RFID Standardization for Logistics Applications – Status Quo and Challenges from the Automotive Industry's Perspective

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Abstract **– Standardization remains an ongoing challenge for RFID adoption in many application domains. Although progress has been made in recent years, areas remain where standards are lacking or where several standards are competing. In this paper we focus on automotive logistics. We discuss recent developments and remaining challenges for standards development and adoption in the automotive industry.**

I. Introduction

Standardization has been identified as an important requirement for widespread adoption in many application domains. Although significant progress has been made in recent years, standardization remains an important issue for practice and research: Several authors have discussed RFID standardization issues regarding industry-specific and cross-industry aspects [1, 2, 3], visionary approaches such as the *Internet of Things* [4] and related developments such as combined application of RFID and sensor technology [5].

RFID standards for the automotive industry have been addressed as well [6, 7]. However, especially in the last two years there has been a lot of progress regarding the standardization of RFID for automotive logistics, which is not reflected in these articles. This paper therefore aims at presenting an up-to-date overview of the current state and future challenges for RFID standardization in automotive logistics. It is one of the first contributions that relates current ISO/IEC and GS1/EPC characteristics to actual industry practice.

The rest of the paper is organized as follows: The next section describes the significance of standardization for RFID adoption. In section 3 we focus on the current state of standardization from the automotive industry's perspective. We present recent activities and results from relevant standardization bodies. Subsequently we analyze how these standards are used in practical projects using the example of Volkswagen AG, where a multitude of RFID projects have been conducted in recent years. Several interviews with project stakeholders have been conducted in order to analyze practical issues for standards adoption. Future challenges for RFID standards adoption in automotive logistics are discussed in section 4. The paper ends with a brief conclusion and outlook in section 5.

II. Significance of Standardization for RFID Adoption

RFID applications are typical *critical mass* systems [8], i.e. RFID systems require a minimum amount of users and tagged objects in order to accomplish economy of scale and create economic value [9]. Standards support companies during the adoption and diffusion phase of new technologies [10, 11]. They canalize and catalyze industry activities thus speed up the innovation process [12]. Standards ensure the compatibility/ interoperability of RFID systems and required data exchange. Stakeholders may choose to implement proprietary guidelines for internal RFID implementations, however, cross-company applications require the establishment of mandatory industry standards [1, 13, 14].

III. Standardization Issues for Automotive Logistics

Existing standards can be classified as follows: *Air Interface*, *Data Protocols*, *Application Standards*, *IT-Architecture and Data Exchange*. In addition there are multiple *Industry Recommendations*, which provide industry-specific guidance on how to apply the proposed *Air Interface*, *Data Protocols* and *Application Standards*. In general *Industry Recommendations* focus on process-related aspects of RFID implementation thus ignore generic hard- and software details as described in the available *IT-Architecture* and *Data Exchange* specifications. The proposed standards and recommendations are affected by two standardization bodies: ISO/IEC and GS1/EPC. Table 1 shows an overview of the relevant documents, which are discussed in the following sections.

3.1 Air Interface

The air interface has been specified in ISO/IEC 18000-6C. ISO/IEC 18000-6C references EPC Class 1 Gen 2 and vice versa. Despite the common approach towards air interface design, there are regional differences. Ultra high frequency (UHF) systems operate at 868-960 MHz. Within this range the *International Telecommunications Union* (ITU) distinguishes between three different application zones: Europe (865-868 MHz), USA (902-928 MHz) und Japan (950-960 MHz) [15]. RFID transponders are usually optimized for one of these regions [16]. To some extent they may be read by RFID readers/antennas that operate at different frequencies. However, such mixed systems usually suffer from severe performance restrictions. Regional differences therefore represent one of the remaining challenges for global RFID application as business partners need to make sure that transponders can be read by all parties involved.

