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Adoption and Diffusion of RFID Technology in the Automotive Industry

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Abstract

The adoption of novel information technologies like Radio Frequency Identification (RFID) can improve the transparency and efficiency within supply chains. After many years of hyping the RFID technology it becomes increasingly evident that the actual adoption and diffusion of RFID lags behind the expectations of its optimistic promoters. In this paper we identify factors with a top-down approach which are fostering the adoption and diffusion of RFID in a particular industry such as automotive. With a look at the theory of innovation diffusion, reviews of IS and IT diffusion studies with more than hundred factors, case reports, documented interviews with industry experts and workshops in the automotive industry we extract the factors compatibility, complexity, costs, performance and top management support as most important for the adoption and diffusion of RFID in the automotive industry, today.

1. Introduction

1.1. Practical relevance of the contribution

The technologies of Radio Frequency Identification (RFID) enjoy an enormous interest at the current time, not only from the standpoint of research but also from corporate practice. Enterprises from diverse branches are hoping for solutions to a wide range of management problems through RFID, from simple increases in processing efficiency for the receipt and despatch of goods in distribution centres through to improvements in goods availability on the shelves and on to the struggle against shrinkage and product counterfeiting. After many years of hyping the technology, however, it becomes increasingly evident that the actual adoption of RFID lags behind the optimistic expectations of the early years. Matta and Moberg (2006), for example, state that besides all attention which has been paid to RFID technology, the pace of actual or planned RFID adoptions by companies in their supply chains remains low to moderate.

On the other hand, the current trend does not necessarily allow for extrapolations of future developments since technology adoption can hardly be regarded as a linear process. One important finding of prior research on the diffusion of technological innovations is that new technologies will not be fully adopted by an industry in all processes at a single point of time. Typically one will observe a gradual process of infiltration of the innovative technology. Empirical studies of diffusion processes show in most cases, that if one plots market penetration of a technology against time the resulting curve is S-shaped (Rogers 2003). Furthermore, a second conclusion that could be drawn from empirical analyses is that diffusion rates differ across industries, regions and countries and also across technologies (Stoneman 2002).

1.2. Research Question and Structure

Much academic research has been published on organizational innovation diffusion in general. However, the majority of prior research on IT innovations diffusion focussed rather on economic-rationalistic models than on quantitative analyses of factors which foster diffusion (Swanson 1994, Fichman 2004). In a way, this also holds for RFID: In contrast to the overwhelming number of trade publications and white papers on RFID there is a surprisingly poor number of conceptual and empirical research contributions on RFID in the body of supply chain and technology diffusion literature. Against this background, the research question that we address in this paper is which factors do have an impact on the adoption and diffusion of the RFID technology with a particular focus on the automotive industry. Knowing these factors, potential technology users are able to evaluate if it is reasonable to adopt RFID under certain conditions and at a certain point of time. Furthermore, they can attempt to actively influence these variables in order to reduce the failure probability of RFID deployments.

For this purpose, the remainder of the contribution is structured as follows. First, section 2 provides an overview of RFID, its technical foundations, main advantages compared to other Auto-ID technologies, and the status-quo of standardization initiatives. Section 3 evaluates the benefits of RFID from the perspective of the automotive industry. In section 4 we investigate which factors promote the diffusion of RFID in the automotive supply chain. Therefore, we first take a look at the theory of technological diffusion economics. We analyze the relevant factors in the field of diffusion of RFID in manufacturing, continued by filtering of publications with relevant topics of RFID in the automotive industry. The findings will be completed by a depiction of experiences gained in projects with the automotive industry and relevant case studies. The paper closes with a summary and proposals for further research.

2. Radio Frequency Identification

2.1. Technical foundations

RFID is a technology for the automatic identification by radio of physical objects such as industrial containers, palettes, individual products and also people. The identification event takes place over transponders located in or on the respective objects, which can be addressed without physical contact, over the so-called "air interface", by the antenna on a scanner device. Transponders are manufactured in various shapes and styles, operate in various frequency ranges and have either their own battery (active transponder) or are provided with energy from the electromagnetic field of the scanner (passive transponder). On the other hand, scanners are available on the market as both mobile devices with limited range and as devices for stationary installation, to which one or more external antennas can be connected to enable coverage of larger areas (Garfinkel and Holtzman 2005).

