Co-existence of RFID and Barcode in Automotive Logistics

Malte Schmidt
Volkswagen AG ITP Inhouse Logistics, malte.schmidt@volkswagen.de

Lars Thoroe
Chair of Information Systems and E-Business, lthoroe@uni-goettingen.de

Matthias Schumann
Universität Göttingen Chair of Information Systems and E-Business, mschuma1@uni-goettingen.de

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Malte Schmidt  
Volkswagen AG  
ITP Inhouse Logistics  
malte.schmidt@volkswagen.de

Lars Thoroe  
Universität Göttingen  
Chair of Information Systems and E-Business  
lthoroe@uni-goettingen.de

Matthias Schumann  
Universität Göttingen  
Chair of Information Systems and E-Business  
mschuma1@uni-goettingen.de

ABSTRACT
Today barcode is the dominant auto-ID technology in the automotive supply chain. The prevalence of barcode is likely to affect the adoption and diffusion of RFID technology. In this paper, we focus on the migration from barcode to RFID in the automotive industry and point out the relevance of barcode for future RFID rollouts. We study the case of a RFID pilot project to derive a concept for managing the technological co-existence of barcode and RFID technology. Our research demonstrates that the implementation of interfaces on multiple levels ensures the interoperability of barcode and RFID and supports companies in achieving gradual RFID migration in large-scale RFID rollouts.

Keywords
RFID, barcode, automotive industry, technological co-existence

INTRODUCTION
Radio Frequency Identification (RFID) is expected to increase supply chain efficiency and transparency (McFarlane and Sheffi, 2003; Gaulker and Seifert, 2007; Wamba and Bendavid, 2008). Barcode is the incumbent auto-id technology in logistics and has successfully conquered the automotive supply chain. The introduction of barcode technology has affected supply chain practice like few other technologies before (Suraj and Singh, 2009). In contrast to barcode, RFID enables bulk reading and does not require line of sight to identify objects. Due to these characteristics, RFID is considered to be the potential successor of barcode and may complement or replace barcode (McCathie and Michael, 2005). The increasing number of conducted RFID projects indicates that RFID is gradually getting more attention and may gain momentum in the near future. For large-scale cross-company applications, a big bang rollout of RFID is hardly possible, due to the number of objects which have to be tagged as well as the complexity of implementing the necessary reader infrastructure along the supply chain. In the recent past considerable progress has been made on adoption and diffusion topics but at this point there is little information that helps to understand the impact of barcode on future RFID migration scenarios. On the one hand the popularity of barcodes and entrenched business practices may slow down RFID migration (Tajima, 2007). On the other hand barcode solutions may turn out to be a prerequisite for RFID implementation and even speed up the migration process (Oehlmann, 2008). During the transition from barcode to RFID the automotive industry will rely on barcode to manage established logistic processes and provide appropriate backup concepts. Companies aiming to deploy RFID technology require approaches to promote RFID but support established barcode procedures in the meantime.

In this paper we identify technological co-existence as one of the principal challenges for RFID rollouts. We consult literature and identify interface principles as a feasible strategy to face related technology management implications. Our findings indicate that concepts which provide some level of compatibility and interoperability among new and incumbent technologies facilitate migration to new technologies. Subsequently we conducted a case study at the Volkswagen Aktiengesellschaft in Germany and transferred these principles to a real life project environment in the automotive industry in order to get an understanding on how interface principles are applied. Our case study shows that the Volkswagen Aktiengesellschaft implements technological interoperability on multiple levels. We identify these levels and demonstrate how the implemented interfaces promote gradual RFID migration. Information used in this paper was derived from extensive interviews with project members and by hands on project participation.

This paper is organized as follows: In the next section we summarize related work on RFID adoption and diffusion. In the following sections, we describe the models of technology migration and the concept of multilevel technology interfaces,
which we apply to a case of RFID implementation in automotive logistics. In the last section, we summarize our main findings and address identified research limitations.

LITERATURE REVIEW

Kwon and Zmud (1987) defined a comprehensive framework for studying technology adoption and diffusion in organizations. The framework distinguishes between five contextual factors which may affect technology diffusion: user community factors, organizational factors, technological factors, task related factors, and environmental factors. Each of these factors may impact any of six stages of technology implementation: (I) initiation, (II) adoption, (III) adaptation, (IV) acceptance, (V) routinization and (VI) infusion. Kye, Son and Cho (2008) developed an adoption and diffusion model for RFID technology to replace barcode. The model is based on the Kwon and Zmud framework and references the Technology Acceptance Model (TAM) proposed by Davis, Bagozzi and Warshaw (1989) to derive four stages of RFID adoption and diffusion: (I) adoption, (II) migration, (III) integration and (IV) diffusion.