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TABLE 1 – RFID STANDARDS AND RECOMMENDATIONS

ISO/IEC	GS1/EPC
Air Interface	
ISO/IEC 18000-6C/ EPC Class 1 Gen 2 (UHF 860-930 MHz)	
Data Protocols and Application Standards	
Data Protocols ISO/IEC 15418 (Data Representation) ISO/IEC 15459 (Unique Identification) ISO/IEC 15961 (Application Interface) ISO/IEC 15962 (Transponder Interface) ISO/IEC 15963 (Tag Identification) ***Application Standards*** ISO/IEC 17358 (Appl. Requirements) ISO/IEC 17363 (Freight Containers) ISO/IEC 17364 (Return. Transport Items) ISO/IEC 17365 (Transport Units) ISO/IEC 17366 (Product Packaging) ISO/IEC 17367 (Product Identification) ISO/IEC 29133 (Hybrid Media)	EPC Tag Data Standard EPC Tag Data Translation
IT-Architecture and Data Exchange	
ISO/IEC 24791-1 (Software Architecture) ISO/IEC 24791-2 (Data Management) ISO/IEC 24791-3 (Device Management) ISO/IEC 24791-4 (Application Interface) ISO/IEC 24791-5 (Device Interface)	EPC Information Services, Application Level Events, Reader Management, Reader Protocol, Low Level Reader Protocol, Discovery Configuration & Initialization, Discovery Services, Object Naming Services, Core Business Vocabulary
Industry Recommendations	
VDA 5501 (Container Management), VDA 5509, 5510 (Component and Part Tracking), VDA 5520 (Vehicle Distribution), AIAG-B11 (Object Identification), JAIF Global RTI (Returnable Transport Items), JAIF Global Item Level Standard (Components and Parts)	

3.2 Data Protocols and Application Standards

The automotive industry has not agreed on whether to implement ISO/IEC or GS1/EPC data protocols and application standards yet. This issue has been identified as one of the reasons for hesitant RFID adoption and diffusion [7]. According to the *Organisation for Economic Co-operation and Development* (OECD) the ongoing discussion about ISO/IEC and GS1/EPC is splitting the automotive industry into two camps [17]. Sprafke, head of the RFID Competence Center at the Volkswagen Aktiengesellschaft, puts this position into perspective and states that there is no direct competition between the two standards. The automotive industry is working with both organizations and international partners to achieve a standard that meets the needs of the industry [18]. While some of the major players from the consumer goods industry decided to adopt GS1/EPC standards, the automotive industry still hesitates [7]. According to Sprafke the automotive industry prefers ISO/IEC standards [19]. There are several reasons for this. The majority of existing auto-ID applications in the automotive industry are based on ISO/IEC standards [18]. These standards have evolved over time and are not necessarily covered by GS1/EPC. The original GS1/EPC approach implements centralized data organisation. A numeric reference ID is stored on the transponder. Additional object and process data is kept on the network [20]. Harmon claims that more generic approaches are required to turn GS1/EPC into an applicable standard for cross-industry application [21].

Industry recommendations such as AIAG-B11, VDA 5509, VDA 5510 and VDA 5520 indicate the requirement to store alphanumeric reference schemes and additional user data on the RFID transponder. ISO/IEC provides a generic approach that is able to cope with these requirements. Both numeric and alphanumeric reference schemes as well as additional user data may be applied.
By now GS1/EPC has extended UII capabilities and provides for additional user data [see GS1 EPC Tag Data Standard 1.6], however, the basic principle of numeric referencing IDs has not been changed and remains an open issue for RFID adoption in the automotive industry. Alphanumeric referencing schemes such as Vehicle Identification Numbers (VIN) and part numbers are deeply entrenched in today`s business culture and in contemporary IT systems. Switching to GS1/EPC principles may come with extensive investments and endanger established business processes [22].

