand while maintaining lowest possible inventory levels.

The following section reviews the above outlined systems in greater detail with reference to motivation, structure, and limitations.

### 3.2.1. Material Requirements Planning (MRP):

The concept of MRP was first defined by Orlicky in 1975. MRP systems are used in manufacturing environments for "high level scheduling, priority, and capacity management" (Chung & Snyder, 1999). MRP combines input from the master production schedule (MPS), which represents the expected demand, the bill of materials (BOM), which lists the components of the product, and the inventory status of items. The computation results in a detailed output with "the exact quantity, need date and planned order release date for each of the sub-assemblies, components and materials required to manufacture products listed on the MPS" (Joshi, 2000). Since the result is based on the demand as a fixed input, the fundamental optimisation goal lies in the minimisation of the production costs through the determination of minimised lead time, schedule variance, inventory or maximised capacity utilisation (Wöhe, 2002).

Because of the consecutive planning of each input the success of an MRP system is highly dependent on the correct inputs. Nevertheless, the rigidity resulting from the predetermined MPS and the lack of technical and information integration of MRP led to the development of manufacturing resource planning (MRP II) in the 1980s (Chung & Snyder, 1999; Klaus & Krieger, 2004).

### 3.2.2. Manufacturing Resource Planning (MRP II)

The higher integration of more functional areas within a firm by scenario planning in MRP II provides for a better management of company resources by offering information based on the production plan across functions like purchasing, production, finance, and accounting.

Instead of working with a predetermined MPS like MRP, MRP II provides feedback loops within several planning levels in which the firm is divided. Each level determines the limitations for the lower level and in case of conflict when plans can not be fulfilled feedback is given to the upper level (Gronau, 2004). Apart from that, capacity planning is carried out in MRP II, as plant and equipment requirements are considered in scheduling. Nevertheless, planning and scheduling both are combined with the assumption of infinite capacity, leading to problems when capacity limitations occur late in the process, i.e. after the preparation of the MRP schedule (Joshi, 2000; Chung & Snyder, 1999). MRP II is based on other unrealistic assumptions of fixed lead times, lot sizes are considered isolated without consideration of interdependencies and the availability of resources is not verified systematically at any planning stage (Pfohl, 2004). As a result increased inventory is build up due to the planning process (Mehlich, 2005).

These unrealistic assumptions and the limitations that MRP II is focused on the internal operations in a firm where manufacturing is carried out mostly situated on one production site result in the realisation that information exchange with other functional units and sites across the enterprise is needed. Thus, enterprise resource planning systems evolved in the late 1980s (Joshi, 2000).

### 3.2.3. Enterprise Resource Planning (ERP)

ERP systems map workflows, organisational structures, information and data flows of entire organisations (Günthner, Boppert, & Rinza, 2005). They integrate data across the enterprise so that every user of the system, regardless of function, accesses the same consistent data set (Prockl, 2004). SAP's mySAP ERP solution comprises several modules, depicted in figure 1: function range of SAP ERP (SAP, 2005a).

| | | | | | |
|---|---|---|---|---|---|
| Analytics | Strategic Enterprise Management | Financial Analytics | Operations Analytics | Workforce Analytics | |
| Financials | Financial Supply Chain Management | Financial Accounting | Management Accounting | Corporate Governance | |
| Human Capital Management | Talent Management | Workforce Process Management | Workforce Deployment | | |
| Procurement and Logistics Execution | Procurement | Supplier Collaboration | Inventory and Warehouse Management | Inbound and Outbound Logistics | Transportation Management |
| Product Development and Manufacturing | Production Planning | Manufacturing Execution | Enterprise Asset Management | Product Development | Life-Cycle Data Management |
| Sales and Service | Sales Order Management | Aftermarket Sales and Service | Professional-Service Delivery | Global Trade Services | Incentive and Commission Management |
| Corporate Services | Real Estate Management | Project Portfolio Management | Travel Management | Environment, Health and Safety | Quality Management |

**figure 1: function range of SAP ERP (SAP, 2005a).**

ERP vendors base their ERP solutions on reference models which are promoted as "best practice". Nevertheless, a common problem in ERP implementations is a mismatch between the processes and organisational structures of the system and the firm (Davenport, 1998).

As an ERP system is designed to record events which already occurred, the planning level is not advanced compared to that of MRP (II) systems (Joshi, 2000; Prockl, 2004). The batch oriented planning runs on the individual planning levels and still inhibits flexibility in planning as alterations would result in complete iteration of the planning process. Additionally, as production planning is the main focus of ERP systems, traditional systems still interpret demand as an independent requirement which lead to the problem that short-term changes are mostly not considered or considered too late in planning. Even though ERP systems integrate factories and manufacturing sites of an entire enterprise, the integration happens only on an organisational and inventory level. The possibility of substitution between resources is rather neglected.

In the light of SCM, ERP systems neither provide the needed transparency, technical support, and flexibility to visualise, plan, and coordinate supply and demand in an entire supply chain due to the limited focus on the internal supply chain (Prockl, 2004; Edwards, Peters, and Sharman, 2001).

### 3.2.4. Advanced planning and scheduling (APS)

Despite the above mentioned limitations in ERP systems, the developments in enterprise systems, namely advanced planning and scheduling systems, are building on them. While APS systems take over the planning tasks, ERP systems are still needed as transaction and executions systems (Stadtler, 2002; Gronau, 2004). APS systems use the data stored in the relational databases of the ERP. Taking an object-oriented design and memory-resident nature, APS systems allow for planning in real time or near real time instead of traditional batch processing (Joshi, 2000). The simultaneous planning process is carried out at least across the internal supply chain of a firm, is constraint-based and because of the speed of the computation process provides simulation scenarios in form of ‘what if’ questions. Especially the fast responsiveness of APS systems can support customer service by providing available to promise (ATP) checks because changes due to new orders are immediately calculated. Because of the higher automation of standard planning procedures, available capacities are freed for exception handling resulting in a better customer service (Gronau, 2004).

### 3.2.5. Collaborative Planning, Forecasting and Replenishment (CPFR)

CPFR is a business practice where, amongst other activities, systems are connected in order to share plans and information about constraints and exceptional events between partners in the supply chain. As the goal is to have minimal inventory on the one hand but also be able to fulfil demand at any time, all partners in the supply chain must know for example when the retailer plans product promotions which result in swings in demand (Joshi, 2000). Nevertheless, CPFR tries not to harmonise the activities of supply chain members but to align planning information of these activities (Prockl, 2004). The Voluntary Interindustry Commerce Standards (VICS) CPFR committee first published guidelines governing this business practice in 1998 and reports improvements of two to eight percent for products in store and simultaneous inventory reduction of between ten and forty percent along the entire supply chain (VICS, 2004).

With systems enabling information exchange for CPFR, visibility can be achieved across the entire supply chain. But this information exchange needs trust in supply chain partners and the quality of information gathered and stored in the systems determines the success.

### 3.2.6. Understanding of SCM systems

The above history demonstrates the development of enterprise information systems. With parallels in SCM the systems can be classified into two groups, the first having a focus on the internal supply chain (MRP, MRP II, and ERP systems), and the second group with an emphasis on the extended supply chain (APS and CPFR systems). In the holistic concept of SCM used in this study, all of the introduced systems facilitate certain SCM operations and activities. They vary only in the extent to which they cover them.

## *3.3. Automatic Identification (Auto-ID) data capture*

The developments in enterprise information systems which evolved from solving clerical problems into powerful SCM and planning systems followed a top-down approach. The technical possibilities to achieve information visibility across an entire supply chain exist, but one main problem of all of the introduced SCM systems is the dependence of the success on the data and information collected and used. (Günthner et. al., 2005)

Generally, the data can be collected from within the own supply chain activities or other supply chain members, typically the supplier, might provide information about incoming goods through interfaces. Automatic identification methods provide information about items moving along the supply chain. Instead of manual data entry which is prone to error, information about goods is captured automatically by reading devices which are connected with the information systems. The most popular Auto-ID solution is the barcode. However, several shortcomings in the technology and its use, in addition to the emergence of RFID technology as Auto-ID, may result in declining use of barcodes in the long term. In the meanwhile so called smart-labels, combining barcodes and RFID transponders, are used in pilot schemes.

Following is an introduction to barcode and RFID technology as Auto-ID methods deployed in supply chain operations.

### 3.3.1. Barcode

Barcodes are symbolic representations of bits of information which are printed on an adhesive label or printed directly on a product or packaging and are machine readable. One dimensional barcodes are combinations of black and white bars varying in width. The scanning device uses a laser which moves across the combination of bars and spaces, thereby recovering the data. Whereas one dimensional barcodes simply hold serial numbers such as universal product codes (UPC or EAN.UCC-12) which are linked to database entries containing more information such as the price, two dimensional barcodes can encode up to several hundred bytes due to matrix arrangement of dots and spaces.

Because of the benefits and the low operating expenses of barcode systems, they are the dominant form of Auto-ID in supply chain operations. Nevertheless, the technology has several constraints: The scanning process is dependent on line of sight and the scanning device must be manually operated. Also, the scanning process fails when there is dirt on the label or the label is torn. Additionally, it is not possible to embed a label into products and scan more than one barcode at a time. Once a barcode is printed, its value cannot be changed. Another disadvantage for supply chain visibility is the concept of the UPC which only represents a class of product but not a uniquely identifiable item.

### 3.3.2. RFID

Instead of using symbolism to encode data, RFID uses an electronic data-carrying device, the transponder which transmits the data by means of electromagnetic waves to a reading device. The main advantages over the use of barcodes are the possibility to identify items without line-of-sight, simultaneous reading of several transponders which is achieved by anti-collision mechanisms and the possibility to uniquely identify items using the electronic product code (EPC) concept. Because RFID systems can be operated without human interaction, the scanning process can be fully automated.

The above introduced fundamentals of supply chain management and supply chain management systems have shown the need for efficient data collection technologies. Also, the explanation of the emergence of supply chain management systems has shown that today the computation power and storage capacity of these systems is ready for full scale item-level automatic identification solutions. In order to fully comprehend the functionality of RFID and its implications as a data capture technique, a detailed description of RFID systems is given in chapter 4.