In contrast to the Barcode currently used for goods identification, RFID differentiates itself through the possibilities for bulk registration, identification without visual connection, unambiguous identification of each individual object, data storage on the object as well as great robustness towards environmental influences and destruction (Finkenzeller 2003, Shepard 2005). The mutuality of all transponder types lies in a unique ID number, which allows for identification no longer only of the product type but at the item level. Further characteristics cover, dependant on the manufacturer, also possibilities for data storage on the physical object, security mechanisms or sensors integrated into the tag, e.g. for recording temperatures or vibration.

Typical areas of application for RFID lie, adjacent to classics such as animal identification or access control systems, above all in Supply Chain Management, where the technology makes possible simplified goods turnover, automatic stock control in the storeroom resp. on the sales area, theft protection, product tracking etc (Bose and Pal 2005). Further application potential comes from the areas of product life-cycle management (e.g. with call-back actions, maintenance and service) and customer relationship management (e.g. for individualised product information) through to novel business models through use-based payments or vendor managed inventories (Ferguson 2002, Fleisch and Dierkes 2003, Kelly and Erickson 2005).

2.2. Standardization

In a global business environment, interoperability among information and communication technologies is a fundamental requirement which is essential for the use of RFID. Therefore RFID standards – e.g. the RF protocol, data-on-tag structures, etc. – are a major issue for the industry. Unfortunately though, not only different standards coexist in parallel, but different actors with divergent interests influence the standardization process to some extent as well. At the time of writing, there are two major initiatives regarding RFID standardization: ISO and EPCglobal. ISO adopts a cross industry perspective with a generic approach while EPCglobal as a not-for-profit organization driven by large end users and their needs adopts a more application-specific approach.

The trigger for the dramatically elevated interest in RFID in the retail industry over the past several years has been especially the activities of the Auto-ID Center, a project founded in 1999 at the Massachusetts Institute of Technology (MIT), in cooperation with numerous industrial sponsors, for the development of RFID Standards. The main result of the Auto-ID Center was the "Electronic Product Code (EPC)" (Sarma et al. 2001), a worldwide unambiguous numbering scheme for the designation of arbitrary physical goods which should ensure the interoperability of the technology in supply chain wide applications. On the basis of EPC there followed specifications for a series of protocol standards for communications between transponders, scanner-hardware and information systems. Since the termination of the Auto-ID Center in October 2003 the EPC technology is being commercialised and further developed by EPCglobal Inc., a subsidiary of GS1, the industry organisation responsible for Barcode standardisation (Sarma 2005). In the following years EPC became the technical foundation for the multiple RFID initiatives of large chain stores such as Wal-Mart and Metro.

In contrast to that, ISO's RFID standards are defined on a very generic level, focusing predominantly on the air interface. ISO standards cover the areas of technology (e.g. ISO 18000 series including air interface standards), data content (e.g. ISO 15418), conformance and performance (ISO 18046), and application standards (e.g. ISO 10374). Therefore ISO RFID standards can generally be considered as more application-independent with regard to processes and industry-specific context. However, EPCglobal is anxious to submit its standards to ISO for an additional approval aiming on conformity of both standards. The "EPC Class 1 Generation 2" (i.e. EPC Gen2) standard for the UHF air interface, for example, corresponds to ISO's 18000-6C standard.

3. RFID in the automotive industry

3.1. Current trends in the automotive industry

Over the last 15 to 20 years, an extensive reorganisation of the automotive supply chain could be observed. Modern and novel approaches like make-and-deliver-to-order, zero-error-production, lean management, just-in-sequence (JIS) and just-in-time (JIT) production, the constant necessity to reduce costs, reduced cycle time and the need for increasing efficiency had manifold outcomes: On the market side, vehicle manufacturers had to look for both new sources of production economies and continuous product development. On the technology side, the fast-growing complexity of the manufacturing processes and products turned the automotive supply chain in one of the world's most information-intensive management processes.