In the recent years extensive research has been done on financial, technological, organizational and environmental aspects in order to identify relevant factors for RFID adoption and diffusion in industrial environments (cf. Strassner and Fleisch, 2003; Strassner, Fleisch, Ringbeck, Stroh and Plenge, 2004; Schmitt, Thiesse and Fleisch, 2007; Schmitt, Michahelles and Fleisch, 2008; Curtin, Kauffman and Riggins, 2007; Krasnova, Weser and Ivantysynova, 2008; Huber, Michael and McCathie, 2007; Matta and Moberg, 2006). Most of these works relate to the Kwon and Zmud framework and identify adoption and diffusion factors that may be classified according to the proposed categories. Numerous articles have been published that compare the characteristics of auto-ID technologies and help to get an understanding of the future positioning of RFID and barcode in the supply chain (cf. White, Gardiner, Prabjhakar and Razak, 2007; McCathie and Michael, 2005).

Michael, Michael, Tootel and Baker (2006) conducted an analysis of multiple auto-ID technologies (e.g. magnetic stripe, smart cards, barcode and RFID) and extracted principle patterns in the adoption and diffusion of auto-ID technologies. They point out technological (I) migration and (II) integration/hybridization as essential steps in adoption and diffusion process:

(I) Migration: Transition between barcodes and RFID technology.
(II) Integration/hybridization: The incorporation of barcode and RFID in one single object, device or process.

In many application scenarios, RFID is not likely to replace but to complement barcode technology, especially in the short and medium term. One single auto-ID technology is not likely to meet the needs of a complete end-to-end application in the supply chain. Based on historic evidence “auto-ID technologies usually work in concert to fulfill large-scale initiatives” (Michael et al., 2006). Whereas some authors take position for one technology or the other, the scenario of co-existing auto-id technologies seems to be widely accepted (McCathie and Michael, 2005; Wu, Nystrom, Lin, Yu, 2006; Chao, Yang and Jen, 2007).

MIGRATION PATHS

After many years of hyping RFID technology it becomes evident that the actual adoption and diffusion rates in the automotive industry lag behind the propagandized expectations (Schmitt et al., 2007). RFID has been used for years as a means to support internal production control and asset management (Strassner et al., 2004) but even today RFID technology “has not made a decisive step from the meeting rooms to real life in the supply chain” (Krasnova et al., 2009). In the last years several automotive companies have conducted projects to gain experience with the technology in supply chain domains. The Robert Bosch GmbH for instance implemented a RFID based Kanban system to enhance internal production supply (Faupel, 2009). RFID projects conducted by the Volkswagen Aktiengesellschaft in Wolfsburg (VW, 2009) and Puebla (O’Connor, 2009) have been completed successfully and resulted in the preparation of IT-infrastructures to cope with large-scale RFID rollouts. However, the time frame required to reach decent adoption and diffusion rates remains unknown, due to the vast number of RTIs which have to be tagged as well as the size of the required reader infrastructure.

Barcode and RFID fulfill similar tasks in the supply chain and are subject to comparable environmental influences. It seems reasonable to assume that the adoption and diffusion of RFID may require a similar time frame. It took approximately 25 years from the development of the first barcode in 1949 to the first large-scale commercial installation in 1974. A similar time frame has passed between the first demonstration of modern RFID equipment and larger implementations in the earlier 2000s (Wu et al., 2006).

Karshenas and Stoneman (1995) reason that it takes decades rather than years to reach decent adoption and diffusion levels for new technologies. There are indications that in the last decades the adoption and diffusion of new technologies has been accelerating (Comin and Hobijn, 2006). No matter how long adoption and diffusion will actually take – the automotive
industry needs to prepare for an extended migration scenario. As so far examples for the technological co-existence of RFID and barcode are relatively scarce we consult migration scenarios from other technology domains:

Hovav, Patnayakuni and Schuff (2004) analyzed the case of internet standards adoption and derived a model of optional adoption paths (see Figure 1). According to this model technology adoption may come in three principal shapes: (I) adoption through co-existence, (II) adoption through replacement or (III) straightforward implementation in case no comparable technology exists.