# 4. RFID technology

## *4.1. History*

The first application of RFID technology was developed in 1939 and used by the British in world war two. For the so called ‘identification, friend or foe’ (IFF) system, aircraft carry equipment which responds to electromagnetic transmissions in order to distinguish them from enemies (EPCGlobal, 2004; Wikipedia, 2005). Stockman’s paper “Communication by Means of Reflected Power” (1948) represented a next step towards contemporary RFID systems. However, the first commercial applications appeared in the 1960s in form of electronic article surveillance systems, followed by applications in animal tracking, industrial use and payment on toll roads in the 1980s (RFID Survival, 2003).

With advances in the technology and advantages over other automatic ID systems such as the bar code system, RFID becomes an important solution for automatic identification in supply chain operations.

## *4.2. Components of a RFID system*

According to Sheffi (2004), a RFID system which is used in supply chain operations typically consists of the following four elements.

### 4.2.1. Unique identification number /Electronic Product Code (EPC)

A unique identification number is assigned to a particular entity “in motion in the supply chain” (EPCGlobal, 2004, p.9). The EPC is the unique identification number which is used in the EPCGlobal Network Architecture. It is defined by the EPCGlobal Tag Data Specification (EPCGlobal, 2005a). The concept of the EPC allows for unique identification on all levels of implementation, i.e. each container, pallet, case and or item can be individually identified.

### 4.2.2. Transponder

The transponder is attached to or integrated in an entity. It carries the data, e.g. the EPC, and transmits the data to the reader when it moves through the electromagnetic zone of the reader. It contains a coupling element and a microchip (Finkenzeller, 2003).

### 4.2.3. Networked readers and data processing systems

The reader holds a radio frequency transmitter and receiver in order to read the information transmitted by the transponders. The readers pass the collected data to processing systems such as Manufacturing Execution System (MES), Supply Chain Management (SCM) system, and Enterprise Resource Planning (ERP) system (Chang et al., 2002).

### 4.2.4. Databases which store information and enable information exchange

The databases which process the information and enable the information exchange are the above mentioned processing systems. With regard to the supply chain integration, the MES and the ERP system have a focus within the company whereas the SCM system typically includes information exchange with supply chain partners. (Busch, Dangelmaier, Pape, & Rüther, 2003).

## *4.3. Differentiation features of RFID systems*

RFID systems can be classified according to the performance features of the transponders and the readers. A classification with regard to the technical capabilities results in a differentiation between low-end, middle, and high-end systems (Bundesamt für Sicherheit in der Informationstechnik, 2004); additionally, frequency and power supply of the transponders provide further classification criteria relevant in supply chain operations due to differences in reading ranges and costs.

### 4.3.1. Technical capabilities

Regarding the technical capabilities, RFID systems can be classified into the following three groups.

#### 4.3.1.1.Low-end systems

The bottom-of-the-range RFID systems include 1 bit systems where the transponder acts as a state machine and the reader can only detect if either a transponder is in the electromagnetic field or no transponder is in the field.

Furthermore, 'write once read many' (WORM) systems rank among low-end systems and are used in supply chain operations. (Bundesamt für Sicherheit in der Informationstechnik, 2004; Finkenzeller, 2003). Typically they carry an electronic product code which does not need to be changed.

#### 4.3.1.2. Systems of medium technical capabilities

These systems contain transponders which are rewritable. The memory capacity varies from a few bytes to over 100 kilobytes. The transponders can either contain a state machine or a microprocessor. Anti-collision methods are used to prevent interference of several transponders in a field of a reader and to enable the reader to selectively communicate to individual transponders. (Bundesamt für Sicherheit in der Informationstechnik, 2004)

#### 4.3.1.3. High-end systems

These systems are mainly used in conjunction with contact less chip cards with a microprocessor and a chip card operating system. Additionally to write and read operations, they enable strong cryptography mechanisms. (Bundesamt für Sicherheit in der Informationstechnik, 2004) Because of their complexity and high costs per transponder, high-end systems are not considered for supply chain operations but can be found in access and payment systems.

### 4.3.2. Power supply of the transponder

The power supply of the transponder determines the reading range and cost and design of the transponders. They are classified into passive, semi-passive and active transponders.

#### 4.3.2.1. Passive transponders

Passive transponders do not have their own power source and use the power transmitted by the reader through the electromagnetic field. They are the smallest and cheapest transponders.

#### 4.3.2.2. Semi-Passive transponders

Whereas passive transponders do not contain their own power source, semi-passive transponders hold a power-source for the microprocessor. However, the data transmission is powered by the reader. (Psion Teklogix, 2004)

#### 4.3.2.3. Active transponders

Active transponders contain their own power source in form of a battery. Because the power source is used not only for the microprocessor but also for transmission of the data they usually have longer reading ranges. They are larger than passive transponders and several times more expensive.

### 4.3.3. Physical classifications

#### 4.3.3.1. Frequency classifications

The frequency of a RFID system refers to the operating frequency of the reader. Generally, the frequency of the transponder is the same as the frequency of the reader but it is the reader which activates the transmission of data from the transponder. (Finkenzeller, 2003).

On the one hand, the frequency determines the reading range of a system and on the other hand, the frequency determines the interoperability of systems for global use as certain frequency bands are allowed for RFID systems in some countries but are forbidden in other countries. Only three frequency bands can be used globally (Finkenzeller, 2003). But apart from the frequencies, the permitted transmitting powers vary in different countries. (Haberger, 2004) The frequencies used in RFID systems can be classified as depicted in the following table. (Datta, 2005; Finkenzeller, 2003; Wikipedia, 2005)

| Notation | Frequency (band) |
|---|---|
| Low frequency | 125 to 134 kHz |
| High frequency | 13.56 MHz |
| Ultra high frequency | 868 to 956 MHz |
| Microwave | Above 1 GHz<br>(particular 2.45 GHz and 5.8 GHz) |

**table 1: RFID frequencies (notation is not according to ITU radiofrequency bands).**

#### 4.3.3.2. Reading range

The following three physical coupling methods are a classification with regard to the reading range of a RFID system. (Finkenzeller, 2003)

| Notation | Reading range |
|---|---|
| Close coupling system | < 1 centimetre |
| Remote coupling system | >1 centimetre < 1 metre |
| Long-range system | > 1 meter |

**table 2: reading range classification of RFID systems**

## *4.4. Standards*

Several standardization institutions have developed standards for various RFID technologies, data structures and applications. Additionally, the postal or telecommunication authorities regularise the frequency bands.

The most important standardisation bodies regarding RFID and its use in the supply chain are EPCGlobal and ISO.

### 4.4.1. EPCGlobal architecture framework

EPCGlobal is an organisation which is funded by large companies with an interest in developing international RFID standards in order to enhance supply chain operations.

The "EPCglobal Architecture Framework is a collection of interrelated standards for hardware, software, and data interfaces…" (EPCGlobal, 2005b).
The EPCGlobal architecture framework inter alia comprises the following components (Walk & Walk, 2004).

#### 4.4.1.1.EPC

As already explained in 4.2.1, the EPC is used to identify a particular item in the supply chain. It consists of several partitions which uniquely identify the version, the producer (also called EPC Manager), the object class and the serial number of the item as shown in figure 2: The Electronic Product Code (Brock, 2001, p. 20).


**figure 2: The Electronic Product Code (Brock, 2001, p. 20)**

#### 4.4.1.2. EPC transponder and reader

EPCGlobal developed the UHF Class 1 Gen 2 standard in 2004. This is the air interface protocol which regulates the communication between the reader and transponder. It superseded the standards UHF Class 0 Gen 1 and UHF Class 1 Gen 1. The Gen 1 standards where developed by the Auto-ID Center. The Gen 2 now represents a single global standard for the air interface and use of the memory space of transponders of UHF systems and is closely aligned with ISO standards.

#### 4.4.1.3. Object Name Service (ONS)

Because the EPC just contains the identification number of an item, the object name service is needed to connect the item with the corresponding information. The ONS "provides a lookup service to translate an EPC™ number into an internet address where the data can be accessed" (Harrison, Moran, Brusey, & McFarlane, 2003)

#### 4.4.1.4. Physical Markup Language (PML)

The information to an item, such as EPC-number, time stamp, barcode data or sensor data are described with the PML which is based on XML. However, the PML only describes how the data is communicated. (Brock, Milne, Kang, & Lewis, 2001)

#### 4.4.1.5. Savant

The management and the effective exchange of EPC data is realised through Savant, a software technology with a distributed architecture. In its hierarchy, the low-level Savants process and filter event data and only forward information of interest to superior Savants. (Goyal, 2003)

### 4.4.2. ISO RFID standards

The International Organization for Standardization has developed several different standards for RFID use. However, only the following RFID standards are relevant in the context of supply chain operations.

#### 4.4.2.1. Air interface standards

The ISO/IEC 18000 standard series covers generic parameters for air interfaces (18000-1) and six frequency specific air interfaces (18000-2 to 18000-7). As already mentioned in 4.3.3.1, the different frequency bands determine the functionality of the corresponding RFID systems. These differences are accounted for in the frequency specific air interfaces, e.g. in form of specific transmission data rates.

| Notation | Frequency band |
|---|---|
| ISO/IEC 18000-2 | >135 KHz. |
| ISO/IEC 18000-3 | 13.56 MHz |
| ISO/IEC 18000-4 | 2.45 GHz |
| ISO/IEC 18000-6 A/B | 860 - 960 MHz |
| ISO/IEC 18000-7 | 433 MHz |

**table 3: ISO frequency specific air interface standards (ISO, 2004a)**

### 4.4.2.2. Data content structure standards

The data protocol for the application interface in RFID systems for item management is described in ISO/IEC 15961 and the data processing and encoding is specified in ISO/IEC 15962. The ISO/IEC standard 15963 deals with the "Unique identification for RF tags" (ISO, 2004b, p.1). It is the counterpart of the EPC in the EPCGlobal architecture framework.