From the early 1990s on, vehicle manufacturers started to restructure their supply chains and their own operations regarding internal processes as well as collaboration with suppliers. The major objectives of these supply chain focused efforts were (a) to reduce the number of direct shipping suppliers, (b) to establish a new supply chain hierarchy which divides suppliers in tiers, (c) to outsource functions which are no longer seen as core competencies, and (d) to extend strategic control throughout the supply chain to establish a real "network".

The automotive industry realized the need for tighter links and closer cooperation between all supply chain partners. As a consequence, being able to control the system as a whole requires the capability to exchange information with a degree of completeness, speed, and precision which was much higher than in the past. A shift from classic tools of data transmission (e.g. sheets of paper, fax, phone calls, etc.) towards complete information flow integration was needed. That was the dawn of Electronic Data Interchange (EDI) and Enterprise Resource Planning (ERP) systems in the automotive industry which, in combination with Barcode technology, led to a significant increase of data and information quality (Vopato and Stocchetti 2002, Strassner and Fleisch 2002).

A decade later the automotive industry is still constantly looking for innovative technologies to further improve both the quality of process-related data and thus the efficiency of their supply chain operations. RFID and its potential for seamless data capturing and processing, increased supply chain visibility, and significantly reduced cycle times is one of the most promising technologies today and for the foreseeable future. The automotive industry already uses RFID, e.g. in vehicle immobilizers since the 1990s. But the adoption in supply chain processes, however, is just at the beginning. This encompasses all those processes that are associated with the movement and shipping of goods from raw-material stage up to the final products which are delivered to customers as well as backwards at the end of the product's life for recycling purposes, i.e. procurement, inventory management, assembly control, order processing, distribution, transportation, quality control, theft control, anti-counterfeiting, and warehousing (Strassner and Fleisch 2002, Lu et al. 2006).

3.2. RFID in closed-loop systems

The first RFID systems that were implemented in the automotive supply chain were closed-loop systems. In this context, the term 'closed-loop' denotes a system with RFID transponders that are attached to an object and permanently remain on it while it is shipped or moved within a cycle and eventually returns to its point of origin. Typical examples for closed-loop systems are (a) the management of valuable assets, tools, and returnable containers or (b) inventory management where pallets or cases are equipped with a transponder for identification purposes.

The rationale for initial RFID adoption in closed-loop systems is simple: Because of high prices for tags and infrastructure in the beginning of RFID adoption in former years, it was reasonable to start pilot studies in cycle processes with returnable assets. Companies wanted to gain experiences with the technology itself and the performance in a specific manufacturing environment. Therefore, in the first a small number of partners, particularly 1:1 relationships, are easier to coordinate. Furthermore, it is not likely that standardization issues are that important in such a limited environment. Today, many vehicle manufacturers like DaimlerChrylser, BMW and Volkswagen are already using or testing RFID systems in closed-loops.

A further classification of closed-loop systems can be made by distinguishing between local and collaborative closed-loop systems. A local closed-loop is limited to a process within a manufacturing site, e.g. RFID equipped tool management, assembly control, or a Kanban system within a plant. Collaborative closed-loops encompass processes with two or more supply chain partners or manufacturing sides involved, e.g. container management or the management of special transportation racks between an OEM and a first tier (Strassner 2005, Lu et al. 2006).

3.3. RFID in open-loop systems

While closed-loop systems are already in place in the automotive industry, open-loop systems are rare. The main characteristic of an open-loop system is that the RFID transponder remains on an object and leaves the process or production site for a long period of time or without reuse for the same process. Examples are the tagging of specific parts, modules or vehicles for distribution, recall management, maintenance history, anti-counterfeiting, or recycling purposes.

Possible reasons for the poor present diffusion of open-loop RFID applications seem to be the high failure and loss rate of the still rather expensive transponders, complex 1:n relationships, the need for a widespread infrastructure for most applications, and the lack of an appropriate and widely accepted global standard within the automotive industry (Strassner and Fleisch 2002, Strassner 2005, Lu et al. 2006, Ghiladi 2003).