The Data Universal Numbering System (DUNS) is another concept that is used in automobile logistics. DUNS numbers uniquely identify business partners and organizational units. The *Global Transport Label* (GTL) for instance implements DUNS numbers as part of the *License Plate*, which uniquely identifies a package item. DUNS numbers may be obtained at Dun & Bradstreet (D&B) and are free of charge. In contrast, GS1/EPC charges for unique identification numbers. Volkswagen Aktiengesellschaft and other automotive manufacturers expect that suppliers may shift related costs to the automobile manufacturers and consequently affect product pricing [22, 23]. Another argument for ISO/IEC standards is the capability to apply hybrid barcode and RFID approaches. Today barcode is the dominant identification in the automotive supply chain [24]. The barcodes contain established numbering schemes such as the DUNS number, the Vehicle Identification Number (VIN) or part numbers. Barcodes usually implement ISO/IEC standards. ISO/IEC standards provide a generic methodology which allows transferring established data structuring elements and data contents to related RFID applications [25]. Hybrid barcode/RFID approaches are expected to support the migration from barcode to RFID and to foster the adoption and diffusion of RFID technology since new RFID techniques are likely to profit from established infrastructure [26, 27]. At this stage GS1/EPC standards provide for limited interoperability/ compatibility only. Consequently they do not necessarily support such incremental implementation strategies.

GS1/EPC has been first in proposing resilient RFID standards. However, in the recent past ISO/IEC specifications have been aligned accordingly. Remarkably GS1/EPC standards increasingly reference ISO/IEC norms such as ISO/IEC 15961, ISO/IEC 15962, ISO/IEC 15963 and provide for enhanced interoperability/ compatibility. It seems reasonable to assume that ongoing standardization will lead to further harmonization and assimilation of the two standards families. However, at his point ISO/IEC standards cover prevalent application domains in the automotive industry and provide for better alignment with established numbering schemes.

Volkswagen Aktiengesellschaft decided to implement ISO/IEC data structures. ISO/IEC data structures implement Application Family Identifiers (AFIs) [see ISO/IEC 17367]. AFIs describe the application context and enable the implementation of application-specific filtering algorithms. For instance, AFIs may be used to distinguish between Products and Returnable Transport Items (RTIs). The Unique Item Identifier (UII) and the User Memory (UM) of RFID tags contain object and process related data and are structured using Data Identifiers (DIs). Data Identifiers account for more detailed description of the data contents and provide for additional filtering algorithms [see ANSI MH10.8.2 2006]. The Unique Item Identifier (UII) allows for unique object identification. If necessary additional data is written to the User Memory (UM). In this way ISO/IEC provides extensive flexibility regarding on-Tag data representation. ISO/IEC is well suited for structuring dynamic User Memory contents. GS1/EPC has not developed a proprietary concept to structure dynamic User Memory content and recommends implementing established ISO/IEC methodology for this particular purpose [see GS1 EPC Tag Data Standard 1.6].

We analyzed eight RFID (pilot) projects at Volkswagen Aktiengesellschaft (2009-2012) in order to understand typical requirements in the automotive supply chain. The projects cover a wide range of application scenarios of RFID systems in automotive logistics: Four projects (conducted in Germany and Spain) deal with material logistics and management of returnable transport items

(RTI). Two projects (conducted in Germany and Mexico) cover the use of RFID for spare parts logistics. One project in Germany deals with the use of RFID to identify vehicle components in automotive development processes. In the last project, RFID was used to track vehicles in distribution processes.

Our research shows that the basic requirements of Volkswagen Aktiengesellschaft are covered by four types of data structures. Figure 1 shows these data structures which were deduced from existing ISO/IEC standards and referenced industry recommendations. While ISO/IEC standards were able to cope with the requirement that were put forward, GS1/EPC standards provided for limited coverage only. This stems from the restricted ability of GS1/EPC standards to deal with alphanumeric numbering schemes and flexible data field lengths.

Preliminary studies at Volkswagen Aktiengesellschaft (2009/2010) showed that back then ISO/IEC standards provided insufficient guidance regarding the definition of appropriate Data Identifiers (DIs), Data Separators (+) and Padding to be applied. Considering the progress that ISO/IEC standards have made since then and the arguments that were put forward in the previous discussion, there are reasonable doubts that the automobile industry will adopt GS1/EPC standards in the near future.

