Gain in Transparency versus Investment in the EPC Network – Analysis and Results of a Discrete Event Simulation Based on a Case Study in the Fashion Industry

Jürgen Müller[1], Ralph Tröger[2], Alexander Zeier[1], and Rainer Alt[3]

[1] Hasso Plattner Institute for IT Systems Engineering
Prof.-Dr.-Helmert-Str. 2-3, 14482 Potsdam, Germany
{juergen.mueller,zeier}@hpi.uni-potsdam.de
[2] Gerry Weber International AG
Neulehenstraße 8, 33790 Halle/Westfalen, Germany
r.troeger@gerryweber.de
[3] University of Leipzig
Grimmaische Straße 12, 04109 Leipzig, Germany
rainer.alt@uni-leipzig.de

Abstract. The diffusion rate of Radio Frequency Identification (RFID) technology in supply chains is lower than expected. The main reason is the doubtful Return On Investment (ROI) mainly due to high tag prices. In this contribution, we leverage a prototypical RFID implementation in the fashion industry, extend this prototype by a discrete event simulation, and discuss the impact of an Electronic Product Code (EPC)-enabled supply chain concerning higher visibility. Thereby, we illustrate the benefit of the EPC network for Supply Chain Event Management (SCEM). Future researchers are provided with the simulation data which is available online and can be investigated.

Keywords: EPC Network, Supply Chain Event Management, Simulation.

1 Introduction

The idea of RFID in the fashion industry is to attach a unique identifier to articles to be able to track them on their way in the supply chain. This results in higher visibility and enables the supply chain partners to react in time, e. g., taking measures to deliver a shipment in time even if there had been a delay in production [1].

Utilizing experiences of its prototypical RFID implementation with its distribution centers and selected retail stores, the fashion company Gerry Weber recently published a case study about how to obtain a positive ROI in RFID projects [2]. One recommendation was to deploy reusable RFID transponders to reduce expenditures. Since then, three developments have taken place: (a) major drop in RFID inlay prices; (b) applicability of RFID as Electronic Article Surveillance (EAS), and (c) advancements in the development of textile RFID labels.

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Given this new situation, Gerry Weber has to reconsider its RFID strategy. In the former project, reusable RFID tags were used due to high tag prices. This is subject to change because of the achievements in RFID technology. Furthermore, we present a model of the potential structure of Gerry Weber's future supply chain including a global RFID deployment at all levels in the supply chain. To this end, we utilize the progress made in the EPC network which includes all components to collect RFID read events and share them with selected business partners [3, 4].

The remainder of this paper is organized as follows. In Section 2, we discuss related work and our research methodology. Section 3 describes Gerry Weber's supply chain how it is structured today. In Section 4, we discuss a projection of that supply chain if the EPC network was used. Section 5 describes how we modeled, implemented, and executed the supply chain presented in Section 4 in a simulation and shows the simulation results. Section 6 addresses the calculation of benefits for the utilization of the EPC network. Section 7 closes the paper with a conclusion.

2 Related Work and Methodology

In this section, we describe the related work about RFID, the EPC network, and SCEM. Finally, we present our research methodology and research questions.

2.1 RFID and the EPC Network

In recent years, application of RFID received increasing attention among researchers of information systems and operations management [5]. For instance, fields like RFID in manufacturing, cost-benefit sharing, drivers of adoption, system architecture, or integration in ERP systems have been addressed. Major aspects of RFID implementation especially for the apparel industry (requirements, business case, problem analysis and expected benefits) have also been investigated [6].

Concerning supply chain visibility and RFID, a comprehensive analysis was accomplished by Dittmann, who determined the appropriate level of visibility for supply chain networks from a normative, strategic and operational perspective [7]. Meydanoglu provided conceptual work regarding the use of RFID systems as data source for SCEM systems [8].

2.2 SCEM

SCEM can be characterized as an approach to achieve inter-organizational visibility over logistical processes enabling companies to detect critical exceptions in their supply chains in time. Thus, measures against those "events" can be taken proactively before they endanger given business plans [9].

