AUTO–ID LABS

Why RFID Adoption and Diffusion takes Time: The Role of Standards in the Automotive Industry

Author:

Patrick Schmitt, Florian Michahelles, Elgar Fleisch

Abstract:

The adoption and diffusion of RFID technology take longer time than it was expected years ago. While few industries adopted RFID right away others are reluctant and took up a ‘wait and see’ position. Especially standards play a major role. Even standards are available today, many industries announced additional requirements for their specific processes. As an example we analyze the developments regarding RFID standardization in the automotive industry and identify three central reasons why the adoption and diffusion is slow compared to other industry sectors like retail and consumer goods: (1) Skepticism about EPCglobal and the capability of the Electronic Product Code for processes in the automotive industry, (2) a long lasting standardization process through various national and international committees, and (3) the lack of a mandatory announced by a dominant supply chain partner.

Keywords:

Radio Frequency Identification (RFID), Adoption and Diffusion, Standards, Automotive Industry.

1 Introduction

Today, the term ‘Internet of Things’ is closely connected to the technologies of ubiquitous computing and especially to Radio Identification (RFID). ‘Internet of Things’ stands for the connection of (computer) networks with physical objects and the improvement e.g. of industrial operations and increasing transparency in supply chains. Whereas the term ‘internet’ suggests that it already exists or will be shortly set up, the reality looks quite different because the adoption and diffusion of new technologies take a long time.

RFID currently enjoys an enormous interest. Researchers as well as the industry are closely observing the recent developments. 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 dispatch of goods in distribution centers through to improvements in goods availability on the shelves and on to the struggle against shrinkage and product counterfeiting. The automotive industry is not an exception and has carefully evaluated the possibilities of the RFID technology for a long time. But different from the retail sector that adopted RFID quite early and fast the automotive industry is more reluctant.

After many years of hyping the technology, however, it becomes increasingly evident that the actual adoption and diffusion of RFID lags behind the optimistic expectations of the early years. Matta and Moberg [1], for example, state that besides all attention which has been paid to RFID technology, the pace of actual or planned RFID adoption by companies in their supply chains remains low to moderate.

The current trend does not necessarily allow for extrapolation of future developments since technology adoption can hardly be described 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 [8].

This holds for the automotive industry as well. Using RFID technology in some specific implementations for years (e.g. vehicle immobilizers), applications in supply chain processes with many partners are rare. One reason for that seems to be the lack of an agreement for a single RFID standard - especially regarding a data standard and a unique identifier like the Electronic Product Code (EPC) - that can be used for the industry’s purposes across enterprises. Standards organizations as well as the industry are working on the development of an acceptable and sufficient standard.

This contribution will give an overview of the premises of RFID adoption with a focus on recent developments in RFID standardization in the automotive industry. Problems regarding standardization efforts will be analyzed and highlighted why RFID adoption is sometimes slow. For this purpose, the remainder of the paper is structured as follows: First, Section 2 provides an overview of the trends and use regarding information technologies in the automotive industry. Section 3 summarizes basic knowledge regarding RFID technology and its use in the automotive industry. Section 4 deals with relevant factors of the adoption and diffusion of RFID technology and the importance and development of a RFID standard with a focus on the automotive industry. The findings will be discussed in Section 5 before the paper closes with a summary and an outlook.

2 Trends in the Automotive Industry

An extensive reorganization of the automotive supply chain could be observed over the last 15 to 20 years. 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 efficiency increase had manifold outcomes: On the market side, carmakers 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.

Vehicle manufacturers started to restructure the supply chain and their own operations including both their internal processes as well as the collaboration with suppliers. The major objectives of these efforts were to reduce the overall number of direct shipping suppliers, to establish a new supply chain hierarchy which divides suppliers in tiers, to outsource functions which are no longer seen as core competencies, and to extend the strategic control throughout the supply chain to establish a real 'network'.

Against this background, the automotive industry realized the need for tighter links and closer cooperation between all companies belonging to the supply chain. To be able to control the system as a whole it requires the capability to exchange information with a degree of completeness, speed, and precision which was much higher than in the years before. A shift from classic tools of data transmission e.g. sheets of paper, fax, and phone calls; 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. In combination with barcode technology these systems led to a significant increase of data and information quality [3], [4], [5].