### 4.4.2.3. RFID performance/conformance standards

Additionally, the ISO provides methods performance tests for transponders and readers (ISO 18046) and RFID device conformance test methods for 13,56 MHz, 2,45 GHz and 433 MHz systems (18047-3, 18047-4, and 18047-7). (Rees, 2004)

### 4.4.2.4. Supply chain application standards

ISO also currently develops several supply chain application standards shown in table 4: ISO supply chain application standards for RFID. However, the document containing general application requirements has been discarded.

| Notation | Supply Chain Application | Status of document |
|---|---|---|
| ISO 17358 | General application requirements | discarded |

| | | |
|---|---|---|
| ISO 17363 | Freight containers | Under development |
| ISO 17364 | Transport units | Under development |
| ISO 17365 | Returnable transport items | Under development |
| ISO 17366 | Product packaging | Under development |
| ISO 17367 | Product tagging | Under development |

**table 4: ISO supply chain application standards for RFID**

The given introduction on RFID technology and systems has shown that RFID systems typically consist of the following four components (Seffi, 2004):

- Unique identification number
- Transponder
- Networked readers and data processing systems and
- Databases which store information and enable information exchange

Whereas the first two components are truly RFID specific, the latter two are likely to be represented through the supply chain management systems which enable the integration of the RFID systems along the supply chain.

The number of different capabilities, features, and physical classifications of RFID systems indicates that in each case of RFID deployment the environmental factors have to be considered carefully in order to allow for the desired functionality at minimum costs.

Regarding the development of global standards for RFID technology, it became clear that there are currently the two key players EPCGlobal and ISO which need to align their approaches along with governmental telecommunication regulation institutions in order to arrive at one global RFID standard which can be used for supply chain operations at low costs.

The next chapter will introduce the RFID approach taken by SAP’s Auto-ID Infrastructure which integrates automatic identification technology with supply chain management systems.

# 5. SAP RFID solution

Existing SCM systems need to integrate the granularity of data provided by RFID technology. In order to understand the integration effects of RFID technology on the systems, this chapter describes SAP's approach which comprises several components. Auto-ID Infrastructure (AII) provides the connection of RFID devices with existing information systems. It is designed as generic infrastructure integrating with heterogeneous systems but also integrates seamlessly with existing logistics systems by SAP (SAP, 2005b). The possibility of deploying AII as standalone solution is disregarded as in this study the focus is on the integration with existing systems. Therefore, an integration scenario with a SCM system is assumed and described.

The RFID solution offered by SAP can be mapped to the architecture framework of EPCGlobal (SAP is member of EPCGlobal) which was already described in chapter 4.

## *5.1. System components*

The RFID solution package of SAP, apart from readers and tags manufactured by other companies, comprises five key components which are illustrated in figure 3: SAP RFID Solution Package (SAP, 2005c) and explained subsequently.

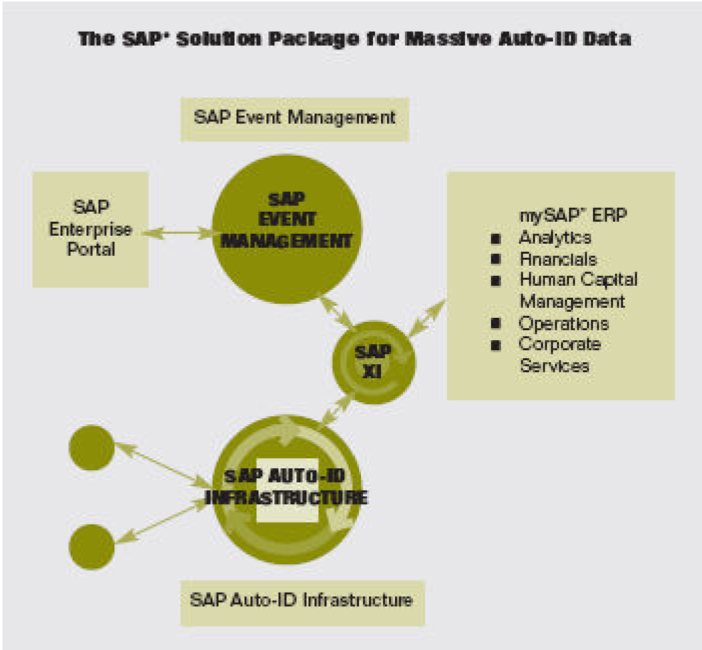


**figure 3: SAP RFID Solution Package (SAP, 2005c)**

### 5.1.1. SAP Auto-ID Infrastructure

The AII on the one hand integrates the RFID devices, i.e. transponders, readers and printers, and on the other hand the SCM systems. Therefore, it "filters, buffers, verifies, and aggregates data coming from different hardware sources, [and] gives business context to the data, drawing on the applications in mySAP™ ERP that support the business processes" (SAP, 2005c, p. 6). It supports the following inbound and outbound processes (SAP, 2005d):

- RFID tagging of cases and pallets
- Packing cases onto pallets (unit load building)
- Moving pallets within the warehouse
- Loading pallets for outbound shipment

In the context of the EPCglobal Architecture Framework, the AII represents the lowest level Savant. The AII system communicates with higher level components, e.g. the ERP system, via the so called Exchange Infrastructure (XI) by use of XML/PML messages.

### 5.1.2. SAP Exchange Infrastructure

SAP XI provides the integration platform for data exchange. In this way point-to-point connections between separate systems are avoided and integration with systems from other vendors is possible as well (Buxmann, König, Fricke, Hollich, Diaz, & Weber, 2004). Whereas the AII communicates using the XML data format, the ERP and SCM systems of SAP do so using the intermediate document (IDoc) format. The XI then converts the format and maps the field contents. Additionally, it queues, sequences, and routes the messages between ERP system, event management software and AII. Through the XI, RFID data such as the EPC is merged with transaction data from the backend systems, for example with an advanced shipping notice (ASN) which is send to the buyer to inform about a forthcoming shipment and its packaging. (Schäfer, 2005)

By coordinating and filtering messages between systems, the XI is a savant system one level above the AII. It links the information about physical goods from the backend systems with the actual items through the EPC received by the reading devices.

### 5.1.3. ERP adapters

For compatibility with older SAP systems and non-SAP systems, ERP adapters are used to "control and use the auto-ID data involved in the warehouse management, fulfilment, delivery, and handling of unit-oriented (pallet) activities" (SAP 2005c, p. 7). The latest ERP release (mySAP ERP) has built-in adaptors. The ERP system assigns the EPC number ranges to AII systems for printing smart labels or writing EPC numbers to transponders and supports all processes which involve RFID data. Therefore, the data needed for "packing, unpacking, loading, unloading, and advanced shipping notification (ASN) processes" are provided by the ERP system (SAP 2005c, p. 7).

### 5.1.4. SAP Event Management (EM)

SAP Event Management (EM) is a component of the SCM solution and allows for tracking and exchanging RFID data with other supply chain members. It informs supply chain members of events, such as the ASN, thus providing transparency and visibility across the supply chain. Predefined scenarios are used to distinguish expected from unexpected events. In case of unexpected events, automatic alerts are created. Additionally, reports on key performance indicators (KPI) are provided through the Enterprise Portal. EM together with the Enterprise Portal represent the highest level savant in the hierarchy of SAP's RFID solution (SAP 2003; SAP 2005c).

### 5.1.5. SAP Enterprise Portal

The Enterprise Portal provides role based access to information gathered by RFID devices for employees, partners and customers as well. It enables visibility on report and event management information (SAP 2005c).

The AII solution of SAP provides support for RFID deployments and integration with supply chain management systems. The five introduced components represent a generic framework for the integration of RFID with supply chain management and ERP systems through data exchange standards supported by all major system vendors, thus allowing for integration along the entire supply chain.

# 6. Results

The following section introduces the examined case studies. Among them are RFID projects from a logistics service provider, a fashion and lifestyle company in the textile trade, a mail-order and online retailer, an industrial printer supplier, as well as a semiconductor producer. The descriptions of the projects give an understanding of how the examined RFID systems work and take into consideration the particularities of each deployment.

## *6.1. Logistics service provider implements RFID pilot with healthcare producer for Metro's Future Store Initiative*

A leading logistics service provider was chosen by a healthcare company and Germany's largest retail company Metro to test RFID deployment in the context of Metro's Future Store Initiative. The task was to tag pallets for shipments bound from the healthcare company warehouse (which is operated by the logistics service provider) to certain Metro distribution centres.

In Germany, the logistic service provider operates a central warehouse for the healthcare company with room for 33,000 pallets. In this warehouse, outbound pallets are picked individually per order. In case a shipment is bound for a Metro distribution centre a smart label is printed. On the front the smart label contains the number of the shipping unit in plain writing as well as in bar code form and on the back of the label an RFID transponder is located. This smart label is then attached to the pallet during inspection of completeness. Before the pallet is loaded on trucks it passes an RFID reader attached to the gate. As soon as all pallets are loaded and therefore scanned, the logistics service provider sends a despatch advice (DESADV) electronically to Metro, informing about the readiness of the shipment, its contents, and expected arrival time. (Kranke, 2005) On arrival of the shipment at a Metro distribution centre, the shipment again passes an RFID-enabled gate and the pallet's EPC is collected.

The anticipated benefits of this RFID pilot were an enhanced supply chain visibility, more accurate and efficient scanning processes and thus cost reductions.

## *6.2. RFID Pilot at a fashion and lifestyle company and its retailer*

Another RFID pilot project was conducted in Germany by a global fashion and lifestyle company together with its logistics partner and a retail company. Its goal was to test current technology, examine possible applications for reasonable RFID deployment, and to identify both costs and benefits of RFID solutions in the textile trade.

Therefore, logistic units as well as the items are tagged at the logistics service provider during the control of goods received. These tags are then read (bulk reading) before as well as after the order picking process at the logistics service provider. When arriving at the retail stores the control of goods received is done by scanning the goods when they pass RFID-enabled gates.

Apart from these logistical functions, additional functions in the retail stores are tested. For instance, the stocktaking for RFID-enabled goods is simplified and improved because of bulk reading and RFID-enabled shelves which recognize if goods are taken from them. Thus, errors resulting from manual data entry are minimised. In order to prevent theft, the RFID tags are used for article surveillance as well. The latest transaction in this supply chain, being the check out process for these products, is streamlined because RFID readers are used at the check out counters allowing for faster and simultaneous reads. Because this RFID system works as a closed loop system, the transponders are removed at the check out counters and sent back to the logistics service provider for reuse.

