Assessment of EPCIS Standard for Interoperable Tracking in the Supply Chain

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Abstract. With increasing globalization and loosely-coupled business relations between different companies, the importance of information exchange standards is increasing. GS1's Electronic Product Code Information Services (EPCIS) is currently one of the main standards proposed for inter-organizational data exchange for track and trace purposes in the supply chain. However, despite its strong industrial background and maturity, EPCIS is not yet used as a global standard for trace and track applications. This paper attempts to analyze why EPCIS has not been universally adopted as a global data-exchange standard for track and trace by analyzing three application areas where the use of EPCIS should provide substantial benefits. The results of this analysis should provide useful insights into the challenges of introducing new, global standards and guidelines for similar initiatives in the future.

Keywords: Track and trace, supply chain management, inter-organizational data exchange, interoperability, EPCIS.

1 Introduction

Inter-organizational data exchange has probably existed in some form for nearly as long as there has been life on our planet. Data exchange between humans and other living beings, as well as communities and organizations, is performed by sounds, gestures, chemical substances, light, smoke or other media. In our current society, paper-, telephone-, fax-based etc. technologies have been the state-of-the-art during the 20th century. Now these technologies are being replaced or complemented by technologies using computer networks, where the internet has become the main network for inter-organizational data exchange.

Computer networks make it possible to exchange information much faster than before, including the possibility to process the data automatically. Also, data transmission delays are no longer dependent of geographical distances. These new possibilities enable organizations to set up inter-organizational operations much faster and with little or no human intervention, as long as different organizations implement the same protocols for data exchange. Standards are the cornerstone for enabling such implementations where the implementation effort does not depend on the number of

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organizations that exchange data. Successful examples of such standards in Supply Chain Management (SCM) are Electronic Data Interchange (EDI) and RosettaNet standards.

Supply chains are getting more and more geographically spread and loosely coupled [1], which signifies that they need to be able to set up new supplier relationships at a higher pace than before. Concepts used for this kind of loosely coupled supply chains are Virtual Enterprises [2] and Extended Enterprises [3]. Loose coupling is particularly challenging for inter-organizational data exchange, which still today often requires long and expensive setup of EDI communication. Even after EDI integration, supply chains have great challenges in implementing fundamental operations such as tracking shipments and deliveries, as well as handling after-sales and service operations on product individuals. The advance shipping notice (ASN) in EDI is the message that gets the closest to shipment tracking but it is not suitable or intended even for shipment tracking. This is why most shipment tracking systems are organization, specific, such as those provided by companies like FedEx, UPS etc.

In order to implement shipment tracking, and after-sales and service operations on product individuals and so on, it is necessary to identify shipments and products as individual instances rather than just belonging to some product category. Company-specific tracking or serial numbers are currently the most used identifiers for product individuals. However, due to their company-specific nature, they are not suited for inter-organizational data exchange. One example of a globally accepted and widely used shipment individual identifier is the serial shipping container code (SSCC) that is standardized by GS1. The SSCC can easily be used with barcodes. However, the advances in radio frequency identification (RFID) technology, as well as the decreasing cost of implementing that technology, has opened up completely new possibilities for the identification of shipment and product individuals. RFID supports product individual-level identification nearly "by definition" because all RFID tags are identified by a unique tag identifier. RFID also provides new application opportunities because RFID does not need a line of sight, so many identifiers can be read with one single read operation. Such properties signify that many kinds of inventory operations can be made automatic, thus providing an increased accuracy of material flows while speeding up operations and reducing the need for manpower.

The use of RFID tags and product individual-level identification in general creates challenges for existing SCM information systems. Several initiatives have been created for implementing inter-organizational data exchange protocols and interfaces, such as the Auto-ID Centre at MIT, the DIALOG initiative at Helsinki University of Technology [4] and the peer-to-peer based paradigms of the company Trackway [5]. Elements developed by the MIT Auto-ID Centre were taken up by the non-profit company EPCglobal, which later became a part of GS1. Especially the electronic product code (EPC) and the related radio interface protocols defined by EPCglobal have been undeniable successes as standards for UHF-based RFID tags. UHF tags are the most used ones in SCM applications due to their long read range, which can be over several meters in optimal conditions. It is also possible to read hundreds of tags with one single operation, therefore providing considerable advantage in reception points for incoming goods, for taking inventories, etc.