4. Factors of RFID Diffusion

4.1. Management research on the diffusion of new technologies

In this section, we identify and analyze relevant factors which are most likely to have a significant influence on the diffusion of RFID in the automotive industry. For this reason, we first examine the general diffusion of innovation theory and discuss a list of factors which are known to be drivers and barriers for new technology diffusion. In a second step, we continue with a review of prior research of RFID technology diffusion and implementations in the manufacturing industry before taking a closer look at contributions dealing with RFID applications in the automotive industry. Additionally, our first-hand experience from project work with the German association of the automotive industry ("Verband der Automobilindustrie", VDA) and vehicle manufacturers complemented by case reports from the industry helps us to shape a qualitative picture of relevant factors.

The diffusion of innovation theory provides well-developed concepts and a large amount of empirical results which are useful for the study of technology evaluation, adoption and implementation. It provides both qualitative and quantitative tools for assessing the rate of diffusion of a new technology and to identify various factors that facilitate or hinder technology adoption and diffusion. Therefore, it is not surprising that innovation diffusion has become a very popular reference theory for current research of information and communication technologies (Fichman 1992, 195).

The seminal work by Rogers (2003) provides an overview of research on diffusion and discusses the potential relevance of factors that foster the implementation of innovations and organizational changes. Fichman (1992) analyzes numerous studies of information technology diffusion and focuses on relevant factors for the adoption of information technology by organizations. More recently, Jeyaraj et al. (2006) conducted a review of 99 studies, interviews, and news reports dealing with the predictors, linkages, and biases in IT innovation adoption research. In the following, the latter contribution serves as basis for our analysis.

Over the last 20 years, quite a rich but also diverse body of theoretical and empirical work has been conducted on the adoption and diffusion of innovations. Management research has developed various theories whose explanatory power was tested empirically by many qualitative and quantitative studies. According to Fichman (1992), researchers usually consider two different aspects of adoption: (a) the characteristics of a given technology and the consequences for adoption and diffusion process, and (b) the locus of adoption, i.e. adoption on an individual or an organizational level (cf. Table 1).

Theory	Main author(s)	Adoption level	
		individual	organizational
Innovation Diffusion Theory	Rogers (1983, 1995, 2003)	X	X
Perceived Characteristics of	Moore & Benbasat (1991)	X	
Innovation	Bandurra (1986)	X	
Social Cognitive Theory	Davis (1989)	X	
Technology Acceptance Model	Venkatesh et al. (2003)	X	
Technology Acceptance Model II	Ajzen (1991)	X	
Theory of Planned Behaviour	Fishbein & Ajzen (1975)	X	
Theory of Reasoned Action	Venkatesh et al. (2003)	X	
Unified Theory of Acceptance and			
Use of Technology			X
Diffusion/Implementation Model	Kwon & Zmud (1987)		X
Tri-Core Model	Swanson (1994)		X
Technology-Organization-	Depietro et al. (1990)		
Environment (TOE) Framework			

Table 1. Theories of adoption research (based on Jeyaraj et al. 2006)

Since this paper focuses on the diffusion of RFID in the automotive industry, we concentrate on factors which are relevant to organizational adoption. Organizational adoption studies analyze the adoption by large aggregates, such as companies, business units, agencies, or departments (Fichman 1992). Therefore, our research bases on the theories of Rogers (2003), Kwon and Zmud (1987), Swanson (1994), and Dipietro et al. (1990). These works deal with the decision to adopt, intention to adopt, intention to use, adoption, and diffusion of innovations within organizations. In their studies, the authors distinguish different stages of adoption: Kwon and Zmund (1987) mention the stages of adoption, adaptation, acceptance, routinization, and infusion. Rogers (2003) describes the stages of initiation and implementation, both involving sub-stages. Additionally, Swanson (1994) establishes a tri-core model of IS innovation diffusion in organizations which is subdivided into a technical, IS, and administrative core because IT permeates all these domains in contrast to other innovations.