### *6.3. German mail-order and online retailer tests RFID for theft reduction of high value goods*

In order to test practicability of RFID technology and to prevent theft of its high value electronic goods during shipment, a major German mail-order and online retailer opted for an RFID solution. In the central warehouse RFID transponders are attached to the packaging of high value goods like jewellery, digital cameras or cellular phones. The passive smart label transponders, working in the 13.56 MHz frequency band, contain a unique article number, the shipment code, as well as a number used for returned goods. Therefore, the goods arrive at the end customers with the transponder. In order to anticipate any privacy concerns the packages comprise an informative letter about the technology and the confirmation that no personal data is stored on the transponder.

Along their way through the central warehouse the transponders are read at certain points such as the picking or packaging stations to identify the products which are then shipped to the distribution centres of the logistics service provider. During the processing in the distribution centres, the items are also identified by RFID readers. The data collected along the shipment route is combined with local data from each read activity. Thus, in case of theft or loss, the last location where the product was identified can be found but also improved tracking for customers increases the service level.

According to the company, the benefits of this RFID system for theft reduction alone outweigh the costs by more than 20 percent. Therefore, the RFID solution is used in practice but because of the costs of the transponders is restricted to high value goods only.

### *6.4. Supplier of industrial printers deploys transatlantic RFID solution*

In cooperation with a freight forwarder and an airfreight carrier, a supplier of industrial printers tracks shipments from its Germany based warehouse alongside the route to American customers.

With the intention of providing better customer service, the printer supplier needed to track shipments at shorter intervals and to gain better visibility of the shipments during the time they were handled by the freight forwarder and the airfreight carrier. The goal was to provide more timely and accurate information which could allow for a comparison of the planned execution plan with the actual shipment execution. For that reason, in the German warehouse the printers together with spare parts and supplies are picked and tagged at case level with 96 bits UHF transponders and then loaded onto pallets. Before the shipment leaves the warehouse, it passes an RFID-enabled gate which is activated manually and indicates shipment conformance with expected values with a traffic light signal. At arrival at the freight forwarder's warehouse the shipment again passes an RFID-enabled gate with traffic light signal and the same happens when the shipment leave the warehouse and is loaded onto the plane of the airfreight carrier. Being shipped to North America, the shipment is read again in the loading dock when it is loaded onto trucks bound either for the last part of the journey to the customers or for a warehouse of the printer company.

Conducting the project provided the company with insights in how to integrate RFID solutions by different vendors deployed on two continents, increase supply chain visibility and deploy real-time SCEM.

## *6.5. RFID solution in the semiconductor supply chain*

A semiconductor company simplified its supply chain processes using an RFID solution between its manufacturing plant and a distribution centre. The main purpose of the pilot project was to present a valid business case for RFID deployment. On the one hand, the pilot serves as reference project for other company locations but also as a showcase for customers as the company produces RFID transponders.

In the manufacturing plant RFID transponders are used at three levels. Every pallet, carton box and individual packaging unit is tagged with passive smart labels and scanned before shipment to the distribution centre. On arrival at the distribution centre, the receiving process is largely automated now. Before, every carton and packaging unit had to be opened to tally the shipment. Now, the shipment passes an

RFID-enabled gate and information of a shipment is collected and the receipt process is shortened to a quarter of the previously needed time. The achieved costs savings also result from reduced redistribution time.

One of the main efforts of the project was the process-reengineering. In order to allow for very high reading rates with products and packaging containing aluminium the location of the transponder on the packaging was critical. Also the stacking provides a source for error as transponders put too close together can block each other. The integration to the IT environment was mainly concentrated on changes in the warehouse management system.

Because of the internal business benefits, the company plans to extend the scope of the project to include customers as well.

Having illustrated current uses of RFID in supply chain operations in different industries, it already became clear that the requirements as well as the results of RFID deployment vary from case to case but also have certain similarities. The goal of the next chapter is to analyse the common themes and factors.

# 7. Analysis

The examined RFID projects are carried out in five different industries with different objectives. Therefore, the motivation which led to RFID technology introduction varied.

In this chapter, the underlying variables and factors of the anticipated variations are inspected in the light of the research questions. Consequently, the first part of the chapter focuses on the current use of RFID and the second part investigates the resulting impacts on supply chain management systems.

## *7.1. Current use of RFID technology in supply chain operations*

To begin with, the positions of the participants in their companies were rather mixed. Though they had in common that they were responsible for the RFID projects, two of them were employed in the logistics department, two stated that they were project managers and one participant was the chief information officer (CIO) of his company. This mixture adds to the ambiguity of SCM and its function as described in the literature review.

### 7.1.1. RFID projects at the companies

However, all of the examined RFID projects were carried out as pilot schemes. Questions were asked about the motivation and drivers of the projects as well as what the participants expected as business benefits. The prime reason to start the projects was to test the technology and to experiment with it.

> "Test for cost reduction, theft reduction, more accurate and efficient scanning processes, and item-level information."

> “To gain insight in shipment status and location of goods while in transit to provide better customer service with better forecasts and test the possibility to deploy a solution in different standard-regions”.

The main testing theme mentioned by the participants, as depicted in figure 4, was the improvement in scanning processes which goes along with the findings in previous research regarding the expected automation in the process in comparison to manual barcode scanning (McFarlane & Sheffi, 2003; Kambil & Brooks, 2002). Also, cost reduction is stated as a motivational factor for the use of RFID technology as well as the enhanced supply chain visibility mentioned by Joshi (2000). In two cases RFID technology was tested for theft reduction based on item-level solutions. Nevertheless, in opposition to expected and hailed RFID benefits (Sheffi 2004; McFarlane and Sheffi, 2003), the possibility to store and use more data on an RFID transponder than with a conventional barcode was only mentioned once.

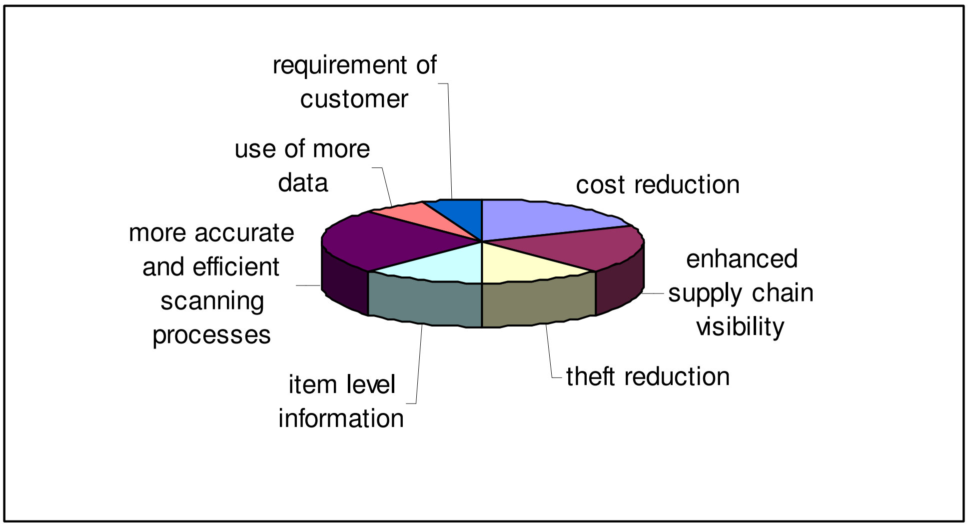


**figure 4: motivational factors for RFID projects stated by the research participants**

In the interaction with the participants it became clear that the companies were mainly trying to introduce RFID technology at a small scale in order to be better prepared for possible global rollouts. The semiconductor company wanted to “showcase the benefits of RFID and generate a positive business case” for possible RFID customers.

In all RFID projects, the numbering scheme of the Electronic Product Code developed by the Auto-ID Center was used. But, consistent with the stated motivation only in one case was additional information stored in the memory of the transponder. It also contained the shipment number and a return identification number only used internally.

The wish for a better supply chain visibility was not only expected to be solved through the use of more check points but also by identifying entities at a lower data collection level. The extension of unique identification numbers of the Electronic Product Code compared to the barcode was used in four of the five examined cases. In these cases, the older data collection level was still used but additionally lower levels came into operation. In three cases item-level information was employed and in one project individual cases were identified. Only in one project, which was initiated because it was mandated by a customer, was the data collection level not affected.

Regarding the transponders used in the projects only passive transponders without their own power source were in operation. Because the systems were set up mainly to facilitate the shipping processes of receiving, picking and loading, distances between reading devices and transponders were rather short so that the passive transponders were sufficient. In four cases, the RFID systems were deployed in open loop systems, meaning that the transponders were disposed of and only in the case of the fashion and lifestyle company, were the transponders removed from the clothing at the point of sale and then sent back to the manufacturer's warehouse.

This layout of the systems also determined the form of the transponders. In the closed loop system, robust plastic cases like the widespread but less sophisticated tags of the older article surveillance systems were used. Whereas in the open loop systems smart labels were in operation. The limited use of memory and the fact that the smart labels are printed and written to just once did not make it necessary to use more complex and expensive transponders. Another of the mentioned reasons why smart labels were used is the fact that the front side of the smart labels still contain the traditional barcode symbols and numbers. In the interaction with the participants it became clear that the barcode on the labels was still needed as it provided a twofold backup in case the transponder did not work. The barcode could be scanned or the numbers could be entered manually.

The use of real time data which is collected via RFID technology and is one of the proposed benefits (McFarlane & Sheffi, 2003; Sheffi, 2004) was only implemented and tested in two of the five projects. In the fashion and lifestyle case the stock keeping data is permanently gathered at the retail store with RFID-enabled smart shelves and monitored by the supply chain management systems to avoid out-of-stock situations. The company expects to benefit from more sales through the improved customer service.

In the transatlantic RFID deployment of the printer supplier, "RFID event information is combined with route maps which are updated immediately to reflect the time differences between plan and actual execution." Therefore, the company can provide more timely information about the location of products and the forecasts of arrival time are more accurate. Additionally, costs savings due to less express charges and contractual penalties are expected.