EPCglobal's information system framework is called the EPC network [6]. It contains specifications for managing RFID readers and collecting information from them

(Application Layer Events, ALE), the *EPC Information System* (EPCIS) and other components for looking up information sources about shipments and products. EPCIS is the standard proposed for being used for inter-organizational data exchange in the EPC network. When considering the background of EPCIS and the maturity of the standard, one would expect that it would by now be universally used for tracking items in inter-organizational settings. However, it seems like it is far from being so in reality. The main research question set out for this paper is to what extent EPCIS is being used in reality, as well as identifying the main application domains in which it is used. The main objective of the paper is to analyze and understand the reasons for which EPCIS has not yet become universally used, as well as if and when it eventually will become universally used.

After this introduction, the paper provides an overview of inter-organizational data exchange in general and EPCIS in particular. Then we provide an overview of different domains where EPCIS has been used to some extent and identify three domains that are of particular interest due to their relatively advanced state regarding inter-organizational data exchange and experiences from using EPCIS. The level of use of EPCIS is analyzed in detail for the selected domains, followed by conclusions.

2 Background

Inter-organizational data exchange signifies the transfer of electronic documents or business data from one computer system to another computer system, i.e. from one trading partner to another trading partner without human intervention. Data exchange requires some kind of physical media for transmitting the data from one system to the other, a protocol that allows determining what system should send when, one or more interfaces that send and/or receive data and a semantic layer for understanding the data in a uniform way. When two humans communicate using voice only, frequency modulation of air vibrations is the media. The protocol is determined by tone, facial expressions, content etc. The interface for sending is the mouth and ears are used for receiving. The brains take care of the semantic interpretation of the data received, the processing of it and sending back new data.

All these same elements (media, protocol, interfaces, semantic interpretation) are also present in computer-to-computer communication. A major difference between computer-to-computer communication and human-to-human communication is that humans can tolerate some degree of noise, errors and misunderstandings. An intellectual dialogue between humans can usually filter out the worst misunderstandings. However, computers are not yet capable of performing such dialogue, which creates strict requirements on how unambiguously all data exchange standards must be defined. The further ”up” we go towards the semantic level, the more challenging it is to create data exchange standards that are unambiguous, while providing a sufficient power of expression. EPCIS is mainly an interface standard, even though it also contains both protocol and semantic elements. This makes it particularly interesting to study the level of usage of EPCIS because it may provide an indication of the challenges faced when attempting to develop standards for even higher levels of semantic data.

2.1 Overview of Inter-organizational Data Exchange Standards

The classic example of an inter-organizational data exchange standard is traditional EDI [7, 8]. The best known and most widely used EDI-standards are ANSI X.12 (mainly in the US) and EDIFACT (developed by UN, intended as a global standard) [9]. EDI standards date back to 1970s and beyond; in the mid-1980 EDI use began to expand significantly, following the introduction of the first version of ANSI X.12 in 1981 [7] and the EDIFACT starting from 1985 [10].

Lately, it has been suggested that newer standards would overcome the challenges of traditional EDI [11] by adding to the syntactic and semantic level of EDI standards. These newer pragmatic level standards have been claimed to help create more flexible and economical inter-organizational system-to-system integrations. Typically, these standards utilize the power of the XML (Extensible Markup Language), dating back to 1996 [12]. XML defines besides the data, through the so called tags, meta-data, i.e. data on data [10]. However, XML as such defines only the syntax for describing data and notably not how to exchange XML-based data between the information systems of separate organizations, nor the semantic meaning of the actual data [13].

Some relatively widely diffused examples of XML-based standards are RosettaNet [14, 15] and ebXML (Electronic Business using eXtensible Markup Language). RosettaNet is designed to fulfill the growing demand for unified methods of B2B integration among buyers and sellers in the global information industry supply chain [13]. It has gained significant footing within the semiconductor and electronic components manufacturing industries [15]. ebXML is suggested to be the most ambitious business process standard [16] originated from UN/CEFACT (United Nations Center for Trade Facilitation and Electronic Business) and OASIS (Organization for the Advancement of Structured Information Standards) in late 1999. ebXML and its related standards attempt to found a universal electronic market and similar regulations. With ebXML, companies from various industries can discover applicable trading partners dynamically, negotiate trading process automatically, and conduct business transactions [16].