Today, the automotive industry is still looking for new innovative technologies to further improve both the quality of process-related data and the efficiency of their supply chain operations. Therefore, 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 for the foreseeable future [4], [6].

3 RFID in the Automotive Industry

RFID is an information technology for the automatic identification by radio of physical objects such as industrial containers and transportation racks, palettes, individual products and also people. In order to identify an object, transponders are attached to the respective object, which can be addressed without physical contact, over the so-called “air interface”, by the antenna on a scanner device. Today, transponders are available 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). Scanners are manufactured as both mobile appliances with limited range and as appliances for stationary installations. It is possible to connect one or more antennas to one stationary scanner to enable coverage of larger areas [2], [28]. A more detailed introduction of the technology can be found in Finkenzeller [28].

The development and the usage of information technologies in the automotive industry as well as the willingness to adopt new technologies to further enhance supply chain management has always been influenced by recent trends. Although the automotive industry already uses RFID (e.g. in vehicle immobilizers since the 1990s), the adoption in supply chain processes 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, anticounterfeiting, and warehousing [4], [6]. RFID applications can be further distinguished in two basic layouts: Closed-loop systems (CL) and open-loop systems (OL).

3.1 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 the (a) 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 years ago, 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. Therefor, in the first internal processes or 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 [6].

3.2 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, anticounterfeiting, 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 and the need for a widespread infrastructure for most applications, and the lack of an appropriate and widely accepted global standard within the automotive industry [4], [6], [7]. Table 1 gives an overview of the already existing RFID systems or completed pilot studies in the automotive industry.

Table 1. Existing RFID systems and pilot studies in the automotive industry [21].

Field of application	Application example	CL/OL	Project stage
Asset utilization	Container management Loading equipment management Truck control at loading stations	Mainly CL	Mainly implementation projects (pilot projects for first OL projects)
Asset monitoring and maintenance	Torque key control	CL	Mainly implementation projects
Item flow control	Tagging of car bodies in - Body shell work - Painting - Assembly	CL	Implementation projects
Inventory audit	Tracking of finished cars Warehouse management Pallet tagging	OL CL	Pilot projects/ Implementation projects Implementation projects
Authentication	Assembly documentation for security-relevant items Identification of car gears	CL CL/OL	Mainly implementation projects Mainly pilot projects
Theft control	Car keys	other	Implementation projects

Against this background, Section 4 analyzes relevant factors which accelerate the adoption and diffusion of RFID. Especially the ongoing standardization initiatives by ISO and EPCglobal as well as standardization activities by the automotive industry will be described in detail.

4 Adoption and Diffusion of RFID

The adoption and diffusion of technological innovations have been objects of investigation of many researchers. This section gives an overview of factors that have an influence on the decision to adopt RFID technology by organizations. These factors are analyzed by various adoption studies within the field of diffusion of innovations and information technology, reviews of RFID adoption studies we conducted, industrial projects as well as from semi-structured interviews with industry experts.

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. Therefore, we focus on the factor ‘standard’ and analyze in detail the developments regarding standardization by ISO, EPCglobal, and the automotive industry.

4.1 Factors influencing the RFID Adoption and Diffusion

Much academic research has been published on organizational innovation diffusion in general. The seminal work by Rogers [8] provides an overview of research on the diffusion of innovations and discusses the potential relevance of factors (i.e. relative advantage, compatibility, complexity, trialability, and observeability) that foster the implementation of innovations and organizational changes. Furthermore, Fichman [9] analyzes numerous studies of information technology (IT) diffusion and focuses on relevant factors for the adoption of information technology by organizations. More recently, Jeyaraj et al. [10] conducted a review of 99 studies, interviews, and news reports dealing with the predictors, linkages, and biases in IT innovation adoption research. They identify top management support, external pressure, professionalism of the information systems (IS) unit, and external information sources as most important for organizational adoption and diffusion of IT innovations. Additionally, we reviewed studies of the years 2005-2007 which identify factors influencing the adoption and diffusion of RFID technology by organizations [22]-[27]. The resulting most important adoption factors of RFID technology are:

- Perceived benefits
- Costs
- Complexity
- Organizational Size
- External Pressure
- Performance
- Compatibility
- Top Management Support
- Standards

The factor ‘perceived benefits’ shows to what extend companies think that advantages can be generated by adopting RFID technology. ‘Costs’ encompasses the initial investment in the technology, e.g. infrastructure, as well as current costs for transponders. For first experiences with the technology and rather small scale pilot studies costs are not that important compared to other factors while getting more and more important when discussing large scale roll-outs and full implementation in an open-loop system. The ‘complexity’ of the RFID technology is another important factor because firms have to evaluate the difficulties of implementing a new technology into their existing systems and processes. This factor gains in importance the bigger the RFID project gets and the more interfaces or partners are involved and is therefore directly linked to the accruing costs. ‘Organizational size’ plays a major role regarding first mover implementations. Bigger organizations are typically able to invest more money into a new promising technology and are usually able to generate the return on investment much faster than smaller companies. 'External pressure' summarizes influences from the environment of the company. These could be competitive pressure, mandates to implement RFID, or legal restraints. The factor 'performance' is probably the most important factor for initial tests and pilot studies. Only if the promised performance will be reached RFID projects will proceed. The factor 'compatibility' describes the fit of the new technology to the adopting company. This includes already existing technologies as well as the fit to the organizational structure of a company. 'Top management support' is always crucial for IS technology projects because of the cross sectional character of the technology that affects numerous departments and functions of a company. Especially if a RFID project involves other supply chain partners, management support is needed. The factor 'standard' as one of the most mentioned regarding RFID will be analyzed in detail with a focus on the automotive industry in the following section.

It is crucial to be aware of these factors when thinking about an implementation of RFID in processes and supply chains. Thereby, potential adopters become able to address the right factors and critically check their company's readiness for a new technology. Altogether, a dominant research paradigm has emerged: The more organizations are well positioned with the regard to these factors ("right stuff"), the more the innovation will be adopted [11].

4.2 Importance of Standards

The great variety of standards can be structured by different types. Many economists favor a categorization based on the process of standard building, the so-called "formal" or "de facto" standards or a typology which is based on whether the standard relates to products, services or processes. Blind [12] introduces the following dimensions of standards:

- Minimum quality and safety standards
- Variety reducing standards
- Information standards
- Compatibility and interface standards

Minimum quality and safety standards define a certain framework which e.g. a product has to fulfill. Customers who are not able to test the functionalities of a product as well as do not have all information about ingredients and production processes can rely on these types of standards (e.g. the German GS-Label).

A variety-reducing standard has two different purposes: First, it leads to economies of scale by reducing the number of variations of a product or a technology. Manufacturers become able to mass source input factors, produce more, and gain advantages via mass distribution. Typical and well known examples are the letter formats in the USA or the DIN A format in Germany. Second, a variety-reducing standard helps to achieve a focus and hence helps a market to take off.

Standards of information and product description are often treated as a distinct category of the variety-reducing standards. They describe in a generally accepted or known manner the characteristics of a certain product, e.g. the different grades of gas with 91 octane, 95 octane etc.

Last but not least there are compatibility and interface standards. RFID Standards predominantly belong to this group. Starting with the first network industries (i.e. railways) the importance of these standards grew significantly. Additionally, the progress in information and communication technologies in the last few decades has demonstrated the importance of this kind of standards. Because manufacturers and their suppliers' decisions are influenced by network effects it is preferable in a network to choose a system or technology that is widely used by others. Further positive effects of compatibility and interface standards are network externalities, avoidance of lock-ins regarding suboptimal solutions, and an increased variety of systems products. A negative effect can be the appearance of a monopoly, e.g. by a single hardware manufacturer and a patent-protected technology [12].