Regarding the scope of the pilot schemes, the companies were mainly involving other supply chain members as well. Only the semiconductor company build the entire business case internally. This was necessary due to the fact that it wanted to provide the customers with reliable and uncensored data from within the company.

The other projects involved all logistics service providers as well. This finding refutes the expectation of Kambil and Brooks (2002) who argued that most early RFID deployments would not be of collaborative nature. But it also indicates that the companies are aware that the greatest benefits of RFID solutions lie in a cooperative use of the technology by several supply chain members (McFarlane & Sheffi, 2003; Sheffi, 2004).

### 7.1.2. General evaluations of the use of RFID in supply chain operations

Because the nature of the examined projects was experimental due to the testing purpose, the given answers also contain a certain degree of criticism which results from the testing issues discovered in the pilots. These issues represent flaws in the technology from a user perspective. Interestingly, these shortcomings were addressed by four participants but not the participant from the semiconductor company which also produces integrated circuits (IC) for RFID transponders.

Among the detected weaknesses, the technical barriers for the use with products containing metal or liquids and problems with reading rates during bulk reading procedures were mentioned. Also the different standards used on different continents were brought up as a disadvantage leading to higher costs.

Nevertheless, the participants revealed mainly two groups of advantages of RFID technology compared to barcodes. They often mentioned the increased efficiency in scanning, identification and receipt processes and that the time savings enabled better inventory turns. The other main group relates to the increased supply chain visibility which resulted from more checkpoints and better tracking and inventory control. Additionally, the participants appraised RFID as a more robust technology, that it can be used in counterfeit protection and that it can become a standard which has coverage of more than one industry.

The participants expect to convert these advantages into business benefits. Better customer service with a higher supply chain transparency, less out-of-stock, increased sales, theft reduction, higher delivery reliability, increased inventory turns, and improved warehouse performance are expected to accrue in the examined industries. These findings resemble the benefits expected by McFarlane and Sheffi (2003). Interestingly, the stated benefits can be classified in two different themes. Benefits accruing to companies due to improved supply chain performance play the major role, whereas only the participant of the fashion and lifestyle company talks about improved sales performance due to less out-of-stock problems.

Estimations about the future relationship of barcodes and RFID technology were rather consistent among the participants, even across the different industries. They expect a co-existence of the two for the following reasons:

- bar code has broad coverage today,
- bar code is still cheaper and more reliable,
- investments required to switch to RFID,
- RFID is only sensible for high value goods due to low prices of bar codes,
- RFID is not mature enough, and
- barcodes are needed in order to provide a human-readable code in case the tag is damaged

As can be seen, the trust in the technology was not 100% as the participants mentioned the barcode symbols and numbers were still needed in case the transponders did not function as expected.

Nonetheless, the outlook given on the longer term (more than five years) of the barcode and RFID relationship is in favour of a substitution as RFID is expected to provide more benefits and the possibility of value added services. However, the majority of the participants does not expect a complete substitution to happen within the next ten years.

When comparing the RFID deployments in the different industries, the price of the products is associated with the data collection level. In general, it can be said that the more expensive the product, the lower the data collection level is. Whereas the item-level information of single wafer cartons justifies the price of a smart label, information about single shampoo bottles with small margins is not economic but information on pallet level serves its purpose. Currently, the mail-order and online retailer makes use of RFID labels only on high valued goods but plans to extend the use to cheaper goods as soon as the prices for transponders fall below certain price levels.

Concerning the barriers of widespread RFID technology integration, the participants mentioned different themes. Some stated that the technology is not mature enough and made reference to problems with bulk reading procedures, one of the main benefits which accelerates warehousing and loading processes. Here the required reading rates are seldom reached. But also the costs of the transponders and reading devices compared to barcode solutions are seen as a hindrance for fast large scale RFID applications. The participants also stated that the inconsistencies in the RFID standards both in frequencies and protocols, which were mentioned in chapter four, were posing problems because global standards would be needed. Davenport and Brooks (2004) found that a single supply chain member cannot individually decide on a technology vendor, thus, being a reason for hesitation. Nevertheless, the printer supplier and its two partners proved that the technology from different suppliers deployed in different standards locations worked along the supply chain. Only the costs due to the different standards requirements were mentioned as a barrier.

But the participants also see other hindrances, for instance that current systems do not reflect RFID processes, and that there is lack of professional knowledge in the companies which could deploy RFID technology.

Also, the participants are aware that privacy issues with private end-consumers need to be addressed by government regulations before open loop RFID systems can be securely deployed in retail stores.

Unfortunately, none of the examined projects dealt with more sophisticated types of RFID technology. This is probably related to the analysed industries. The business scenarios did not require sensors to be deployed. Such systems can be expected to be used for instance in the food section of the consumer packaged goods industry or along the pharmaceuticals supply chain.

## *7.2. Impacts of RFID use on Supply Chain Management Systems*

With the intention of gaining a better understanding of the current supply chain integration efforts and to situate the RFID technology introduction in a superior supply chain management strategy, the researcher asked questions about the current supply chain integration efforts of the companies. The answers revealed two distinguishable themes. The participant from the logistics service provider explained the goal of becoming the market leader in the segment of lead logistics providers, which means that the company consults, plans, and controls entire supply chains of other companies with their own logistics capacities. Therefore, the company's integration focus lies in the external supply chain. Also, the participants from the fashion and lifestyle, mail order, and printer supplier companies stated that they were concentrating their efforts on external supply chain integration.

> "external integration in order to boost supply chain efficiency and shorten time to market"

> "external; to develop better relationships with supply chain partners for better customer service"

> "external integration; link systems and provide and use real time data for plan updates and corrections; to provide more accurate information for the customers"

These comments indicate that the introduction of RFID technology is part of a larger systems' integration intention among supply chain members.

However this was not the case with the semiconductor producer whose participant stated that the RFID project was only used for the internal integration efforts, he added that it was also planned to integrate external systems in the pilot scheme in order to "to leverage the potential with customers as well". So in the long term RFID technology fits into or facilitates the external system integration reflected by the supply chain management system development.

Concerning the experienced and expected impacts of RFID technology on supply chain management systems in the industries, the participants' statements are aligned with the projections found in literature (McFarlane & Sheffi, 2003; Davenport & Brooks, 2004; Sheffi 2004; Angeles, 2005). From a bottom-up perspective, the mentioned impacts which are all depicted in figure 5 start with redesigned, faster scanning processes which lead to improved stacked lead time. Because the data collection level mainly shifted to lower levels and even towards item-level in three cases, the systems are provided with a higher granularity of data. Additionally to the higher granularity, the more efficient scanning processes allow for more check points which can be integrated along the supply chain. The previous labour- and time-intensive barcode scanning processes forbid a higher number of check points. Therefore, the occurring data volume is increased by the shifted data collection level and the higher number of check points.

The faster and higher information availability allows the supply chain management systems to conduct real time data processing. However, as already stated, only two of the participants stated that they were actually using real time data. Faster data processing in turn leads to "increased information visibility" and "better supply chain visibility" together with greater system integration. In terms of the impacts on business performance, one of the participants reported "increased inventory turns", "better delivery reliability and warehouse performance". Other participants stated they could provide better customer service because of fewer out-of-stock situations which also lead to higher sales. Therefore, RFID is seen as serving the main goal of supply chain management, namely increased customer service.

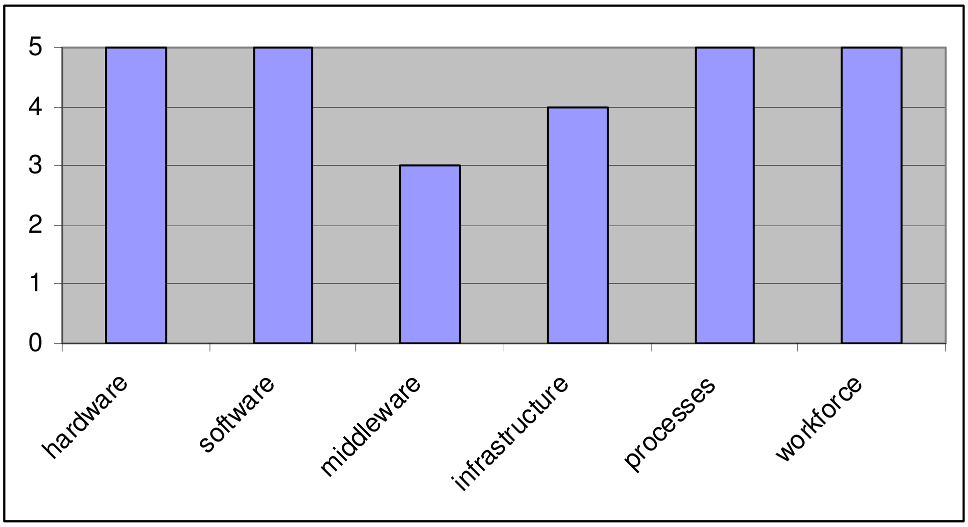


**figure 5: affected SCM system parts in RFID technology introduction as mentioned by the research participants**

As the literature review has indicated, the extent to which SCM systems are thought to be impacted by RFID technology introduction varies greatly. Nevertheless, the participants showed a more uniform assessment of the impact. They found that in each case, the hardware, software, processes as well as the workforce were affected. Additionally, the RFID technology introduction affected infrastructure (for instance warehouse design) in four cases and middleware was impacted in three cases.

These findings oppose Morán, Ayub, and McFarlane (2003) but support the methodologies for system integration presented by Chang et al. (2002). They also show that disregarding required modifications of business information systems as found by Morán, MacFarlane and Milne (2003) was not the case with the participants' pilot schemes.

Regarding the main integration efforts which were encountered in the SCM systems integration, the cooperation of all supply chain partners was especially mentioned. Four of the five participants stated that the alignment of the partners' systems or the cooperation between the partners was the critical integration effort.

> "standardize the data management between the supply chain partners"

> "cooperation of all SC partners"

> "integration of the partners' SCM systems and providing an open platform"

It seems that one of the most crucial aspects of external supply chain integration in RFID projects is rather not of technical nature but a question of how supply chain members are able to cooperate. But the comments also highlight the importance of a standardised data structure and a harmonised system landscape between the supply chain members.