In this paper we are focusing on inter-organizational exchange of shipment tracking data, as well as data related to product individuals in general. Our own work in this area started in 2000 with the goal to create systems for implementing the Internet of Things (IoT). In 2001 the first version of such a system was implemented under the name DIALOG (Distributed information architectures for collaborative logistics) [17]. DIALOG was used in multi-organizational and international pilots for tracking shipments and warehouse items in 2002 [18] and 2003 [19]. DIALOG was also used and demonstrated for storing and retrieving product individual information in after-sales and maintenance settings, as well as for many kinds of consumer applications. In later years, DIALOG has mainly been used for asset management, after-sales service and maintenance and product individual lifecycle management applications [20]. We are also involved in a standards initiative called Quantum Lifecycle Management with the Open Group (http://www.opengroup.org/qlm/) for defining data exchange standards that can be generally applicable to handling any kind of product individual data.

It is in this context that we have been closely following the evolution of EPCglobal standards as a potential candidate for use in our own applications. EPCIS [6] is the standard that is technically closest to the kind of data exchange that we have needed over the years. Unfortunately EPCIS still seems suitable mainly for SCM but we still

think that an analysis of the evolution and the degree of acceptance and use of EPCIS in real applications can provide valuable insight about the actual need and readiness for inter-organizational data exchange, as well as about the challenges related to the launch of standards in this domain.

2.2 Overview of EPC Network

GS1's EPC is a unique code that is assigned to each good or material tagged and is read when passed through a RFID reader. The RFID technology and associated computer networks use the EPCglobal Network and its EPCIS as an interface to enable EPC-related data to be 'captured' and 'queried' using a defined set of operations and associated EPC-related standards, combined with security mechanisms that satisfy the needs of the parties involved [6]. In other words, EPCIS provides a standard interface for storage and access of EPC-related data that can be read and written by the authorized parties involved. The hardware and the software components of the framework can be grouped into important entities, namely

1. *EPC tags* and *readers* where tags communicate their EPC information to readers via radio waves and deliver data to information system of parties involved through EPC Middleware,
2. *EPC Middleware* that acts as an interface between read events and company's other existing data information systems and also for communication with EPCIS,
3. *EPCIS*, which enables partners to exchange data and events throughout the supply chain. The EPC Information Services consists of capture, Query Interfaces and a repository for storage of event data. The Capture interface collects and delivers EPC event data to the repository and to the accessing applications. An EPCIS Accessing application is responsible for processes such as warehouse management, shipping and receiving, and output analysis facilitated by EPC-related data. EPCIS Query application provides a mechanism for authentication of data exchange between two parties and facilitates a provision to limit or control the scope of data that is being accessed by different parties.
4. *Object Naming Service* (ONS): A look up service that takes an EPC as input and produces output in the form of a Uniform Resource Locator (URL) of an EPCIS repository.
5. *EPCIS Discovery Services* that facilitates the users to find and request access to specific EPC data.

An RFID tag attached to a trade item contains a unique EPC that globally identifies that item while it is in the supply chain. The EPC would typically be encoded with a Serialized Global Trade Item Number (SGTIN) which contains: The EPC Manager Number (company specific code), Object Class (product number), and Serial Number for each object tagged. These tags are scanned by readers, which send EPC information contained in the tags to EPC middleware. The middleware software filters, collects and stores the information in the EPCIS repository, queries the ONS to find information related to that product and then gets supply chain event data about that product from the EPCIS repository of the parties involved. Access to the EPCIS

servers of other trading partners needs authorization and authentication based on predetermined business contracts [6]. EPCIS is a standard that is intended for use in track and trace applications. In a nutshell, it holds the WHAT, WHEN, WHERE and WHY details of each individual unit of the products moving through the supply chain.