The model is transferable to the case of RFID and barcode in supply chain management even though the proposed options need to be put into perspective. The use of RFID in automotive logistics pertains to both forward logistics (e.g. identify material and parts) and reverse logistics (e.g. identify and track returnable transport units). Forward and reverse logistics are strongly interrelated thus progress in forward logistics is likely to affect adoption and diffusion in reverse logistics and vice versa. Barcode is a well-established auto-ID technology in forward logistics. However, it is hardly used in reverse logistics. The automation level which may be achieved using barcode is not high enough to track and trace transport units efficiently. The fact that RFID may be used to run both forward and reverse logistics is likely to have a positive impact on corresponding adoption and diffusion rates. With reference to forward logistics we may see a phase of replacement and/ or co-existence. In reverse logistics, RFID may ‘jump’ to direct implementation. Arguing from a cross-process perspective the automotive industry will have to manage a phase of technological co-existence. The proposed scenario will in parts be characterized by technological competition, a phenomenon which has been analyzed extensively in innovation theory. We will draw on selected works in the next section, in order to analyze technological co-existence of RFID and barcode in the automotive industry.

TECHNOLOGY INTERFACES

Jin, Soumya, Guérin, Hosanagar and Zhang (2008) explored the dynamics of competition between incumbent and emerging networking technologies. The authors refer to the migration of IPv4 (Internet Protocol Version 4) to IPv6 (Internet Protocol Version 6) and point out the importance of gateway or converter technologies to translate between the incumbent protocol and the new version. According to Jin et al. (2008) the role of gateways is a diverse one. A basic degree of interoperability among new and established technologies may either promote or hinder the adoption and diffusion of emerging technologies.

Nair and Ahlstrom (2003) studied the co-existence of technologies but argue from a different perspective. They emphasize the potential of meta-technologies to delay creative destruction. Their work references Arthur (1996) putting forward the case of Apple and Microsoft operating systems. Nair and Ahlstrom (2003) assume that Apple might have been able to prevent the dominance of Windows systems implementing a meta-technology to run Windows programs on Apple machines and vice versa from the very beginning. Pursuing this approach compatibility and interoperability are not just capable of facilitating the adoption and diffusion of emerging technologies but also expand the life time of incumbent ones. In the case of RFID and barcode technological interoperability may have a positive influence on adoption and diffusion of RFID, but may also delay the replacement of barcode technology and thus expand the phase of technological co-existence.

Meta-technologies and gateways/converters as proposed by Nair and Ahlstrom (2003) and Jin et al. (2008) respectively may interface between RFID and barcode technology. They allow running barcode and RFID supported processes simultaneously, thus enabling a gradual migration process. However, we assume that the principles of gateways and meta-technologies apply not just on a technological level but have to be seen in a broader perspective. The migration of RFID requires a multilevel approach. In this paper we use the term ‘technology interface’ rather than ‘gateway technology’ or ‘meta-technology’ and anticipate results of our case study to put forward the following definition:
Technology interfaces bridge the gap between barcode and RFID technology on an object, device, operational and informational level. On the object, device and operational level they allow to switch between the technologies involved. On the informational level they allow tracking both barcode and RFID readings in a dedicated IT-system thus providing visualization and analysis of the respective supply chain events.

In the following section we analyze the case of project LeoPARD and illustrate interface principles that are applied on multiple levels in order to manage the co-existence of barcode and RFID and promote gradual RFID migration.

**CASE STUDY: RFID AT VOLKSWAGEN AKTIENGESELLSCHAFT**

In 2008/2009 Volkswagen Aktiengesellschaft and two participating suppliers conducted the pilot project LeoPARD (Logistic Process Acceleration through RFID) at the Wolfsburg plant and nearby supplier facilities. More than 3000 containers were equipped with passive EPCglobal UHF Gen 2 tags (868 MHz) to support material logistics via RFID. RFID equipped forklifts and mobile handheld scanners were used to identify incoming materials and increase process efficiency in goods receipt (Figure 2).

LeoPARD implements RFID to support forward logistics. In the current project stage LeoPARD adds RFID-specific capabilities to the process but does not replace existing barcode solutions. The project at this stage demonstrates temporary technological co-existence of barcode and RFID implementations. On the long term, however, RFID may actually substitute barcode throughout the forwarding process.