Most of the studies propose different classes of factors responsible for innovation diffusion, such as technology, organizational, and environmental characteristics (see e.g. Dipietro et al. 1990) each including a number of factors and independent variables, respectively. Technology characteristics include, for example, variables such as relative advantage, complexity, compatibility, observability, and trialability. Organizational characteristics include e.g. top management support, organization structure, and organization size. Environmental characteristics include e.g. external pressure, competition, and coercive influence. Altogether, a dominant research paradigm has emerged: The more organizations are well positioned with regard to these variables ("right stuff"), the more the innovation will be adopted (Fichman 2004, 315).

4.2. Adoption and diffusion in organizations

Jeyaraj et al. (2006) reviewed 48 empirical studies on individual and 51 studies on organizational IT adoption published between 1992 and 2003. They focussed on identifying factors that foster the adoption and diffusion of new IT technologies. The sample includes 135 independent variables, eight dependent variables, and 505 relationships between independent and dependent variables. They identified top management support, external pressure, professionalism of the IS unit, and external information sources as the most important independent variables of IT adoption by organizations. On an aggregate level they identified the two groups of independent variables, innovation (technology) and organizational characteristics as good predictors of IT adoption.

In their analysis of IT adoption initiatives, Bradford and Florin (2003) found technical compatibility, perceived complexity and business process reengineering (BPR) to be technology characteristic variables. For the class of organizational characteristics, they enumerate top management support, organizational objectives consensus (strategy), and training as well as competitive pressure as an important environmental characteristics factor.

Premkumar et al. (1994) present a more specific study dealing with the implementation of electronic data interchange. The authors identify the independent variables compatibility, complexity, relative advantage, costs, and communicability as main drivers of the innovation diffusion of information systems.

4.3. RFID adoption in supply chains

Matta and Moberg (2006) describe the adoption and resulting benefits of RFID as a new information technology such as improved speed, accuracy, and visibility of information exchange within supply chains. These eventually lead e.g. to reduced inventory costs and improved customer service. In their article, they highlight the importance of RFID diffusion factors standards (i.e. compatibility), top management support, both operational and strategic information exchange (cooperation), commitment to supply chain principles and the size of an organization. Another important factor is the existence of coercive influence or a mandate to adopt RFID e.g. by a supply chain leader.

Lu et al. (2006) describe RFID technology enabled manufacturing in various environments. Seven examples of possible RFID implementations are specified in the manufacturing industry. The emphasized factors of technology diffusion are costs of adoption, technological performance, standards, need of interaction with supply chain partners (cooperation) and the perceived benefits and risks of an RFID adoption.

Sharma et al. (2006) analyze the literature of adoption and diffusion of innovation and extract a number of factors which are grouped to organizational readiness factors, technology factors, external environment factors and inter-organizational pressure factors. The factors are then used as key words and respectively variables in semi-structured interviews with industry experts and numerous news reports and tested for significance to RFID technology adoption and diffusion. The most mentioned factors are the perceived benefit of the technology, costs, the existence of a dominant supply chain partner (coercive influence), intellectual property and ownership standards adoption, data and software standards (compatibility), diffusion champion presence, and top management support.

Swedberg (2007) describes the future development of RFID applications in the manufacturing industry and states that many companies were still stuck in RFID pilot phases. In the author’s opinion, the factors that are strongly influencing the future diffusion of RFID are performance, standards and costs derived from a recent study with manufacturing companies.

Fleisch and Tellkamp (2003) describe the challenge of identifying value-creating ubiquitous computing applications with a strong focus on RFID in supply chain applications of various industries. They identify perceived benefits, costs, performance of the technology, compatibility, and the relative advantage as important factors of the diffusion of innovation.

Gerst et al. (2005) and Ilui-Zudor (2006) discuss various issues in RFID standardisation and current applications. Beside of the factors standards (or compatibility) they mention information exchange, complexity, costs, the need to adjust processes, and the perceived benefits of the technology as important factors for the future diffusion of RFID technology.

4.4. RFID Adoption in the automotive industry

Fleisch et al. (2004) conducted a study on the potential of RFID for the automotive industry. The factors of RFID technology diffusion that were enumerated by the interviewed industry experts are costs, perceived benefits, cooperation, performance, compatibility, complexity, top management support, and centralized planning and control.