3 Case Studies

To illustrate the extent of EPCIS usage and potential challenges for its deployment, authors chose to examine different EPCIS use cases. Firstly, use cases were extensively searched from a variety of sources, including article databases, websites and expert statements. It was found out that EPCIS standard has been used and "experimented" (term used by several interviewees) in many successful pilots such as in Swedish Fisheries [21], in electronic pallet tracking [22], in Norwegian Meat manufacturing company Nortura, by retailer Wal-Mart and in Hong Kong baggage handling and pharmaceutical manufacturing [23], as an example. Bridge EU project has also been using the EPCIS standard [24]. Many IT service providers – such as Axway, IBM, and Oracle – provide EPCIS-based track and trace solutions to customers [25-27]. The most prominent application domains were found to be SCM, e-pedigree in the US, and tracking and tracing in general. It became evident eventually that use cases – at least with a fully-fledged EPCIS implementation – were not of ample supply. Thus, three use cases with a relative strong advancement or potential in EPCIS usage were chosen. These three cases are "e-pedigree in the US pharmaceutical supply chain", "Railways" and "Technical trade". The former two were chosen due to their apparent advancement and maturity with EPCIS compared to other domains. The third case was chosen because of its potential for a wide-scale use for EPCIS and also because it was a research project in which some of the authors participated, giving first-hand view on the issues of EPCIS implementation.

The three chosen cases are analyzed in the following subsections. The structure of the analyses proceeds as follows: Firstly, each case is introduced and its state of RFID deployment is discussed. Thereafter, the use of inter-organizational data exchange and EPCIS is analyzed. Finally, challenges are discussed and conclusions drawn.

3.1 e-Pedigree

The pharmaceutical industry exhibits one of the most complex supply chains involving many trading partners including manufacturers, re-packagers, distributors, third party logistics providers, hospitals, clinics and retail pharmacies [28]. Approximately a billion sellable units moved through this intricate chain in the United States (US) in 2008 [29]. The health care industry is under constant pressure to supply prescription drugs to patients safely and securely and, at the same time, reduce the overall costs and improving service levels [25, 30].

Drug-counterfeiting poses a serious threat to patient safety and also harms the image of manufacturers, their profitability and revenue [28]. According to WHO reports, the illegal sale of counterfeit drugs globally results in loss of revenues to the tune of over US $35 billion and might reach US $75 billion [30]. To combat this threat, governments are concluding that secured and transparent distribution of drugs between

trading partners must be insured. Markets such as Turkey, Brazil, France and the US have begun to mandate that manufacturers and distributors who supply drugs to citizens conform to some sort of e-Pedigree standards, such as GS1 EPCIS or GS1 Drug Pedigree Messaging Standard (DPMS), for tracking and tracing purposes and 2D matrix barcodes or RFID for carrying product information on each saleable package [27]. For effective drug identification and traceability, drugs are mass serialized where each drug package is given a unique identification such as an EPC. Matrix codes and RFID tags are used to encode the unique identification and make it machine readable. In some countries the government specifies the technology, but in others it is left up to the industry to agree on standards.

The US pharmaceutical supply chain is being driven towards the adoption of ePedigree because of State and Federal laws. The GS1 DPMS standard was specifically created enabling the pharmaceutical industry in the US to generate interoperable electronic document pedigrees for drugs that were serialized (California) or not serialized (Federal, Florida and elsewhere). Because the California law is the first to require the use of serialization, companies that are facing the future effective date of that law are now experimenting with systems that are based on GS1's EPCIS standard.

RFID Deployment. While RFID has been around for many years, the use of the technology has spread slowly, even if most of the technical challenges even at unit-level have been solved. There are also available possibilities for secure authentication of RFID tags and the technology for preventing the tags from being copied even if their use is scarce [23]. The biggest challenge in RFID deployment in the healthcare supply chain seems to be the high cost of tags compared to widely used 2D barcodes [31]. The extent of use of RFID tags varies according to the size of the company. Bigger distributors such as McKesson prefer to use RFID tags while average size companies like AstraZeneca and Genzyme favor GS1 2D Datamatrix barcodes. Some companies who make biological drugs have chosen to avoid placing RFID tags on their packages out of concern that radio signals involved with RFID tags and readers could possibly modify the effectiveness of their drugs, although recent research studies indicate that this is not the case [31, 32]. Other drug manufacturers intend to employ 2D barcodes on the labels they attach to bottles of prescription drugs, and then an RFID tag in addition to barcodes at the case-level [31, 33]. The cost of deployment of RFID tags is higher compared to 2D barcodes at this point and for companies tagging millions of products every year the incurred cost can be difficult to justify.

Many pharmaceutical companies have executed pilots with RFID tags at the unit-level but only Purdue Pharma and Pfizer in the US have applied the technology for an extended period of time [34-35]. Today it appears that most companies facing the serialization requirement of the California law are preparing to apply 2D barcodes on their products at the unit-level. Some are planning to make use of RFID in addition to barcodes at the case- and pallet-levels.