Most authors agree on the perception that SCEM encompasses five core functionalities: *monitor*, *notify*, *simulate*, *control*, and *measure* [9, 10]. Especially for the two functions "monitor" and "measure", we see great usefulness by adopting RFID and the EPC network. The first one observes the supply chain for the occurrence of critical events (i. e., major delays or disturbances) by evaluating any incoming data. The latter one bridges the gap between SCEM and Supply Chain Management (SCM) by analyzing all data generated by the other four functionalities, i. e., number of events, locality/ time of their occurrence, costs effects, and chosen action alternatives. This way, companies are able to identify certain patterns related to the causes of events in order to optimize their supply chain structures.

2.3 Methodology and Research Questions

Until now, no quantitative research about the consequences of RFID/ EPC utilization for a supply chain of the apparel/ fashion industry exists. As described by Müller et al., realistic test data is necessary to analyze information systems precisely [11].

For our research, we want to generate data about which events occur at which time in which place in a fashion supply chain. To this end, simulation is the appropriate methodology because it permits the evaluation of the complete supply chain prior to its implementation [12]. In the area of simulation, Discrete Event Simulation (DES) is widely used and well-established for supply chain simulations [13]. In DES, the activities in a system are represented as a chronological sequence of events [13]. Each event has a timestamp indicating the time when it occurs. Once the simulated time reaches this , the event is triggered, e. g. something is produced, shipped, etc.

As the simulation of an EPC network employment requires comprehensive data, this research method will be applied in combination with a case study [14].

Before conducting the investigation, the following research questions are set up:

- RQ_1: What is the event frequency at different points of a fashion industry supply chain and how huge is the data volume if utilizing the EPC network?
- RQ_2: Does the EPC network fit as data source for the monitoring and measuring task of SCEM systems?
- RQ_3: How can the benefit of an edge on information through utilizing the EPC network in combination with SCEM systems be determined?

Our data sources are semi-structured interviews with seven fashion companies, desk research (press releases, annual reports, company web sites, etc.) and – as one of the authors is employed by Gerry Weber – data and information (such as quantity structures, packing instructions, average lead time tables, order data, etc.) directly from Gerry Weber.

3 Fashion Industry Case Study: Gerry Weber

With its three brands (GERRY WEBER, TAIFUN and SAMOON by GERRY WEBER along with several sub labels) the Gerry Weber group achieved a sales volume of about € 570 Mio. (circa $ 800 Mio.) in the fiscal year 2007/2008 [15]. The German fashion company, which was founded in 1973, currently has 2,350 employees and follows a strategy of becoming increasingly vertically integrated. To this end, the company successively enlarges the number of its own retail stores.

Worldwide, the Gerry Weber group cooperates with around 200 manufacturers, several forwarders and logistics service providers, more than 1,470 shop-in-shops (ca. 1,160 in Germany) and over 300 retail stores. The suppliers are located in three major procurement markets: Far East, Turkey and Eastern Europe. After production, the garments are transported (either by sea, air, or road) to one of the European distribution centers (separated according to hanging/ lying garments). Most of the shipments in Far East and Turkey are consolidated in a cross docking center. After goods receipt in a distribution center, all garments are checked for quality, conditioned, and transported to the retailers.

The company decided to evaluate the potentials of RFID to ease managing this complexity. Thus, RFID infrastructure was installed in all six distribution centers and four retail stores by March 2009. Initial experiences showed that RFID indeed is beneficial for Gerry Weber, especially regarding savings of time and costs. Currently, the company considers switching from reusable tags to one-way labels. One major advantage of using one-way tags is that those would be encoded with a Serialized Global Trade Item Number (SGTIN) [4]. In contrast to that, the reusable RFID tags had a persistent serial code that was associated with the product it was attached to.

4 EPC Network

The EPC network is one step towards the "Internet of things". In this section, we will first describe the general EPC network architecture, then present the EPC network architecture for Gerry Weber, and finally discuss how a SCEM system based on the EPC network can be implemented.