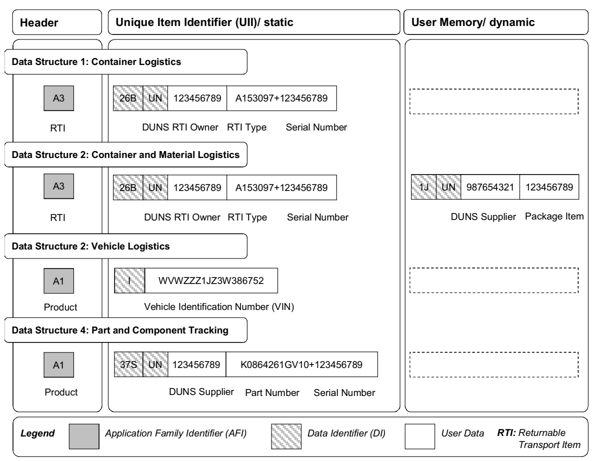

FIGURE 1 – EXEMPLARY DATA STRUCTURES FOR AUTOMOTIVE LOGISTICS (VOLKSWAGEN AKTIENGESELLSCHAFT)

3.3 IT-Architecture and Data Exchange

IT-architecture and data exchange standards may be categorized according to low level and high level contents. Low level standards address the communication between RFID-specific hardware and edge- and middleware. High level standards describe data management and data exchange methods.

Contemporary RFID solutions do not always comply with the proposed low level standards. Volkswagen Aktiengesellschaft uses a variety of RFID readers from different brands. Each one of these readers requires different driver utilities. The example shows that there is plenty of work to do in order to turn RFID hard- and software into plug&play solutions. In the meantime dedicated edge- and middleware approaches need to provide for hardware abstraction and help end users to resolve proprietary reader characteristics [28, 29, 30].

Visionary RFID approaches such as the Internet of Things propagate cross-company services, which allow accessing object-related data anytime and anywhere [31, 32]. High level standards such as the EPCIS (Electronic Product Code Information Services) provide for centralized data repositories and adequate methods to share data between supply chain participants [33, 34]. However, examples such as the German research project RAN (RFID Based Automotive Network) indicate that at this point centralized repositories do not necessarily meet the needs of the automotive industry and raise cost and security concerns. The EPCIS used in this project is still in an early phase of development [35]. So far the participating project partners rely on decentralized IT approaches.

A close look at the contemporary supply chain suggests that there might be a lack of demand for centralized repositories. The automotive supply chain is based on the principle of cascaded responsibility. Supply chain partners are responsible for specific supply chain stages. They need to provide traceability within this stage. Objects need to be traced back to the last participant only. None of the business partners needs to guarantee traceability across the entire supply chain. Obviously there is a demand for transparency within specific supply chain stages. However, this demand is covered by existing IT-systems and data exchange methods such as EDI (Electronic Data Interchange).

Centralized approaches such as the EPCIS raise security concerns. The repository is accessed by multiple business partners. Firstly, adequate role and security concepts need to be established in order to prevent unauthorized data access [36]. Secondly, centralized approaches raise concerns regarding data management and data ownership [37, 38]. The repository contains critical product and business information. Companies are likely to reject the outsourcing of critical information to third party service providers [39]. Moreover, the outsourcing of critical business information creates organizational dependencies and may lead to unpredictable cost implications [19]. The objections that were put forward suggest that in the near future the automotive industry will continue to work with decentralized IT systems and established data exchange methods in in order to avoid potential migration issues. RFID implementations may require incremental adaptions and additional customization. However, considering the mentioned implications of switching to centralized repositories, the majority of automotive manufacturers is not likely to implement such radical changes anytime soon.

Nevertheless, the RFID community has been active in proposing RFID-specific IT infrastructure and data exchange methods. GS1/EPC provided appropriate methodology at a very early stage. The framework allows the certified development of RFID-specific information systems and contributes to the standardization of IT-architectures and software products. EPC Information Services (EPCIS) are intended to process native GS1/EPC data structures. Although the framework has been extended to process ISO/IEC data structures, there are still some limitations regarding the processing of data structures that originate from different standardization bodies. In 2010/2011 ISO/IEC introduced the standard family ISO/IEC 24791. The framework is aligned with proposed GS1/EPC standards but provides more flexibility. Flexibility may be beneficial but involves risks as well. ISO/IEC standards are not as binding as the ECP/GS1 equivalents and require additional interpretation thus may lead to increased coordination efforts and more complex requirements regarding error and exception handling.