Given the history of RFID experimentation in the US pharmaceutical supply chain – particularly the recent elimination of RFID at the item-level by Pfizer, a long-time experimenter with the technology – it appears that the use of RFID for compliance with the California serialization mandate will be limited to cases and pallets for some manufacturers [36].

EPCIS vs. DPMS. By early 2000, most trading partners in the US pharmaceutical supply chain were sharing basic data of shipments and payments received electronically – at least between manufacturers, the larger distributors and larger chain pharmacies. Companies in the US pharmaceutical supply chain showed little interest in serialization and track and trace until 2004 when the State of California, and later Florida, enacted a prescription drug pedigree law that included a requirement that all drugs distributed within their borders contain a unique identifier. The effective date of these requirements continued to drift outward until 2008 when the state legislature set it as 2015 and 2016 for drug manufacturers, mid-2016 for distributors and mid-2017 for pharmacies. EDI was used for sharing data but it lacked the flexibility and control to identify and track the entry of counterfeit drugs in the supply chain.

In 2006 GS1 ratified a document-based pedigree standard, known as the GS1 DPMS, which is used by US drug distributors in the State of Florida to comply with their document-based, non-serialized drug pedigree regulation. The GS1 DPMS standard defines a complex XML schema that allows an entire supply chain history of events for one or more drug packages to be stored in a single XML file. DPMS ePedigrees are exchanged between trading partners in the same way that EDI documents are. The type of events stored within the single file bear a resemblance to the EPCIS Commissioning, Shipping and Receiving events.

Larger pharmaceutical manufacturers and distributors such as AstraZeneca, Genzyme, and AmerisourceBergen have slowly begun to embrace the idea of building applications around GS1's EPCIS standard to help them solve the new challenges with capturing and storing serial number events [27, 33, 37]. AmerisourceBergen has experimented with IBM's EPCIS solution in the past which also supports DPMS. EPCIS is their preferred mechanism of data exchange, but they also plan to have the ability to receive pedigree data in the DPMS format [26].

A larger group of IT giants including IBM, SAP, Axway, and Samsung are supporting and providing track and trace solutions based on the EPCIS standards [38]. Axway has been particularly active in promoting the development of EPCIS-based standards for monitoring the pharmaceutical supply chain. A growing number of successful pilots and projects have been carried out using EPCIS. Axway's solution also meets most of the global compliance regulations of many countries such as Brazil, Turkey, Israel and the US [27].

While EPCIS helps in the product's track and trace by the trading partners, by sharing information on the product's visibility, DPMS ensures the product's security and authenticity. The problem is that the type of inter-organizational data exchange that the EPCIS standard query interface implements is not document-based. In general, track and trace systems based on GS1's EPCIS standard can be used for sharing supply chain event data about serialized products. Though, it still does not have some of its parts well-defined and it lacks the specificity needed to implement all of the pedigree laws in different countries today. Secondly, DPMS is not interoperable with other systems and it has several non-compliance issues that must be dealt with first. A mechanism combing the advantages of both EPCIS and DPMS needs to be developed.

Challenges. By design, using the standard EPCIS query interface as the data exchange mechanism between trading partners would result in distributing snippets of pedigree information for each package of drugs across all of the repositories of the previous owners of those drugs. The result is some amount of confusion about what path companies should take.

Confusion has been inadvertently introduced into the US pharmaceutical supply chain by the recent activities of the GS1 Traceability in Healthcare, Network Centric ePedigree (NCeP) work group which is made up of a few larger companies in US pharmaceutical supply chain. Their goal was to define one or more ways to produce an interoperable electronic pedigree system that makes use of the GS1 EPCIS standard, not only for event data capture, but also for inter-organizational event data exchange [40]. The group has recently published descriptions of the operational characteristics that would result from seven different NCeP's models for consideration by regulatory bodies who might want to enact new pedigree legislation [39]. In particular, it is hoped that the US Congress may enforce a new law that can be met by one of the seven NCeP models and that DPMS will not be needed.