4.3 RFID Standards by ISO and EPCglobal

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 has been the retail industry over the past several years and 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)" [13], 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 the 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 commercialized and further developed by EPCglobal Inc., a subsidiary of GS1, the industry organization responsible for barcode standardization [14]. In the following years EPC became the technical foundation for the multiple RFID initiatives of large chain stores such as Wal-Mart, Tesco and Metro. Figure 1 shows the development of the total number of EPCglobal subscribers across all industries since 2003.

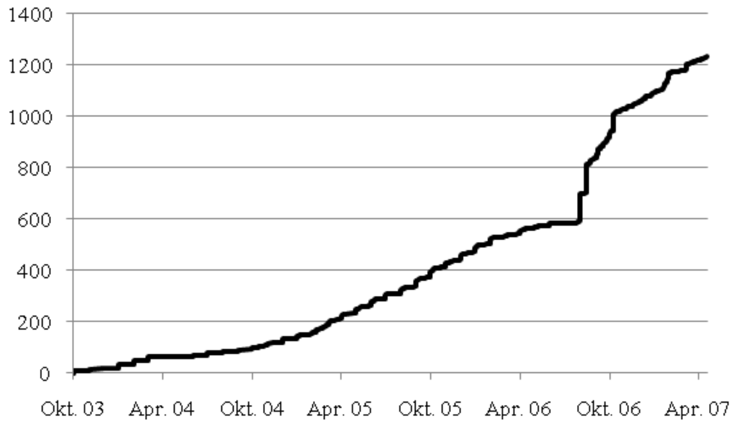

Figure 1. Development of the number of EPCglobal subscribers from September 2003 to April 2007 (Source: EPCglobal Inc.).

Compared to the development of the UPC, i.e. the US barcode standard, and the enormous number of users today, one can see that the development of the adoption and diffusion of RFID as measured by the number of EPCglobal subscribers is just at the beginning (Figure 2). It takes time before different industries adopt a technology and another additional time before adopting a standard as well.

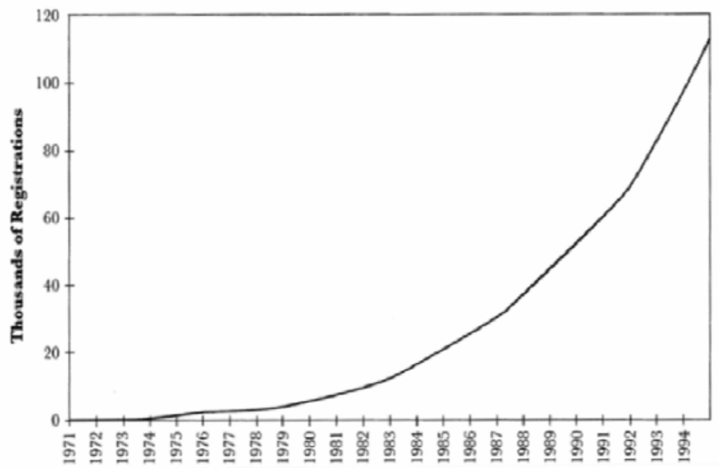

Figure 2. Development of the number of UPC subscribers from 1971 to 1995 [15].

In contrast to EPCglobal, 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. The bend of the EPCglobal subscriber curve in August 2006 (cp. Fig. 1) corresponds to the ratification of the EPC Gen2 by ISO in August 2006. It seems that ISO standards still play a major role even for companies adopting the EPC.

4.4 RFID Standardization Activities in the Automotive Industry

Future RFID systems in the automotive industry will aim on sophisticated supply chain management applications. In open-loop systems with more than one partner and different use cases, a single tag ought to be used for diverse purposes, enabling synergetic effects in a wide network: From parts or modules delivered by a supplier to the assembled car which is distributed to the dealer and from there to the customer. Thereby, RFID will help to transform the automotive industry from a product industry into a more service oriented industry, e.g. by implementing RFID in life-cycle-management and after market processes [16]. For this reason, a RFID standard is needed which can be used in many processes and diverse applications of the industry, at best all over the world.