4.1 General EPC Network Architecture

The EPC network is a set of standards and consists of a layered architecture [4]. A precondition is that an Electronic Product Code (EPC) uniquely identifies all items in the EPC network [4]. This includes articles, cartons, and containers. The data flow in the EPC network in a nutshell is depicted in Figure 1. Once an item is in the range of a RFID read point, a reader recognizes the unique identifier of the item and the current time. Together with the location of the read point, this data is sent to a middleware. The middleware enriches the data with a business step, i. e., "goods produced", "goods issue", or "goods receipt" [4]. After that, the data is sent to a repository implementing the EPC Information Services (EPCIS) standard [16]. Each company operates at least one EPCIS repository and stores all read events, which occurred in this particular company.

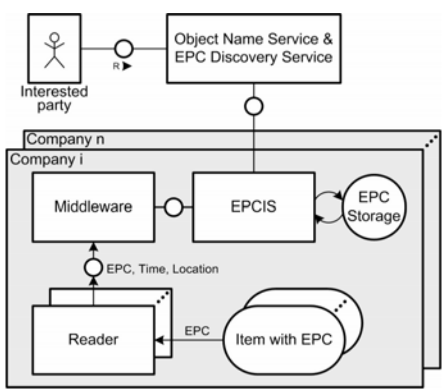

Fig. 1. EPC Network

Obviously, each company has to enforce access rights to secure its information. A situation might happen where the interested party does not have the complete information where an item has been in the supply chain and therefore it is unknown which EPCIS repository to query. For this situation, a Discovery Service acts as an intermediary service to retrieve all the involved parties [17]. The Discovery Service is still subject to research due to the expected data volume, privacy aspects, security aspects, and other challenges in the design of Discovery Services [17].

4.2 Gerry Weber EPC Network Architecture

In this section, we describe how Gerry Weber's supply chain may be structured in the future. To this end, we assume that each participant in the supply chain is equipped with the necessary RFID infrastructure. Furthermore, Gerry Weber has access to the EPCIS repositories operated by its partners.

After production, an article is observed for the first time. Once the article is packed into a carton, a second read event is triggered to indicate which article is stored in which carton. The carton then is brought to the cross docking facility. This results in a read event at goods issue at the supplier and a read event at goods receipt at the cross docking facility. The carton then is loaded onto a container. This, again, results in a read event to determine that the carton is on this particular container. When the container leaves the cross docking facility, it is recognized by a reader and a read event is stored in the cross docking owners EPCIS repository. Subsequently, the container arrives at a distribution center and is recognized by a reader again. Once the carton is unloaded another read event is stored in the distribution centers' EPCIS repository. Finally, the carton leaves the distribution center which, again, is stored in the distribution centers EPCIS repository. Finally the article reaches a retailer and causes a read event at goods receipt. Then, there might be several read events at the retailer before the RFID tag maybe is deactivated.

Gerry Weber places subscriptions at each partner in the supply chain regarding all garments produced for Gerry Weber. Thus, each and every read event is forwarded to the read event repository of Gerry Weber and can be processed by its SCEM system.

4.3 Discussion of a SCEM System Based on the EPC Network

Applying the EPC network as data source for a SCEM system offers the opportunity to get reliable and fine-granular data even at the beginning of the supply chain. At present, the supply chains of the fashion industry before goods receiving at the distribution centers is not adequately transparent as the only source of information consists of manually transmitted data via e-mail, fax, or web-based platforms. However, having available multiple read points with the manufacturer and cross docking centers at which all passing garments can be detected, it is appropriate to concatenate the captured EPCs with context information data (such as Purchase Orders or Advanced Shipping Notices), whereby deviations can be discovered in real-time. Thus, all supply chain partners can be alerted if significant variations are observed which offers the opportunity to readjust scheduled processes in order to satisfy the customers in delivering the items in the right quantity at the right time to the right destination in the right condition.

To give an indication of the potential benefit of this edge on information: research findings from the accomplished case study showed that a bigger part of merchandise is produced in Far East and mostly transported by sea [2]. Assuming to be informed about all delayed orders, the process owner can switch to air transport and reduce lead-time by more than 20 days.

Not only the detection of critical supply chain incidents ("monitor") can be improved by adopting the EPC network, but also the optimization of the supply chain by recognizing certain patterns or systematic weak points, e. g. ("measure"). The latter one can be achieved by analyzing all incoming EPCIS messages, which provide information about time, place, and business context of detected Stock Keeping Units (SKU). In this way, for instance, a company is able to discover who or what causes delays, which offers the opportunity to eliminate or attenuate interfering factors (traffic jams at certain ports, poor performing suppliers or forwarders, etc.) in the medium or long term.