Confusion over which approach to the inter-organization ePedigree data exchange will be necessary to remain compliant with state and federal regulations in the future is causing an understandable hesitancy to invest in solutions. While this is causing slow adoption of EPCIS in the US pharmaceutical supply chain it is likely that the confusion will be resolved by the end of year 2012 when the US federal government either takes a specific action or takes none at all. In either case, there could be a surge of adoption of EPCIS as part of the ePedigree deployments by supply chain members around that time. While there are known examples of successful implementation of systems based on the EPCIS standards on one hand, there are certain obstacles that hold this standard from actually taking off in the pharmaceutical supply chain for applications other than ePedigree compliance. Amongst them, inter-organizational data exchange security issues are primary. Companies might not be willing to share certain data beyond their boundaries and especially with their competitors. Discovery Services, a standard planned by GS1 to address this issue must still be developed and ratified, and then must be accepted and adopted by all pharmaceutical companies worldwide. Worldwide adoption of the EPCIS standard is a very slow process.

The pharmaceutical supply chain is very complex involving the movement of huge numbers of drugs and information across it. With companies needing to implement item-level serialization, the key issue is to comprehend the supply chain based on large amounts of EPCIS data. The challenge here is to extract useful information by combining human reasoning and analysis frameworks, reduce complexity of the data and make informed decisions based on it. Secondly, according to Fabian and Günther [40], EPCIS is prone to attacks from the internet and other possible hacking exploits. Attackers or hackers might gain control of servers/databases handling EPCIS information and forge them. This could be a serious security breach for companies and can increase their operational business risk. Systems to tackle these problems need to be improved and developed for the worldwide use.

3.2 Railways

Railways have been an early domain of RFID usage. Already in the 90's, RFID was applied in railways in several countries in Europe, Asia and Americas [41], and nearly all railcars were RFID tagged in the US by 1994, for example [42]. In Europe, there has also been considerable interest in RFID in railway operations lately. It has either been discussed, piloted or even deployed in several European countries and also in Russia. The main usage has been tagging of wagons or locomotives, which enables automated identification and tracking of rolling stock units. With the use of RFID or other advanced tracking systems arises the question of how to transfer and share the generated tracking information intra- and especially inter-organizationally. Information sharing of tracking information in railways is discussed in this section mostly from the case perspective of Finnish and Swedish railway operations. Both the Finnish and Swedish railway operators and administrators have been early-adopters of RFID tracking and have collaborated in their research and design of the systems. The data sources for the case are public documents and four informants in total from the Finnish Traffic Agency (FTA), VR (a state-owned Finnish railway operator) and Swedish Transport Agency (STA).

RFID Deployment. Enabling and pushing inter-organizational data exchange forward, RFID has been deployed increasingly in the European railway operations. On a higher level, European Commission has published a Technical Specification for Interoperability (TSI) 2006/861/EC regarding rolling stock freight wagon, which specifies RFID air standard ISO18000-6 type A to be used if RFID is applied [43]. It has been argued, however, by the European Rail Infrastructure Managers (EIM) in their position paper on RFID standards published in 2009 that the air standard specified by the 2006/861/EC is outdated and standard ISO18000-6 C, better known as EPC Gen 2 Class 1, should be used instead [44]. This EPC compliant standard has been adopted at least in the Finnish and Swedish railways.

In Finland, VR has recently installed Gen 2 Class 1 EPC compliant RFID tags to all of its cargo wagons [45]. The company intends to use the tags in three different ways: firstly, it has streamlined its own railyard operations by using hand-held RFID readers to identify wagons and transfer data intra-organizationally; secondly, it will start to track its wagons using the upcoming network of fixed RFID readers to be installed by the Finnish Transport Agency; and thirdly, it has planned to install its own fixed readers to offer its customers tracking data of transportations. Regarding the second point, FTA has planned to start deploying the fixed RFID readers along the Finnish railway network at the end of 2011. The purpose is to install around 120 readers to places where it has rolling stock monitoring sites. FTA will use them to collect data for preventive maintenance use, and identification and measurement data will be distributed to rolling stock owners and maintainers as well.

In Sweden, the RFID deployment is not necessarily as wide as in Finland but has been planned and designed extensively. Between 2005 and 2008, SJ (Swedish state-owned railway operator) tested RFID systems based on active tags but a satisfactory standard was not found. From then on, they have been piloting RFID with passive

EPC tags and GS1's Global Returnable Asset Identifiers (GRAI). The results have been satisfying, and the plans include using the tags with the upcoming fixed RFID reader network installed by the Swedish Traffic Administration. There are already 10 readers in pilot use between Falköping and Gothenburg, and the long-term goal is to install between 500 and 700 readers along the Swedish railway network.