Nonetheless, the participants also stated that the integration of new hard and software, warehouse management system adaptations, and process-reengineering were among the main integration efforts. The latter required intensive testing because the location of transponders on packaging must be considered as well as the direction of the products on the pallets to allow for bulk reading.

The analysis of the gathered data has shown that companies are still testing RFID technology in small scale business scenarios. Nevertheless, they do so mostly together with supply chain partners in order to leverage benefits. This testing reveals several shortcomings in the technology which most certainly will be addressed by the RFID producers within the next years. Regarding the integration with supply chain management systems, not only technology related but also organisational and behavioural issues have been encountered in the surveyed cases.

# 8. Discussion

The examined cases of RFID deployment in supply chain operations show that companies are already using the technology. Nevertheless, the limited extent to which they deploy RFID solutions shows that they are still hesitating to use it at a full scale. Because of the lack of knowledge in companies and because of problems of technical nature, mainly pilot schemes are conducted. The participants stated that there are still technological barriers which need to be overcome. These include faultless reading processes with products and packaging containing metals and liquids. But also the performance of RFID hardware in bulk reading processes needs to be addressed by the producers of RFID systems and components. Not until these deficiencies are overcome, are widespread global and industry crossing RFID deployments likely to be seen. These are the main reasons for better performance and more efficient processes compared to barcode solutions. As long as the technology is not mature enough to deliver these promises, companies will keep on hesitating to deploy it.

Apart from the technical advantage and its availability, costs still represent a major hindrance in mass deployment. Whereas high value goods can already be tagged economically on item level, lower value goods with small margins (as can be found in the fast moving consumer goods industry) are still far from being individually identified at reasonable costs. But despite the costs for such item-level identification possibilities, the benefits must be considered. Is it sensible to individually identify for instance every yoghurt pot? From the perspective of one producer it means that out of stock situations are likely to be avoided and thus sales increased. But when every yoghurt producer makes use of such RFID solutions, is it likely that people consume more yoghurt and the total yoghurt market expands? Only the early adopters in such a scenario can leverage RFID technology and expand their market share at the expense of the (late) followers.

Often producers claim that RFID item-level identification will reduce costs for recalls. The logic in such a scenario may be clear, as affected products can be uniquely identified. But should companies not focus on preventing the sources for failures rather than curing the symptoms?

With regard to item-level identification, the end customer plays an important role even for supply chain operations. As stated by the research participants, the acceptance of item-level RFID solutions by the end-customer is ultimately needed because of privacy issues. The companies deploying item-level RFID solutions where the transponders are not deactivated during the transfer of risk are very careful not to violate privacy rights but still have to fight accusations from consumer rights groups. These groups oppose the technology in a fashion similar to those who opposed the emergence of cellular phones in fear of being monitored and eavesdropped. The advantages of item-level tagging for consumers are still far from being available. Therefore, companies have to consider privacy issues very carefully especially until there are no regulations governing the use of RFID solutions.

The price issue being currently debated takes the form of the chicken and egg problem. The users of RFID transponders claim that they will deploy systems with massive numbers of transponders as soon as the prices fall. And yet at the same time, the industry leaders producing RFID devices and transponders argue that the prices will fall as soon as more RFID mass deployments are in place. As the examined cases have shown, in most cases it takes more than one company to economically deploy RFID solutions. But along a supply chain, the costs as well as the financial benefits of RFID deployments vary for each supply chain member.

One way out of this problem is the emergence of solution providers which supply the RFID systems for an entire supply chain and develop innovative concepts which allow for an equitable breakdown of costs according to benefits. Due to the complexity in business and supply chain operations this is hardly achievable. Nonetheless, RFID costing concepts in which supply chain members are charged according to the accessed information are already being developed.

However, the current RFID mandates by retail companies such as WalMart, Tesco, and Metro do not necessarily reflect this. The retailers' power over the end-customer is high enough that they can force their suppliers to meet their RFID requirements. However, it can be expected, that such forced mandates do not reap the benefits which accrue for RFID solutions where companies, on their free will, explore and apply the technology. This goes along with the findings of this study where the pilot project for such a mandate only used pallet-level tagging and tested automation of the previous barcode scanning processes.

The participants assess the coexistence of the barcode and RFID technology as the dominant form for automatic identification within the next five years. Because the system stability of sole RFID solutions is not high enough for supply chain operations, a combination of barcode and RFID will be used. This solution brings the advantage that exception handling with non-working RFID transponders can be solved with barcode scanning or manually entering the human readable numbers. Because reading errors are even likely to occur with more advanced RFID technology it is questionable if a complete substitution will ever take place. However, the participants expected that the substitution will take place at some point in time, but that it will not happen within the next five years.

One way out of this is the development of polymer ICs for transponders which can be printed directly on products. Together with human-readable numbers they might replace the currently deployed smart labels which are impractical on small products and packaging due to their size.

Also, as long as packaging and not the products are tagged, a solution along the entire supply chain is not possible as products are unpacked before they are processed. The data might be collected and available along the supply chain. But the transponders can only be used in the picking, loading, shipping, unloading and goods received processes. As soon as the product is taken from its tagged packaging, it is disconnected from the transponder and its data. Additionally, after it is processed, a new transponder must be attached. These solutions bear inconsistencies and are likely to drive costs. In order to provide the discussed and expected supply chain visibility it is necessary to directly equip the products with transponders. Otherwise, it is likely that the connection of the data with the product is unsustainable. Interestingly, none of the participants mentioned this problem and also the researched literature contained no discussion on that topic.

However, the examined cases showed the participants' views on standardisation issues. Even though EPCGlobal already developed global standards in form of the EPCGlobal Architecture Framework, which in its latest version is closely aligned with the ISO standards, the different frequency bands regulated by postal and telecommunication institutions of the countries pose problems. Even though one of the examined pilots schemes successfully integrates an inter-continental RFID solution with several technology vendors involved, the participant mentioned that this is a suboptimal solution due to the higher costs for devices which support the different standards involved.

Nonetheless, the integration of supply chain systems and the cooperation of the supply chain members is seen as one of the crucial factors in RFID technology introduction projects. It seems that it is an organisational problem to gather all supply chain members together and get them pushing in the same direction. But, for instance, the standardisation of the data management and exchange between systems is taking efforts which the companies could have realised before the advent of RFID technology (since the data collection method does not determine how the data is exchanged between systems). Nevertheless, the participants' attitudes give the impression that they see RFID as a vehicle towards tighter system integration.

# 9. Conclusions

As an emerging technology, RFID is a currently often-discussed topic when process optimisation, efficiency gains and better supply chain visibility and integration are sought after. In the aftermath of large retail companies forcing their suppliers to use RFID technology, more and more companies consider RFID technology as a way to reach long term strategic objectives.

From the series of questionnaires and the conducted interview, insight about the current use of RFID in supply chain operations and how this use impacts supply chain management systems could be gained and key findings were:

- RFID projects of the sample surveyed are overwhelmingly carried out as pilot schemes deploying passive smart labels. The costs and associated risks of large-scale roll-outs are regarded as too high because knowledge in the companies about the technology and its deployment is not sufficient yet.

- Co-existence of barcodes and RFID (in form of smart labels) can be expected at least over the next five years because a backup for defect transponders is needed.

- The current use of RFID technology mainly serves as automation of previous processes whereas the promised extending advantages, for instance the possibility to store more data or to include sensors, are not exploited yet.

- RFID is used as a vehicle for tighter supply chain and systems integration between supply chain partners which theoretically could have taken place before and without the technology.

- The greatest barrier in RFID projects which include several supply chain members is the organisational task to align and coordinate the members towards the common goal and the synchronisation and standardisation of the various systems along the supply chain.

As the conducted research has shown, RFID deployment in supply chain operations is not yet running routinely. Companies are mainly carrying out pilot schemes to evaluate business cases and test the technology. However, these pilot cases reveal weaknesses in the technology itself and flaws in the initially expected possibilities and business benefits. The identification of these deficiencies helps to improve the quality of offered systems, identify best practices, and, maybe above all, clarify what the technology is actually able to deliver. The recent hype about RFID has led to exaggerated assumptions and hopes among many companies which could not (yet) be met. But as expert knowledge about RFID is still rare at most companies, a more realistic assessment of the possibilities without pilot schemes cannot be expected in the near future.

The deployed solutions are based on passive smart labels, a combination of RFID transponder and printed bar code. In this way, problems with defective transponders can be anticipated with exception handling routines as the barcodes can still be scanned or the corresponding numbers can be entered manually into the systems. But still, bulk reading operations where entire pallets with tagged items should be read simultaneously are not working properly with the passive smart labels. Exact placement on the packaging and correct direction on the pallets may increase reading rates but need to be figured out beforehand and strictly maintained. Such routines demand training of the staff in order to deliver the required results.

Concerning the purpose of RFID technology and what it delivers, mainly an automation of previous scanning processes and operations such as picking, counting, stock keeping, loading and unloading can be seen. As budgets are small, positive business cases are strictly required which only leads to solutions on proven applications.

Also, despite the efforts of the two large standardisation bodies EPCGlobal and ISO, differences in regional standards represent a hindering factor in global RFID supply chain applications. Nevertheless, one of the examined cases showed that the technology vendors developed devices which can deal with the different standards' requirements. But still this situation means higher than necessary costs. Especially in industries with low value items and low margins per product, the current status remains prohibitive for global roll-outs.

Based on the sample taken, the development of new value-adding functionalities and services has not taken place yet. Neither the possibility to store more data on the transponders nor the combination with other technologies such as sensors is yet exploited largely. Nevertheless, it can be expected that key players in the fast-moving consumer goods and pharmaceutical industries will experiment with and examine these. Research in this field of RFID deployment needs to be conducted.

As some companies are forced by their customers to adopt RFID technology, their motivation differs from companies examining RFID which wish to use the technology to its benefits of their own free will. However, these differences should be further researched as insight can be expected to prevent suboptimal and costly RFID applications.