LeoPARD integrates RFID into the existing process landscape rather than revolutionizing established process design. One of the principal project goals was to ensure process consistency of barcode and RFID supported processes. Volkswagen Aktiengesellschaft decided to implement a hybrid process which can be run by barcode or RFID depending on which technology is available in the involved process steps. Process consistency is expected to reduce error rates related to the deployment of new RFID procedures. The ability to switch between RFID and barcode technology ensures robust process design and provides a reliable backup solution for RFID, i.e. operational staff may revert to barcode in case RFID fails or is not available. The hybrid process is aiming for gradual migration of RFID technology. At this stage the RFID rollout covers a limited amount of operational areas and process steps only. There is no need to implement RFID all at once. The project team may proceed with the rollout activities step by step as long as barcode-based processes are supported in the meantime. The hybrid process design allows running barcode and RFID processes simultaneously and apply either barcode or RFID depending on the technological capabilities in each operational area. In the following we identify and address the interfaces involved in the process.

**Interface I: Object Level**

LeoPARD is not a stand alone rollout but relies on the previous implementation of the Global Transport Label (GTL). Both RFID tag and GTL are attached to the returnable transport item (RTI) and share a common unique identifier (link). The GTL implements a bar-coded License Plate that provides for unique package item identification and ensures interoperability with downstream warehouse and manufacturing systems. The License Plate is written to both GTL and RFID tag and may be read...
using either barcode or RFID technology. Oehlmann (2008) argues that joint standards for barcode and RFID on the object level stimulate RFID migration. Common standards pave the way for RFID to migrate into the supply chain applications smoothly. Industry consortiums such as AIAG and ISO/IEC developed guidelines that allow storing information on barcodes and RFID tags using interoperable data syntax.

LeoPARD takes an integrative approach regarding RFID migration. Barcode and RFID tag are separately attached to one and the same logistic entity but contain a common identifier to enable material handling. Volkswagen Aktiengesellschaft is not the only automotive company that applies a combined RFID and barcode approach on the object level. Bosch GmbH (Faupel, 2009) and Denso Corporation (Shibata, 2007) took a similar approach to run internal Kanban processes. Rather than applying barcode and RFID tag separately they incorporated both technologies in hybrid Kanban cards to cope with backup requirements and ensure interoperability with downstream processes. The described applications at Volkswagen Aktiengesellschaft, Bosch GmbH and Denso Corporation demonstrate integration and hybridization of auto-id technologies. In large-scale rollouts it is very likely that not all RTIs are equipped with RFID tags from the very beginning. Supplementary tagging may require considerable time period. Simultaneous approaches provide barcode as a potential backup solution thus may serve as a first step to achieve gradual RFID migration and replace barcode in the long run.

Interface II: Device Level

Interfaces on the device level refer to the technical capability of handling both barcode and RFID data, i.e. the technical capability of reading and writing of barcode labels and RFID tags. RFID and barcode capabilities are not necessarily incorporated in one single reading/writing unit. Hybrid approaches, however, incorporate both technologies thus may handle barcode and RFID information using one and the same device (hybrid handhelds, smart label printers).

LeoPARD implements both integrative and hybrid approaches. Suppliers use hybrid handheld scanners (read/write) to copy the License Plate information from the GTL label to the RFID tag. At the Volkswagen Aktiengesellschaft RFID-equipped fork lifts are used to identify shipments. Whenever containers are not equipped with RFID tags or the License Plate information has not been written to the RFID tags, traditional handheld barcode scanners are used instead.

Interface III: Operational Level

Interfaces on the operational level refer to operational areas (i.e. shipping department, goods receipt) that are capable of dealing with either barcode or RFID to achieve a specific business objective. In contrast to interfaces on the device level they put the reading/writing events into a business process perspective and require interfaces to support IT-systems in order to process respective supply chain events.

Today LeoPARD implements two operational interfaces in the forwarding process. The suppliers label the outgoing shipments with GTL labels and copy the License Plate information to the RFID tag. At Volkswagen Aktiengesellschaft either barcode or RFID information is read to perform goods receipt. At this stage manufacturing supply is capable of reading barcode information only and therefore depends on barcode information. Current rollout activities aim to expand the RFID rollout to manufacturing supply and close the remaining gap in the forwarding process.

LeoPARD strictly focuses on material forwarding. At this point LeoPARD does not support reverse logistics. The RFID tags contain essential information to manage empty RTIs but so far the required infrastructure has not been implemented on a larger scale. For economic and technology specific reasons there are no plans to establish barcode for RTI management. With regard to reverse logistics we therefore observe clear limitations for hybrid process design. Rollout plans for auto-id enabled RTI management concentrate on RFID technology only.

Operational interfaces are essential to achieve gradual RFID migration. In the early stage of RFID rollouts not all supply chain stakeholders will equally participate in the rollout activities. Interfaces on the operational level ensure that process stakeholders are integrated into the RFID process depending on their technological capabilities. Companies may tend to harmonize and synchronize barcode and RFID processes to reduce complexity and decrease error rates. However, interfaces on the operational level may not result in identical process handling. The major challenge will be to reach a sufficient degree of harmonization and profit from RFID specific features at the same time.