As can be concluded from the Finnish and Swedish RFID implementations, there seems to be a fertile ground for inter-organizational data interchange from a technological perspective. EPC compliant RFID tags are used and they have gained a strong position as means of identification. What needs to be considered next is whether there is a demand and willingness to share data between organizations and if so, whether EPCIS is the means to accomplish this goal.

Inter-Organizational Data Exchange. Inter-organizational data exchange does exist in Finnish and Swedish railway operations already today. In Finland, VR uses EDI to exchange inter-organizational data – for instance orders, invoices, transportation documents, tracking data – with its customers [46]. It has also a web application for smaller customers without permanent contracts. There are also prospects for further, richer data interchange if VR begins to install its own fixed readers and offer cargo tracking to its customers, as has been planned. Furthermore, the tracking data from FTA's fixed readers, including technical measurement information, is planned to be used once the system is up and running. It is not clear yet if the data provided to customers should be more detailed than just the wagon identification and direction. It could include cargo contents, for example, but then the data content would be more refined than what is directly available in FTA's system. The data standard to be used in the exchange of the tracking information of the fixed readers will be ultimately decided by the FTA but it will take into account the needs of other stakeholders, including VR. EPCIS has been brought up in the discussions every now and then but it has not been favored in any way and no decision for the data exchange standard has been made yet. FTA and VR have been following the EPCIS experimentation of their Swedish counterparts, however.

In Sweden, the development has moved a bit regarding use of EPCIS. The EPC pilot projects have involved use of EPCIS since the beginning and no other standard has been tested or considered for the data interchange. The 10 fixed readers that are operating currently use EPCIS to share tracking data between the Falköping freight terminal and Gothenburg harbor. EPCIS has been regarded to perform well without any major problems.

In summary, stakeholders in both Finnish and Swedish railways exchange data inter-organizationally even without EPCIS [47]. The need for standardizing has been acknowledged as well, as is illustrated by the aforementioned position paper on RFID by EIM suggesting that a standardized RFID message should be defined by a TSI. However, it still remains unclear which standard will offer the best solution and become dominant. The standard to be used did not seem to play a big role in the Finnish railways as long as it proved to function properly, according to the informants. The Swedish railways have embraced EPCIS more than the Finnish railways but the benefits over other ways to share data, like EDI, are harder to identify. It has been

suggested by the STA that after the installation of the fixed RFID readers along the railway network is finished, it is then the role of markets to use the data provided and develop new services and businesses based on it [49]. But we argue that this may not happen so easily – at least with EPCIS – if companies do not see a clear benefit in EPCIS over their existing systems. Even VR, who plans to provide RFID based tracking systems to its customer in the future, has not decided what data standard to use. If they already have a well working EDI infrastructure with their customers, it may be hard to justify new implementations based on EPCIS.

Possibilities for Standardization of Inter-organizational Data Exchange. Clearly, there is a need for a widely used standard in inter-organizational data exchange in railway operations. In Swedish railways, for instance, 60-70% of the wagons come from other European countries [48]. If standardized messages were transferred between organizations from other countries, there would be a big potential for exchange of tracking information. Then again, in the Finnish railways, there are fewer stakeholders and they are less international than in Sweden. Another possible obstacle to a European wide standard for inter-organizational data exchange is that some countries are already building their own tracking systems in railways according to the informants. This might lead to problems of interoperability. One solution or remedy to this could be that an administrative body would impose the standard to be used. In railways, the European Commission could define the standard in its TSI but as for now, there is not that kind of progress to be seen in the near future, the informants say.

3.3 Technical Trade

To spread the use of RFID/EPC technology, GS1 Finland together with two universities launched an exploratory case study project together with 16 companies – 12 manufacturers, 3 wholesalers and one Logistics Service Provider (LSP) – acting mainly in technical trade industry and especially in heating, plumbing and air-conditioning (HPAC) field. The main purpose of the project was to find suitable application areas for RFID/EPC technology in the technical trade supply chain and create a roadmap for adopting supply chain-wide RFID/EPC technology implementation.