Unlike retailers as Wal-Mart, Metro, and Tesco that already adopted the EPC standard and mandated hundreds of suppliers to adopt RFID technology and the EPC as well, the automotive industry uses RFID so far basically in closed-loop systems with proprietary standards. Local closed-loop applications aim basically on the substitution of manual handling and the reduction of media breaks by manual barcode scanning or typing numbers with a keyboard into a computer system. In collaborative closed-loop applications with only one supplier it is more or less simple to implement proprietary standards. Until now the automotive industry aims on carrying process information on transponders, e.g. shipping date, receiving date, sender and recipient information, part numbers, quantities, and process step or sequence. It should be possible to get access to the data even if there is no connection to the backend system which is a crucial precondition for JIT and JIS manufacturing processes. That is a completely different approach compared to the basic EPC principle where the transponder carries a unique identifier which refers to the information in a backend system or data base [13].

The mere dimension of the industry and the quantity of RFID pilot studies in various processes, applications and environments seems to be a reason for slow standard development and therefore slow RFID adoption and diffusion. Requirements and constraints of many key players have to be taken into account. Additionally, the automotive industry is still an ISO-driven industry and probably expects more appropriate ISO standards while other industries adopted the faster developing, user-driven EPC - ISO standardization still takes a long time [7]. Furthermore, especially the European automotive industry is skeptical regarding organizations like EPCglobal. They do not want to become dependent from American based/owned companies even though the EPC is distributed by the GS1 organizations of the home countries of the particular companies. That is one reason (beside costs) the automotive industry never adopted the UCC/EAN barcode standard apart from the aftermarket business where parts and accessories are sold by retailers, dealer’s garages and shops. Last but not least there are powerful national and international associations of the automotive industry which claim standard development as one of their own core competencies. Against this background, we take a closer look to the RFID standardization activities of automotive industry associations:

The US based Automotive Industry Action Group (AIAG) was founded by DaimlerChrysler, Ford Motor Company, and General Motors in the 1980s and provides a platform for the (US) automotive industry to develop new technologies and standards. In 2006, the AIAG published the ‘B-11: Tire and Wheel Label and RFID Standard’ [17]. Driven by major tire manufacturers facing among others the US TREAD Act[1], the AIAG work group developed a standard which is able to facilitate the EPC or ISO AFIs (Application Family Identifiers) with a single RFID tag. That was a basic requirement because on the one hand tire manufacturers wanted to use ISO AFIs and additional data in the user memory of a RFID tag in their supply chain and on the other hand they sell a lot of their products through US retailers like Wal-Mart and have to meet the EPC retail mandates. Therefore the B-11 standard is based on ISO 18000-6C/EPC Gen2 and solves the challenge by using inoperable bits in the code as a flag for EPC or ISO data (“bit toggling”) to denote whether the Memory Bank 11_2 (free user memory) is being used or not (Figure 3).

		MB01_2, bit 17 hex "UII"	
		0=EPC	1=ISO AFI
MB01_2, bit 15 hex User Memory	0	YES EPC Data NO User Data	NO EPC Data NO User Data
	1	YES EPC Data YES User Data (B-11 recommendation)	NO EPC Data YES User Data

Figure 3. B-11 standard for using bits 15h and 17h in Memory Bank 01_2 of ISO 18000-6C/EPC Gen2, to denote whether Memory Bank 11_2 (free user memory) is being used [17].

[1] Transportation Recall Enhancement, Accountability, and Documentation Act, US Public Law 106-414, Nov. 1, 2000.

ISO 18000-6C provides a general structure of the transponders' memory but does not specify a certain user memory structure. A data structure beside of the DoT Tire Identifier for the free user memory is not suggested by the AIAG. The proposal further refers to ISO/IEC 15961 (Data protocol: Application Interface) and ISO/IEC 15962 (Data protocol: Data encoding rules and logical memory functions).

The B-11 standard further defines beside of the frequency of 860-960 MHz (UHF) that the minimum (passive) tag size should be 128 byte (1,024 bits). To meet the requirements of the tire and/or automotive manufacturer a size of 256 bytes (2,048 bits) could be required [17].