Concerning the role of RFID in supply chain management systems, the conducted research shows that RFID technology acts as a system enabler which delivers the needed granularity of item information and greater number of check points for higher supply chain visibility in real-time. Even though supply chain processes have been redesigned because of RFID introduction, the design of entire supply chains has not been affected yet. But RFID is used as a medium to integrate systems along the supply chain. Data structures are standardised in order to allow efficient data exchange among the supply chain members.

These efforts theoretically could have been realised before, as the data collection method does not determine the data exchange. But when situating the advent of RFID technology and the development of business information and especially supply chain management systems, it becomes clear that the company internal integration of systems and data which was realised with the ERP systems in the 1990s preceded the external integration possible only since the development of APS and SCM systems. As discussed in the literature review, this order is widely regarded as superior. Therefore, RFID integration can be regarded as the logical next step in supply chain integration and supply chain management system development.

Still, the coordination of supply chain members proves to be a major factor influencing the progress speed and ease of the RFID introduction process. As the development of open systems and the sharing of crucial information along the supply chain require trust among the supply chain members and especially when companies simultaneously operate in several supply chains, standard procedures and regulations need to be in place. Therefore, further research in the behavioural and organisational issues of the coordination and integration of supply chain members with regard to RFID applications should be conducted.

As current RFID applications do not yet span complete supply chains, the possible inconsistency along the supply chain when packages and not products are tagged has not emerged. However, it is felt, that this issue needs to be researched.

This study was conducted to provide information on the current use of RFID technology in supply chain operations and its impacts on supply chain management systems. As RFID technology can provide important business benefits, the results of this research deliver a better understanding of current problems and issues in RFID technology introduction and show which factors influence the level of success of such projects. As presented in the literature review, a better understanding of these issues will facilitate RFID technology introduction and further development of the technology itself. Also, the discovered impacts on supply chain management systems will enable decision makers of RFID projects to more quickly identify common problems before they occur. Hopefully this will lead to smoother and faster supply chain integration on the basis of RFID technology introduction in supply chain operations.

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# APPENDICES

Appendix 1:

Questions and answers of the questionnaires:

| | | | | |
|---|---|---|---|---|
| **Demographic Data:** | | | | |
| 1. What is your age? | | | | |
| | 30-39 | | 40-49 | |
| 2. If you have higher education, was your higher education in the area of | | | | |
| | technical education | technical education | business education | technical education |
| 3. What is your position within the Company? | | | | |
| Project Manager Consumer/Retail | Head of Logistics | Project Manager | Logisctics Manager | CIO |
| **About the company and SCM and SCM systems** | | | | |
| 4. Where do you see the main focus in the current supply chain integration efforts of your company (i.e., internal or external) and what is the reason? | | | | |
| development of best in class LLP capabilities | external integration in order to boost supply chain efficiency and shorten time to market | external; to develop better relationships with supply chain partners for better customer service | external integration; link systems and provide and use real time data for plan updates and corrections; to provide more accurate information for the customers | internal because we showcase the benefits of RFID and generate a positive business case, but we plan to leverage the potential with customers as well, in future rather external |
| **About RFID technology in your industry** | | | | |
| 5. Please list some main impacts of RFID technology on SCM systems in your industry | | | | |
| faster information availability, more check points | real time data, increased information visibility, faster processes | higher granularity of data, more check points, better supply chain visibility | higher system integration, real time data processing | redesigned processes, tighter integration, increased inventory turns, improved stacked lead time, better delivery reliability and warehouse performance |
| 6. Where do you see the major business benefits of RFID in your industry? | | | | |
| transparency of SC, more sales through higher consumer satisfaction, quality, efficiency | less out of stock, increased sales | theft reduction, faster and cheaper identification processes, better tracking and inventory control | better customer service through higher delivery reliability, reduced costs because of better tracking information | increased inventory turns, improved customer service, improved stacked lead-time, better delivery reliability and warehouse performance |
| 7. How do you see the future relation of Bar Codes to RFID in your industry? (Substitution, | | | | |

| | | | | |
|---|---|---|---|---|
| Co-Existence) And what are the reasons? | | | | |
| Within the next 5 years: | | | | |
| co-existence: bar code has broad coverage today. RFID is not mature enough, investments required to switch to RFID. | co-Existence, bar code is still cheaper and more reliable | co-existence, RFID is only sensible for high value goods due to low prices of bar codes | co-existence because barcodes are needed in order to provide a human-readable code in case the tag is damaged | first co-existence but slowly, as more and more companies understand the benefits and are able to implement, substitution will take place |
| 5 years and longer: | | | | |
| substitution: RFID will give more benefits long term | substitution, but will take longer than 10 years | substitution, but not within 5 years; RFID delivers more possibilities and value added services | substitution because RFID solutions already have ROI | substitution, because RFID is superior to barcode |
| 8. What are the benefits of RFID over Bar Codes in your industry? Please list up to three. | | | | |
| efficiency, More information available, robuster technology, coverage of other industries | faster scans, less errors, counterfeit protection | better tracking and inventory control, supply chain visibility | faster scanning processes, higher supply chain visibility | more efficient receipt processes and thus better inventory turns |
| 9. What are the disadvantages of RFID in your industry? Please list up to three. | | | | |
| technical barriers for metal and liquids; standards not completely defined yet, differences in standards on different continents. | lower reading rates | problems with reading rates in combination of metal and liquids; costs of tags | technology could be further developed (bulk reading problems) and differences in regional standards drive costs | barcode is widely adopted and RFID and especially item-level tagging requires major integration efforts |
| **About RFID at the company** | | | | |
| 10. What was the motivation for the RFID technology introduction? | | | | |
| cost reduction, enhanced supply chain visibility, more accurate and efficient scanning processes, requirement of customer | test for cost reduction, theft reduction, more accurate and efficient scanning processes, item-level information | evaluate the technology for theft reduction, item-level information, more accurate and efficient scanning processes, use of more data | to gain insight in shipment status and location of goods while in transit to provide better customer service with better forecasts and test the possibility to deploy a solution in different standard-regions | cost reduction, enhanced supply chain visibility, more accurate and efficient scanning processes |
| 11. Please give a short description of your RFID project: | | | | |
| Metro Future Store Initiative pilot with J&J | logistics service provider tags products and logistic units with | high value items are tagged in central warehouse before shipment to | shipments are tagged in German warehouse then forwarded by | pallets, cartons and individual packaging items are tagged at |

| | | | | |
|---|---|---|---|---|
| | tags and sends them to the retailer were the products are scanned during control of goods received, used for stocktaking and check out, but at check-out disabled | logistics service provider and scanned along the shipment, order picking and distribution in order to prevent theft. | logistics service provider and shipped by airfreight carrier to North America. From there the shipment goes to the customer or in a warehouse. at each station the shipment is scanned and information is provided to the other parties | manufacturing site and read during receiving process at distribution centre |
| 12. What type(s) of RFID technology are used? (you may tick more than one) | | | | |
| passive | passive | passive | passive | passive |
| 13. What kind of data do you collect with RFID? | | | | |
| EPC | EPC | article number, shipment number, internal return identification number | EPC | EPC |
| 14. If the data collection level was affected, how? | | | | |
| not affected, both on pallet level | pallet to pallet and item level | now item level | case level now | from case to item-level |
| 15. If you collect and effectively make use of real time data through RFID technology, how? | | | | |
| not yet | in stock keeping data is gathered and reflected by the systems | not yet | RFID event information is combined with route maps which are updated immediately to reflect the time differences between plan and actual execution | not yet |
| 16. If you collect real time data with RFID, what are the resulting business benefits? | | | | |
| not yet | better customer satisfaction because less out-of-stocks, more sales | not yet | more timely information about location and more accurate information about shipment and expected arrival time lead to higher customer satisfaction, less express charges in case of delivery problems | not yet |
| 17. Which parts of the existing SCM system are or were affected by the RFID technology introduction | | | | |
| hardware, software, infrastructure (e.g. warehouse design), processes, workforce | hardware, software, middleware/architecture, Infrastructure (e.g. warehaouse design), processes, | hardware, software, processes, work force | hardware, software, middleware/architecture, infrastructure (e.g. warehouse design), processes, | hardware, software, middleware/architecture, infrastructure (e.g.warehouse design), processes, |

| | | | | |
|---|---|---|---|---|
| | workforce | | workforce | workforce |
| **18. Where are the main integration efforts to align the existing SCM system?** | | | | |
| cooperation of all SC partners | integration of new hard and software, standardize the data management between the supply chain partners | to align the systems with the supply chain partners system | integration of the partners' scm systems and providing an open platform | process-reengineering, warehouse management system adaptations |
| **19. What are the expected business benefits?** | | | | |
| improved SC efficiency and visibility | complete control of goods received process, automated stocktaking process, less data entry errors, less out-of-stock, faster check-out, more time for the customer resulting in better service; all leading to higher sales | theft reduction, better customer service | higher customer satisfaction, cost reduction | increased inventory turns, improved customer service, improved stacked leadtime, better delivery reliability and warehouse performance |
| **20. (a) What is the scope of RFID technology introduction?** | | | | |
| with both | with logistics service provider and retailer | with logistics service provider | with logistics companies | internal project |
| **20. (b) Is it a pilot project or a global rollout?** | | | | |
| a pilot project | pilot project | pilot project (used after successful trial period) | pilot project | pilot project |
| **21. Have you already completed RFID integration projects?** | | | | |
| No | no | yes | yes | yes |
| **Barriers to RFID technology integration** | | | | |
| **22. What do you see as the barriers to introduction of RFID technology to SCM systems?** | | | | |
| consumer privacy protection regulations, technical regulations, technology not mature , standards in development | costs compared to barcode, lack of global standards, privacy concerns of end customers | current systems do not reflect RFID specific processes; prices of transponders, privacy issues | lack of professional knowledge about the technology in many companies, standardization issues | uncertainty of possible users as the hype has not produced enough valid business cases, they do not know what they can expect and how to successfully implement RFID technology |
| **23. What impacts do these barriers have on introduction of RFID technology?** | | | | |
| limited global coverage therefore no active implementation yet, Without expected performance and proper standards no real benefits to implement | longer tesing phase as performance problems limit the use of RFID, limited business benefits | delayed implementation | implementation costs are high and companies do not use the technology as they could because they do not know enough about it | introduction phase is postponed and actual introduction will take place step-wise to provide the companies with growing knowledge before global roll-outs |