RFID Deployment. The project was divided into three phases: (1) Research the applicability of RFID technology for the technical trade industry, (2) Test the technology in practice, if RFID turns out to be suitable for the industry, and (3) create a roadmap for promoting the use of RFID to the whole industry.

In the first phase of the project, the participating manufacturer and the wholesaler companies found enough benefits in their operations to consider larger RFID tracking implementation. During the second phase, testing, they also found ways to tackle major industry specific problems of adopting RFID tracking, such as ensuring the reading on metal components typical of the industry. After the test, the biggest wholesaling company participating in the project announced that they will start to implement RFID at first to improve their receiving in the second half of 2012. As this wholesaler has a 43 % market share in HPAC wholesaling in Finland, the participating manufacturers listened

rather carefully to the intentions of that wholesaler. That announcement also gave guidelines for creating a roadmap and helped to set concrete targets and milestones for the project participant companies for adopting RFID. This announcement also encouraged the participant companies to discuss about practical issues of adoption such as what kind of RFID tagging the wholesaler prefers and what would be the format of ASN messages that the wholesaler wants.

Inter-organizational Data Exchange. As GS1 Finland coordinated and initiated the project, their purpose was to propose technological solutions that were in accordance with global GS1 standards. One of the managers of GS1 Finland formulated this in the following form at a steering group meeting in the early phase of the project:

"GS1 is not involved in any project, which does not support global GS1 standards!"

The companies involved in the project did not express any resistance against the use of EPCIS architecture, if it works. In the beginning of the project most of the participant companies did not even use EDI; therefore they could apply any new standard when developing their logistics operations to use electronic data messages, because their existing systems needed considerable modifications in any case.

Possibilities for Standardization of Inter-organizational Data Exchange. When researching the roadmap for industry-wide RFID/EPC implementation, the research team in the project had a problem: Especially GS1 Finland would have liked to recommend implementing EPCIS standards, but they realized that there is no software or integrator company that could provide a ready "EPCIS product". The system integrator company, who is market leader in Finland and in Nordic countries in SCM RFID implementations, does not at least yet have the ability to offer solutions based on EPCIS. One major Finnish software company has developed an "EPCIS product" in an EU project some time ago, but according to GS1 representatives, it still requires further development to be suitable for implementation in the technical trade industry. Therefore, in the end of the research project GS1 ended up to recommend to use other interface standards widely used in the industry at the moment, but keep EPCIS in mind in a way that the system could be developed in the future to apply EPCIS.

The settings for the project seem to be ideal for applying EPCIS, because there was a strong involvement of GS1 in the project, and the project participant companies did not use any other dominant standard, which they would prefer to rely. However, project participant companies had to accept that EPCIS is not mature enough for implementation in this domain. Therefore GS1 did not want to risk the enthusiasm towards RFID tracking by recommending a standard that is still under development.

4 Conclusions

We started developing systems and interfaces for inter-organizational exchange of tracking data in the supply chain because of the clear need for such solutions by companies doing international investment projects in 2001. We have therefore been closely following the evolution and the take-up of such solutions in practice. Despite technical challenges of EPCIS compared to alternative approaches [5], we would have

expected EPCIS and related standards to become universally used in SCM and similar applications. However, the conclusion of the case studies performed is that EPCIS is still mainly being used on an experimental scale in domain-specific applications.

From the case studies, we have attempted to identify the main reasons that would explain why EPCIS is not used more universally. We have identified at least the following potential explanations for the phenomenon:

- Companies may not be ready or willing to share information with other organizations. Most RFID success stories are mainly intra-organizational applications, where the use of EPCIS does not provide enough value for the cost that it causes.
- EPCIS is too tightly coupled with RFID and SCM-focused, which makes it hard to extend for use in other parts of business, thereby limiting the potential profits that could be achieved.
- EPCIS is too complex or costly to implement compared to the benefits. Even though validated EPCIS implementations are provided by many software providers, the required implementation and systems integration may still be perceived as being too high.

Further research would be required in order to understand the impact of these causes for the non-use of EPCIS or other information exchange standards. Such an increased understanding might help us to create standards that would be more widely accepted. Since the popularity of RFID started increasing over ten years ago, it has been said that we only need to find the right "silver bullet" that will make RFID and inter-organizational information exchange "explode" at some moment. However, we are still waiting for that silver bullet to be found.

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