The Association of the German Automotive Industry (VDA) developed in 2006 a recommendation for the use of RFID in container management processes (VDA 5501) [18]. Central statements of the recommendation are the use of the UHF frequency band (860-960 MHz) and technology that is conform to ISO 18000-6C/EPC Gen2. Furthermore, the use of passive R/W-transponders is suggested but no advice for a certain transponder capacity is given [18]. RFID transponders can be employed in two different ways: It is possible to use transponders with only a unique container identifier or with a unique identifier and additional data in the user memory section of the RFID tag according to ISO 18000-6C 18. Therefore, the VDA recommendation adopts the AIAG proposal for using inoperable bits in the code (Fig. 3). Additionally, the VDA defines a data structure which origin is partly recommendation VDA 4913 [19]. This recommendation specifies the data content and structure of an 'EDI delivery note and transport information message'. The unique container identifier that ought to be written on the RFID transponder is not finally specified but the recommendation mentions possible numbering schemes, e.g. a DUNS-Number[2], the serial number of the container, an EPC or a proprietary identifier.

Odette International represents the automotive industry and their members. Odette aims on setting standards for e-business communications, engineering data exchange and logistics management. At the time of writing, Odette represents associations and companies of six European countries. In July 2006, Odette started a RFID project with the purpose to identify how best to apply RFID technology for specific applications within the automotive industry. The mission is to make proposals for global automotive recommendations that harmonize globally with other standards and define a common data structure for use in RFID tags in the automotive industry. Nearly half of the project group members were involved in the development of the VDA 5501, too. The project deploys the results of the VDA activities and ends in December 2007.

[2] Worldwide unique identifier of a company assigned and administrated by Dun & Bradstreet. www.dnb.com

The different standardization approaches show that the automotive industry is actively pushing forward the RFID standard evolution. Central findings for the further development of a RFID standard respectively the planned use of RFID are:

- Progress of standardization from national, to international, to global level
- Use of the UHF frequency band
- Use of EPC conform hardware (but no definite decision to adopt the EPC)
- Use of free memory capacity for user data
- No uniform structure of the user memory

First ideas are discussed in national organizations before proceeding on an international scale. The proposals have in common that they are based on the UHF technology and want to apply EPC conformed hardware. Additionally, they plan to use the free memory capacity of RFID transponders for additional user data. The data structure is designated to be based on ISO, VDA or other norms.

In the following chapter we will discuss the different approaches and the probably evolving problems.

5 Discussion

The various standardization efforts clearly demonstrate the importance of a standard for an industry but as well that a standard which seems to be appropriate for one industry sector is probably not sufficient for another. Therefore, it takes time to develop or adjust a standard for the use in a specific industry which as a result slows down adoption.

By the time the EPC Gen2 standard was ready for submission to ISO many industries claimed for the possibility to store additional user data on the transponder. In the first place the automotive industry, when the AIAG started to develop the B-11 proposal. The pharmaceutical industry identified needs for lot/batch numbers, expiration date, full National Drug Code (NDC) while the electronics industry wants to write harmonized tariff codes and serial numbers on the transponders. There came up a long list of required data for cold chain logistics, the airport transport industry, the aeronautics industry, the telecommunications industry and many more. Unfortunately, EPCglobal and the involved users paid too little attention to those claims and just added the possibility to write data into an unstructured user memory. The reasons for this inattention are that those developing the EPC Gen2 specification were attempting to promote a concept whereby the EPC would have all information incidents to the code resident on a database. Furthermore, the initiative was dominated by the Fast Moving Consumer Goods (FMCG) sector which indented to use the 96-bit code only. Finally the underlying premise of the 96-bit code was that tag prices would remain low and further decrease significantly [20].

The result of this decision is that industries like the automotive industry started to develop data structures by themselves. This would be feasible if tags and products circled only within single industries. But the examples of tires or spare parts show that usually more than one industry is involved. Therefore, each industry needs an application program, middleware and reader protocols to process the user memory data correctly. Every time a supply chain partner wants to add information at a certain position, in another field, the whole network will need an update. If an update is not available early enough many problems will evolve because information cannot be interpreted or - even worse - will be misinterpreted. The same holds for transponders which have been put in circulation before. Additional problems could emerge through data redundancies between data on tag and information on the database.