Appendix 2:

Questions asked during the interview and notes taken during and after the interview

<table>
<tr><th colspan="12">About the company and SCM and SCM systems</th></tr>
<tr><td colspan="12">1. What are the particularities of the supply chain in which your company is operating and how are the resulting requirements met by the SCM systems?</td></tr>
<tr><td colspan="6">production facilities are mainly based in South-East Asia and from there we ship to our distribution centers where the shipments are processed and send to the customers world-wide.</td><td colspan="6">member of Rosettanet, open e-business process standards on a global scale</td></tr>
<tr><th colspan="12">About RFID technology in your industry</th></tr>
<tr><td colspan="12">2. Why is RFID used in your industry?</td></tr>
<tr><td colspan="3">to improve tracking</td><td colspan="3">optimize receiving processes</td><td colspan="3">automate scanning</td><td colspan="3">save costs</td></tr>
<tr><td colspan="12">3. What are the impacts of RFID technology on SCM systems in your industry?</td></tr>
<tr><td colspan="4">visibility in the systems is enhanced because of more data available due to more check points as well as higher granularity of data</td><td colspan="4">unique item-level identification produces more data</td><td colspan="4">data exchange is becoming more standardized</td></tr>
<tr><td colspan="12">4. Why didn't you use more check points and item-level identification with barcodes?</td></tr>
<tr><td colspan="6">scanning processes were to slow and thus to expensive</td><td colspan="6">existing barcode schemes did not allow for item-level identification</td></tr>
<tr><td colspan="12">5. Where do you see the major business benefits of RFID in your industry?</td></tr>
<tr><td colspan="2">increased inventory turns,</td><td colspan="2">improved customer service,</td><td colspan="2">improved stacked leadtime,</td><td colspan="2">better delivery reliability</td><td colspan="2">and warehouse performance</td><td colspan="2">reduced warehouse space</td></tr>
<tr><td colspan="12">6. What are the disadvantages of RFID in your industry?</td></tr>
<tr><td colspan="6">technological barriers when products contain metals and liquids</td><td colspan="6">process reengineering, especially because location of tags must be considered and products must be piled in the right direction on a pallet</td></tr>
<tr><th colspan="12">About RFID at the company</th></tr>
<tr><td colspan="12">7. What was the motivation for the RFID technology introduction?</td></tr>
<tr><td colspan="6">showcase RFID use to customers</td><td colspan="6">demonstrate positive business case</td></tr>
<tr><td colspan="12">8. What was the goal of the project?</td></tr>
<tr><td colspan="6">demonstrate that RFID technology is ready to be implemented with outstanding reading rates</td><td colspan="6">positive ROI even as internal SC project</td></tr>
<tr><td colspan="12">9. What part did the integration with and adaptation of SCM systems play in your decision?</td></tr>
<tr><td colspan="3">here come in the changes and the business benefits</td><td colspan="3">process redesign and reengineering was the longest part in the project</td><td colspan="3">these changes had to be considered in the systems</td><td colspan="3">one of the main reasons for the project</td></tr>
<tr><td colspan="12">10. Why do you expect or experience benefits from the more detailed level of information with item-level identification?</td></tr>
<tr><td colspan="3">the information provides a better view on the shipments we receive</td><td colspan="3">we do not have to unpack the pallets and check them again but just know what is on there and</td><td colspan="3">can check for completeness</td><td colspan="3">the process is faster, cheaper, more accurate</td></tr>
<tr><td colspan="12">11. Which parts of the existing SCM system are or were affected by the RFID technology introduction and how are or were they affected? (e.g. Hardware, Software, Infrastructure (e.g. Warehouse design), Architecture, Processes, Work force)</td></tr>
</table>

<table>
<tr><td colspan="3">mainly the processes where affected and this was reflected in the time spent on the redesign of them</td><td colspan="3">the existing ERP system were not as much affected as the warehouse management systems which needed to be mapped to the new processes and the new information level</td></tr>
<tr><td colspan="6">12. Where do you see the main integration efforts to align the existing SCM system?</td></tr>
<tr><td colspan="3">the main effort was in the alignment of the new processes</td><td colspan="3">the staff needed to understand why processes are changed and to be actively involved in the testing phases</td></tr>
<tr><td colspan="6">Barriers to RFID technology integration</td></tr>
<tr><td colspan="6">13. Where do you see barriers to RFID technology introduction to SCM systems?</td></tr>
<tr><td colspan="2">uncertainty at the possible users of RFID</td><td colspan="2">lack of knowledge,</td><td colspan="2">fear of non-compatibility of systems with future standards</td></tr>
<tr><td colspan="6">14. What impacts do these barriers have on RFID technology introduction?</td></tr>
<tr><td colspan="2">hesitation</td><td colspan="2">as long as the hesitation persists, the prices of the systems won't come down and implementation costs are not likely to decrease fast</td><td colspan="2">companies which implement now or already have done so will have competitive advantages and eventually the followers are too late to catch up because they cannot build up as much knowledge</td></tr>
</table>

Appendix 3:

Information sheet sent along with questionnaire to participants

**Information Sheet**

**RFID technology introduction and impacts on supply chain management systems – A comparative study**

This research project is about RFID technology and its impacts on supply chain management systems. The latest developments in RFID technology allow for a better and more widespread use throughout the entire supply chain. As a decision maker regarding Supply Chain Management in your company, your responses and ideas would be most valuable for us and you will receive the outcome of this study.

I would be grateful if you would take a few minutes (about 15 – 30 minutes) to complete the enclosed questionnaire. You are more than welcome to make any additional comments if you like, simply by typing your words in the end of this sheet.

Your contact information will not be given to third parties or used for marketing purposes.

If you have any further questions or would like to comment on this survey, please contact me by email (rochel@consultancy.ch) or phone +49 6174 937390 or my supervisor Logan Muller at Unitec Institute of Technology, Auckland / New Zealand.

**Please send the survey back by**

- **email (rochel@consultancy.ch),**
- **fax (+49 6174 937373)**
- **or Mail**
  **(Roman Rochel, Goethestr. 38, 61462 Königstein, Germany).**

Thank you for your help and have a nice day!

Appendix 4:

Declaration: Is ethical approval needed for my research?

**1. PROJECT/THESIS TITLE:**

RFID technology introduction and impacts on supply chain management systems

| Dissertation or thesis? | Dissertation |
|---|---|

**2. BRIEF DESCRIPTION OF PROJECT:**

Briefly describe the major aim(s) of the project (up to 50 words)

The impacts of RFID technology introduction on supply chain management systems will be examined by a comparative case study project. The aim is to understand the impacts in different industries and to compare the findings.

**3. PRINCIPAL RESEARCHER (STUDENT)**

| | | | |
|---|---|---|---|
| Name: | Roman Christian Rochel | | |
| Address: | **Goethestr. 38, 61462 Königstein, Germany** | | |
| Email | rochel@consultancy.ch | Phone/ext | **+49 6174 937390** |
| UNITEC Student ID# | **1200001** | | |

**4. DECLARATION:**

**The information supplied is, to the best of my knowledge and belief, accurate. I have considered the ethical issues involved in this research and believe that I have adequately addressed them. I understand that if the methods used in this research change in any way I must inform my Supervisor and Programme Director and obtain their written approval before proceeding. I/We will comply with all other UNITEC policies and the laws of New Zealand.**

| | Signatures | Dates |
|---|---|---|
| Principal researcher: | | |
| Supervisor: | | |

**I have read this form, understood the nature of the research project and declare that it complies with all ethical standards and policies. It is appropriate for this research to be conducted in this school.**

| | Signature | Date |
|---|---|---|
| Programme Director: | | |
| Head of School | | |

Appendix 5:

Checklist: Is ethical approval needed for my research?

| | | Yes | No |
|---|---|---|---|
| **1** | Have you accessed advice from the Ethics Committee in relation to your project, or had access to and read the Policies and Procedures of the Research Ethics Committee? | ☑ | |
| **2** | Are humans used as participants in the research? | ☑ | |
| **3** | Could humans (participants or researchers) be at risk of, or actually, adversely affected (physically, culturally, socially, financially, psychologically) by your research? | | ☑ |
| **4** | Will the participants be given relevant information relating to the project and what is expected of their participation? | ☑ | |
| **5** | Will they voluntarily consent, in writing or by return of questionnaires, to be involved in the project? | ☑ | |
| **6** | Will the methods achieve the stated objectives of the project? i.e. does the sampling methodology adequately enable stated objectives to be met and inferences to be made? | ☑ | |
| **7** | Do you have any known/special relationship with the participants? e.g. teacher-student, doctor-patient, friend/family | | ☑ |
| **8** | Could your research involve Maori as participants, either by deliberate selection or by random sampling? | | ☑ |
| **9** | Could your research affect Maori (directly or indirectly), or be of particular relevance to Maori? | | ☑ |
| **10** | Are members of a particular ethnic, societal or cultural group to be the principal participants or a sub-group of the research? | | ☑ |
| **11** | Are any participants limited in their ability to give informed and voluntary consent? e.g. children, disabled, infirmed | | ☑ |
| **12** | Are social and cultural sensitivities, or intellectual and cultural property issues, relevant to your group of participants?\ | | ☑ |
| **13** | Could the collection of information from or about your participants cause them physical or psychosocial harm, or create a risk of such harm (refer to the definition below)? | | ☑ |
| **14** | Can your participants be individually identified through the data collected, either directly or by inference, by the researchers or anyone else? | | ☑ |
| **15** | Are the participants asked potentially sensitive, incriminating, confidential or personal questions about themselves or their organisation? | | ☑ |
| **16** | Does the project require extraction or use of body tissues or fluids? | | ☑ |
| **17** | Is there any reason you are unable to store your data to keep it secure against unauthorised access, for 5 years following the completion of the project? | | ☑ |
| **18** | Has any other organisation provided financial or in-kind support for this project? | | ☑ |
| **19** | Are you unsure as to whether or not there may be any other ethically-relevant procedure in your project? | | ☑ |