Interface IV: Information Level

Interfaces on the information level allow to manage both barcode and RFID readings. They bridge between traditional barcode systems and RFID middleware to access, operate and visualize respective supply chain events. LeoPARD includes the implementation of informational interfaces (Figure 3). The Volkswagen Aktiengesellschaft Internal Transport Management System (ITMS) interfaces both barcode reading devices and RFID middleware. It is capable of operating
barcode and RFID information. The information is passed on to the Logistics Information System (LOGIS) and visualized in the Logistics Data Warehouse System (LOAD).

Even though the IT-infrastructure is able to deal with both barcode and RFID supply chain events, at this stage the reports generated in the integrated data warehouse solution are not able to distinguish between barcode and RFID supply chain events as the original data sources are not passed on to the report layer. Employees are able to analyze the total of supply chain events but may not determine the fraction of successful RFID readings. During the pilot phase of LeoPARD project members raised the demand for a monitoring solution that is able to keep track of supply chain events and their origin. The monitoring solution is seen as an essential step to manage migration issues and document project results. It is expected to resolve one of the principal challenges with regard to future large-scale RFID rollouts. According to Karshenas and Stoneman (1995) the main problem in estimating the adoption and diffusion curve of new technologies is the availability of data. Using integrated data warehouse solutions companies may monitor the adoption and diffusion level of barcode and RFID. They may evaluate the generated data to forecast adoption and diffusion behavior in the supply chain and adjust their rollout strategies accordingly. Further rollout plans at the Volkswagen Aktiengesellschaft include the implementation of an integrative data warehouse solution to retrieve required data from the installed hybrid processes and draw conclusions on the future deployment of both technologies in the forwarding process.

In this section we analyzed the RFID project LeoPARD to identify and address interface principles that ensure the interoperability and compatibility of barcode and emerging RFID solutions. We identified interfaces on object, device, operational and informational level. The derived concept for interface implementation supports Volkswagen Aktiengesellschaft in managing the co-existence of barcode and RFID in the automotive supply chain. Hybrid process design guarantees that processes may be run by either barcode or RFID and enable gradual process integration of RFID technology. In summary the interface concept has proven to be successful. The proposed concept supports Volkswagen Aktiengesellschaft in substituting barcode step by step rather than replacing barcode along the entire supply chain all at once thus reduces the risk of running large-scale RFID rollouts.

CONCLUSIONS

The phenomenon of co-existing auto-ID technologies is a case sui generis in supply chain history. It is the first time that an emerging auto-ID technology meets an incumbent one that successfully infiltrated the entire supply chain. In the near future the automotive industry will rely on barcode technology. The case of LeoPARD shows that the omnipresence of barcode does not necessarily hinder the spread of RFID but may serve as fundament for large-scale RFID rollouts. The aspect of co-existing auto-id technologies is likely to play an important role regarding RFID migration thus should be considered in RFID specific implementation frameworks.

Companies dealing with large-scale RFID rollouts need strategies to promote RFID technology but support established barcode processes in the meantime. In this paper we reviewed literature and identified interface principles as a feasible approach to deal with technological co-existence. We consulted a real life project environment and derived a multilevel interface concept to achieve gradual RFID migration without endangering established barcode processes. Our findings indicate that multilevel interfaces may come with two different effects. On the one hand they facilitate the shift from barcode
to RFID technology. On the other hand they are likely to expand the life cycle of existing barcode solutions thus extend the period of technological co-existence. LeoPARD demonstrates that the proposed interfaces indeed facilitate the shift from barcode to RFID technology. They are also likely to expand the life time cycle of barcode in the described application context. However, it remains to be seen if they influence the life time of barcode from a global perspective. Our research demonstrates the potential of the multilevel interface approach in a qualitative manner only. The impact of implementing hybrid process design and required interfaces in terms of cost and process efficiency remains subject to further research.

Furthermore, technological co-existence needs to be analyzed regarding the impacts on process innovation. The strategy of running hybrid processes may support migration to RFID, but may also obstruct the development of the technology’s full potential. RFID is integrated into established process landscapes rather than rethinking process design, leading to process improvements rather than IT-enabled revolutionary process transformation (Venkatraman, 1994; Mooney, Gurbaxani, and Kraemer, 1996; Tellkamp, 2006). Future research needs to address the negative impacts of hybrid process design on process innovation.

REFERENCES