The efforts of the automotive industry show that the industry is exerted to keep as many options as possible: Regarding a global standard for RFID supply chain applications it is favorable that the existing approaches are all based on the existing ISO 18000-6C/EPC Gen2 standard even though there is no explicit decision for an overall concept and a unique identifier. The approaches have in common that a bottom-up strategy was chosen for the standard development. Based on the requirements of single closed-loop applications like container management or the track and trace of tires and wheels, the automotive industry is trying to elevate these approaches to a higher level. It is likely that this strategy and the proposed standards will not meet all requirements of the automotive supply chain in the future, e.g. regarding an RFID based maintenance history, life-cycle-management or anticounterfeiting. A top-down strategy for RFID standard development would have been more promising: First, to adopt a generic standard with a “one-fits-all” concept and second, to look into detailed processes and applications and then to adjust these processes to the overall concept.

Against this background, it becomes obvious why the adoption and diffusion of RFID technology takes time and why standards are such important for the industry. In the case of the automotive industry, three reasons can be identified that decelerate the adoption and diffusion of RFID technology:

- Skepticism about the EPC concept and EPCglobal
- Long-lasting standardization process/adoption decision through different national and international industry associations (committees)
- Lack of a RFID mandate

The global availability of a standard (e.g. the EPC) is just a precondition. Much more important is the acceptance by the various types of industry and the length of time until a decision is made. Without a mandatory use of RFID for specific processes in the automotive industry it will take additional time until RFID is broadly diffused into new supply chain applications.

From our perspective it seems to be recommendable that the automotive industry starts to discuss about developing e.g. a hybrid EPC which should meet the requirements of the automotive industry as well as the premises for the use of the EPC network. This would be a possible solution to implement a real RFID networked industry. Therefore, it is important to get involved as early as possible into industry standard development groups as well as to observe the ongoing EPCglobal and ISO standardization processes.

6 Summary and Outlook

Obviously, an accelerating adoption and diffusion of RFID technology across various industries was expected after the first announcements of Wal-Mart's and Metro's EPC supplier mandates. But it did not take place as expected. Even in the automotive industry - as an example in this paper - with long experiences in using RFID technology did not come up with great roll-out plans until today. The reasons can be found in the basic differences of the two industries and are exemplary in the use and development of standards. On the one hand, the use of RFID in the retail sector is predominately focused on merely simple logistical operations between suppliers that deliver finished products to distribution centers or directly to retail stores. On the other hand, the supply chain of the retail sector is highly hierarchically and the major retailers are in a dominant position. In the automotive industry the situation is different: The logistical processes are much more sophisticated e.g. regarding JIT/JIS processes and delayed or missed deliveries have a much higher impact than in the retail sector. Additionally, many production processes have been outsourced: Suppliers deliver parts and modules and work closely together with the vehicle manufacturers already in the development of new products. Therefore, the vehicle manufactures work in partnership with their suppliers – switching of partners is not easy to manage.

The automotive industry already started to use RFID technology in the supply chain in closed-loop systems and on a small scale. Having tested the performance in various pilot studies the need for the adoption of a global standard becomes necessary before starting to implement RFID in larger systems and in open-loop systems. Especially the after market is becoming very important and RFID solutions for life-cycle-management, maintenance and service history, and the reduction of counterfeit products are not feasible without a global standard.

Standards are one of the most important factors for the adoption and diffusion of a new technology. They are especially crucial when implementing a network technology like RFID. Even the automotive industry which is one of the biggest in the world will need to adopt a global standard because of its various interfaces to different suppliers and other branches, e.g. the retail sector. Missing this opportunity in the early stage of RFID adoption will result in higher costs later when it possibly becomes necessary to switch to another or to adopt an additional standard and means loosing advantages in competition and evolving network effects.

Further research regarding the influence of RFID standards and the reason for/against the adoption could be conducted in other industry sectors. Additionally, the comparison of the hierarchy structure in different supply chains and the adoption and diffusion of RFID could yield interesting results.

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