5 Simulation of Gerry Weber's RFID-Enabled Supply Chain

We now simulate the implementation of the RFID and EPC network enabled supply chain of Gerry Weber to foresee the impact of the RFID introduction at the producers and consolidation centers. In this section, we describe the information included in the simulation implementation considerations, as well as the resulting simulation model including its parameters and results.

5.1 Base Data

The data for our simulation is based on two sources: results from a case study with seven fashion companies (Galeria Kaufhof, Gardeur, Gerry Weber, Maerz Muenchen, René Lezard, Seidensticker and Van laack) and – in more detail – data directly from Gerry Weber. As the first RFID read point is with the supplier and as an edge on information is more advantageous the earlier an event has been detected, we decided to display examples of events and countermeasures (see Table 1) only for the supply chain sections production and transport.

Table 1. Examples of Events and Counteractions

	Typical event (E_i)	Countermeasure	Probability
Production	E_1: Delay through capacity constraint due to other customer orders or machine break-down	Alteration of transportation mode	2.00 %
	E_2: Sudden employee leave/ strike	Relocation of production	0.25 %
	E_3: Force majeure (thunder-storm, earthquake, power outage, e. g.)	Situational reaction	0.25 %
	E_4: Too late arrival of fabrics/ trimmings	Prioritize production	5.00 %
Transport	E_5: Strike (forwarder, sea-/ airport staff)	Switch to alternative forwarder/ sea-/ airport	1.00 %
	E_6: Missing customs documents	Notify agency	1.50 %
	E_7: Lost of maritime container/ ship foundering	None	0.05 %
	E_8: Traffic jam	None	1.50 %

5.2 Implementation Considerations

For the implementation of the DES, we use Rockwell Arena 12.0, which is a standard product for DES [18]. We extend the standard capabilities of Arena to be able to simulate an RFID-enabled supply chain [18]. For this purpose, we implement a RFID tagging module, a RFID reader module, an aggregation module, and a disaggregation module. For detailed information, we refer to [11].

5.3 DES Model of the Fashion Supply Chain

Using the capabilities of Arena and our implemented modules, we model the Gerry Weber supply chain, as it would look like if complete adoption of RFID in the supply chain took place. Reflecting the large data set, which is created by our simulation, we limit the simulation to 1/10th of the size of Gerry Weber's supply chain.

Simulation Parameters and Assumptions. We assume an annual production of 2,500,000 garments (57 % laying, 43 % hanging), which are produced by 20 equally large producers. Our model includes two cross docking facilities (one in Far East and one in Turkey). The number of distribution centers in Europe is 6. We assume that there are 178 retailers.

Sea transport accounts for 77 % of the total production in Far East. The rest is transported via air transport. Transportation from Far East takes place in containers. In Turkey, the garments are transported to the cross docking facility via small trucks and then are reloaded to large trucks. The producers in Eastern Europe directly transport the garments to the European distribution centers using small trucks. Then, the garments are transported to the retailers using large trucks.

The air transport from cross docking to the distribution centers takes 5 days. Sea transport takes 30 days in average (Gaussian Distribution (GD), Standard Deviation (SD) of 0.5 days). The transportation from the cross docking facilities in Turkey and the producers in Eastern Europe to the distribution centers also takes 5 days in average (GD, SD of 0.2 days). The handling, warehousing and distribution to the retailers takes 10 days in average (GD, SD of 2 days). Between time of arrival at the retailers and time of sale, 40 days of time elapse in average (GD, SD of 8 days).

For the aggregation and disaggregation, the capacity of cartons etc. is important. We assume that 40 items of lying garments fit into a carton. One small truck has the capacity for 125 cartons of laying garments or 40 bars of hanging garments respectively. We assume that a large truck has the same capacity as a container. 4,200 hanging garments and 250 cartons of laying garments fit into a large truck/ container.