Strassner (2005) analyzes the adoption of RFID technology in supply chain processes in the automotive industry. Various case studies from pilot studies and full implementations of RFID systems at vehicle manufacturer plants and suppliers are documented. These range from process control, container management, and CKD-processes (CKD means "completely knocked down"; the vehicle is exported in parts and will be assembled at its destination) to thoughts about future developments. Additionally, many industry expert interviews as well as the experiences of a project within a work group at the German Association of the Automotive Industry (VDA) entered the findings. As the most critical factors for success of the adoption of RFID technology in the automotive industry, Strassner (2005) identifies the variables information sources, performance, costs, compatibility, business process reengineering, and incremental proceeding.

Weigert (2006) investigates the potentials of RFID in the automotive industry from an information system's perspective. For this purpose, various studies are analyzed and combined with findings of an international acting system provider. The identified factors that have an impact of the diffusion of RFID technology are: Costs, complexity, top management support, compatibility, coercive influence, privacy, and strategy.

Additional reports and studies that we reviewed are the works by Wessel (2006), Strassner and Fleisch (2002), Krampe (2005), Mondragon et al. (2006), Bacheldor (2007). The most mentioned and repeated factors are costs, performance, complexity, and coercive influence. Table 2 summarizes our findings in an overview.

5. Discussion

A first finding from our review is that overall most publications deal with technological factors. Our analysis indicates that the most significant factors of RFID diffusion in the automotive industry are:

- Compatibility (e.g. technological, hardware, software and data standards),
- Costs (e.g. hardware components, system integration and customization),
- Complexity of the technology and its implementation (e.g. because of process change, lack of plug & play components, non-trivial data processing, etc.),
- Performance (e.g. technological capability and environmental influences on systems), and
- Top management support (e.g. perception of RFID as a strategic technology).

		General			Supply Chain							Automotive							
		Jeyaraj et al. (2006)	Bradford & Florin (2003)	Premkumar et al. (1994)	Matta & Moberg (2006)	Lu et al. (2006)	Sharma et al. (2007)	Swedberg (2007)	Fleisch & Tellkamp (2003)	Gerst et al. (2005)	Ilui-Zudor et al. (2004)	Fleisch et al. (2004)	Strassner (2005)	Weigert (2006)	Wessel (2006)	Strassner & Fleisch (2002)	Krampe (2005)	Mondragon et al. (2006)	Bacheldor (2007)
Technology	Compatibility		x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	
	Complexity		x	x						x	x	x		x			x	x	
	Rel. Advantage			x					x										
	Costs			x		x	x	x	x	x	x	x	x	x		x	x	x	
	Communicability			x															
	BPR		x							x			x						
	Performance					x		x	x			x	x			x			x
	Perceived Benefits					x	x		x	x		x							
	Perceived Risks					x													
Organizational	Top Mgmt Sup.	x	x		x		x					x		x					
	Prof. of IS unit	x																	
	Inf. Sources ext.	x											x						
	Strategy		x											x					
	Training		x																
	Commitment to SC principles				x														
	Cooperation				x	x					x	x							
	Org. size				x														
	Incr. proceeding												x						
	Privacy													x			x		
	Centralized planning											x							
Environment	External pressure	x																	
	Competition		x																
	Coercive infl.				x		x							x		x			
	Diff champion						x												
	IP and ownership standard adopt.						x												

Table 2. Extracted RFID adoption factors sorted by category and reviewed publications.

The factor compatibility is important because adopting companies want to integrate the technology into the existing infrastructure and further want to use it within their supply chain in cooperation with suppliers and customers. Costs are initial costs of implementation of a RFID system and running expenses e.g. transponders. As long as the costs for RFID tags do not decrease, open-loop systems will not pay off e.g. low-value parts. A RFID system is much more complex than a barcode system. Many factors do influence the system and there is no one-fits-all solution. So every implementation has to be analyzed for its own. As a result the performance of a RFID system is closely related to the environment, the existing systems and the used components and their integration. Not any company would like to replace an existing system with a technology that is not able to provide the same and respectively better performance than the existing or an alternative system. The adoption of a new technology like RFID needs to be supported by the top management because of its cross-functional characteristic. The IS unit of a company does not have the authority to convince every single division manager of the benefits of a new technology which adoption is fundamentally necessary for the company.