IV. AUTOMOTIVE INDUSTRY RECOMMENDATIONS: STATUS QUO AND FUTURE CHALLENGES

AIAG-B11 is one of the seminal recommendations for RFID applications in the automotive industry. AIAG-B11 is based on ISO 18000-6C/ EPC Gen2 and implements bit toggling to distinguish between ISO/IEC and GS1/EPC data contents and to indicate whether additional User Memory is used or not. The consortium recommends that tags should contain a Unique Item Identifier (UII) Memory Bank (min. 280 bits) for identification reasons and an additional User Memory (min. 512 bits) to store application specific data. The data syntax to be applied is ISO/IEC 15962 and ISO 1736x and based on Data Identifiers (DIs) which are specified within relevant ISO/IEC or GS1/EPC data syntax standards [see AIAG-B11]. The essential benefit of the AIAG standard is that it accounts for both ISO/IEC and GS1/EPC standards. AIAG-B11 may be considered to be a first step towards the harmonization of ISO/IEC and GS1/EPC standards. However, despite the proposed methodology, supply chain partners still need to agree on whether to implement ISO/IEC or GS1/EPC data structures to successfully provide essential object and process information.

Industry recommendations such as VDA 5501, VDA 5509, VDA 5510 and VDA 5520 consider both ISO/IEC and GS1/EPC standards. VDA 5509 and VDA 5520 suggest applying alphanumeric part numbers and the Vehicle Identification Number (VIN) respectively. At this stage both alphanumeric part numbers and Vehicle Identification Numbers are not covered by the GS1/EPC Tag Data Standard which may lead to ISO/IEC orientated interpretation. The same applies for AIAG-B11. AIAG-B11 mainly references ISO/IEC standards such as ISO/IEC 15962 and ISO/IEC 17363-17367 [see AIAG-B11]. Despite the call for harmonization of ISO/IEC and GS1/EPC standards AIAG-B11 seems to be strongly influenced by ISO/IEC approaches.

In the past years the large parts of the hardware and software industry have endorsed GS1/EPC methodology, i.e. providers concentrated on proposed GS1/EPC data structures and reduced memory requirements. At this point relatively few RFID providers and consultancies possess profound knowledge and experience regarding structure and coding/decoding of ISO/IEC data standards. This may be partially due to the fact that GS1/EPC documentation is more accessible than ISO/IEC documentation and free of charge and thus receives more public attention. Since 2009 Volkswagen Aktiengesellschaft repeatedly informed RFID providers and consultancies about ISO/IEC standards and related requirements in order to push the industry to provide RFID transponders with sufficient memory and to supplement appropriate software/hardware to process and interpret ISO/IEC approaches. The industry will have to adapt existing product and service portfolios to cover the automotive industries' requirements and keep up with future developments.

V. Conclusion and Outlook

The development of RFID standards for logistics applications has made considerable progress in recent years. Industry-specific as well as cross-sector standards and recommendations have been developed by ISO/IEC, GS1/EPC and industry-specific standardization bodies. Despite of the progress that has been made in the recent years some challenges remain. Our research at Volkswagen Aktiengesellschaft indicates that hardware- and software-specific standards are subject to ongoing standardization issues. So far the RFID industry has not been able to provide plug&play solutions yet. Regarding Data Protocols and Application Standards the automotive industry has not yet decided on whether to implement ISO/IEC or GS1/EPC approaches. ISO/IEC data standards are preferred by many automotive manufacturers as they allow for better compatibility with established barcode numbering systems. Considering the contemporary practice in the automotive industry ISO/IEC standards are likely to provide for a smoother migration path than GS1/EPC standards. However, some automotive manufacturers are committed to implement GS1/EPC approaches. The further harmonization of application standards will be crucial for RFID adoption in automotive logistics. This particularly refers to cross-company RFID applications.

Remaining challenges such as the different frequency ranges that are applied in Europa, USA and Japan will not be resolved in the foreseeable future and raise the demand for reliable backup concepts. Future research shall focus on the development of multi-frequency transponders. At this stage hybrid barcode and RFID applications provide for reliable backup. We suggest that further research shall address the role of hybrid applications on immediate RFID adoption and diffusion and related migration issues.

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