The results support the conclusions of former studies of the general diffusion of innovation theory as well as with specific research on diffusion of IS innovations in organizations (Rogers 2003, Fichman 2004). In particular, it is evident that the 4 - 5 most mentioned factors belong to the class of technology characteristics. This result is in line with the findings of Jeyaraj et al. (2006), even though the organizational characteristics pale in comparison to the technology characteristics for RFID in the automotive industry. A possible explanation could be that – because of the early stage of RFID technology adoption and diffusion – organizational and environmental factors in the phase of pilot studies and early implementations are not that important. The innovation or technology itself and its capabilities are more relevant to the adopters. Furthermore, most analyzed reports and case studies of RFID implementations describe closed-loop systems. In a closed-loop system inter-organizational relationships may not be that crucial; the same holds for environmental factors. However, it seems likely that centralized planning, competition, and the presence of a diffusion champion gain in importance when the automotive industry starts to implement RFID in open-loop systems.

Perceived benefits of the technology, coercive influence, and cooperation belong to the second group of relevant diffusion factors. Especially interesting are the factors cooperation and coercive influence: While the automotive supply chain and the notable network of suppliers are often mentioned as a perfect example for the interplay of industrial partners, the influence and mandate of e.g. the OEM or supply chain leader seems to be immanent.

Less obvious but nevertheless important are the factors strategy and professionalism of the IS unit in conjunction with top management support. Our experience from industry projects and involvement in relevant associations indicates that it is very difficult to execute a RFID project without top management support and the clear commitment that RFID is considered as a strategic technology and project. The reason as described by Swanson’s (1994) tri-core model is that RFID technology like every IS technology has not only an impact on the IS unit but as well on technical units and the administration of a company.

Surprisingly, the factor external pressure seems to be not that important for the automotive industry at the moment although upcoming regulations, e.g. the end-of-life vehicle directive, the US-TREAD act, or the need for innovative technological solutions for part-tracking and recall management, are often pulled up to legitimate the implementation of RFID systems.

6. Summary and Outlook

RFID is one of the most promising information system technologies for supply chain application in the automotive industry today and in the future. Its potential to increase the transparency in supply chains and thus to advance the control of logistics, manufacturing, distribution, delivery, and reverse-logistics processes is one of the biggest advantages of the technology. However, adoption and deployment of the technology does not come over night – neither in automotive, nor in any other industry.

Against this background, this contribution identifies the significant factors that facilitate the adoption of RFID in the automotive industry. Starting from a general literature review of prior research on the diffusion of innovations and a closer look at the diffusion of IS and IT innovations in particular, we have identified a number of factors that are responsible for the rate of IS technology diffusion by organizations. Then, the factors belonging to the class of technology characteristics, organizational characteristics, and environmental characteristics were further analyzed in order to extract such factors that have an impact on the diffusion of RFID technology in supply chains. Thenceforward we identified the dominant factors compatibility (i.e. technological, hardware, software and data standards), costs, complexity of the technology, performance (i.e. technological capability and environmental influences on systems), and top management support that most likely foster the adoption and diffusion of RFID in the automotive industry. Thus, practitioners, solution and technology providers, and standardization organizations become able to address these factors directly to bring RFID projects to a success.

The results of the analysis of various studies in the automotive industry as well as case studies from pilots and full implementations correspond to the findings of research conducted in the field of diffusion of innovations in general and – more focussed – the diffusion of IS innovations. In contrast to other studies on technology diffusion, the most important factors with regard to the use of RFID in the automotive industry belong to the class of technology characteristics. The reason for this seems to be that the adoption and diffusion of RFID is still in an early stage and therefore basic implementation issues have to be solved first. Another possible explanation is that the described studies relate to closed-loop implementations where inter-organizational factors are not that important. Hence, a suggestion for further research might be to analyze which factors in a particular stage of diffusion are the most relevant ones for the use of RFID in the automotive industry.

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