In Table 1, we presented the probabilities of events. All these events result in delays. In our model, the unit always is hours. These delays are modeled using a triangular distribution, which is presented in the form of three numbers, e. g., {10, 20, 30}. That means that the probability of a lower than 10-hour delay or a higher than 30-hour delay is zero. The highest probability is a 20-hour delay. The delays of events E_1 – E_4 (production) are {3, 120, 336}. A strike or missing customs documents ($E_{5,6}$) causes a delay of {48, 96, 144}. If a container is lost (E_7), it is deleted from the system and never occurs again. The transportation delays caused by traffic jams (E_8), i. e., all ground transportation in our model, are {6, 12, 24}.

Simulation Results. Table 2 shows read events and data volume that occurred in the simulation. We assume that Gerry Weber subscribed to all read events at all supply chain partner's EPCIS repositories. Thus, each EPCIS event (1,257 Bytes in size [16]) is pushed into the EPCIS repository of Gerry Weber. The SCEM system is uses this repository as data source. Table 2 also lists the number of read events indicating delays, which give insights that may improve supply chain transparency.

The simulation results and the analysis of key figures, resulting read events, and data volume answer our research question RQ_1. The raw data of the simulation is available online at http://epic.hpi.uni-potsdam.de/Home/SOCLOG09Simul.

5.4 Simulation Implications

As it can be derived from the simulation results of Gerry Weber's supply chain, the EPC network indeed can contribute to a significantly enhanced supply chain visibility. In comparison to the current situation, all 1,229,522 item-level delays are monitored by the system. Since EPCIS inherently answers the what, when, why, and where of read events, it allows for various statistical analysis. Hence, research question RQ_2 can be affirmed: the fine granular and in real-time available data through the EPC network are highly appropriate as data source for the monitoring and measuring function of SCEM systems.

Table 2. Read Events and Resulting Data Volume

Id	Key Figure	All Read Events	Data Volume (in GB)	Read Events Indicating Delays
1	Total number	13,303,720	15.57	1,229,522
2	Read events at producers	5,118,817	5.99	373,751
3	in Far East	2,816,304	3.30	204,841
4	in Turkey	1,023,981	1.20	75,004
5	in Eastern Europe	1,278,532	1.50	93,906
6	Read events at cross docking	1,712,091	2.00	151,243
7	in Far East	1,252,366	1.47	109,148
8	in Turkey	459,725	0.54	42,095
9	Read events at distribution centers	2,148,807	2.52	205,030
10	Read events at retailers	4,324,005	5.06	499,498

6 Calculation of Benefits

For practitioners, profitability of investments in RFID/ EPC network is of high interest. However, determining the benefits of an edge on information is always company-specific. It especially depends on the kind of events the company has to struggle with as well as on the availability of counteractions in the case of an early knowledge of critical supply chain incidents.

As for the determination of the benefits, we suggest the decision-maker proceeding as follows: identify all critical potential events in the supply chain, prioritize them (according to their potential impact, probability of occurrence, and probability of detection, e. g.) and inquire the measures to be taken in each case. Afterwards, it is to be distinguished between situations that help a company because appropriate measures can be taken and those where an edge on information would make no difference (lost of a maritime container, e. g., see "E_7" in Table 1).

An event that was named by all fashion companies in the course of our prior case study research is a delay at the manufacturer (see "E_1" in Table 1). Here, an early knowledge would be indeed beneficial as altering the transportation mode is an appropriate countermeasure in order to meet the delivery date.

For a fashion company, a delay in production has multiple negative impacts which can be taken into account for the business case: loss in sales (as a fashion line only sells well if all of its combinable trousers, blazers, shirts, skirts, accessories, etc. are available on the sales floor), costs for subsequent deliveries, and contract penalties for delivery date exceeding, e. g.. On the basis of those considerations, we suggest a formula that can be applied to estimate the benefit out of an early detection of "E_1":

$$B(E_1) = (\alpha - \beta) \bullet a \bullet n \bullet \left[(p \bullet \gamma) + c_S + c_P - c_T\right]$$

The symbols are defined as follows:

$B(E_1)$	early detection benefit using the example of event E_1
α	approx. part of events able to be detected through EPC network utilization
β	approx. part of events able to be detected by hitherto means
a	part of units where counteractions can be applied to compensate the delay
n	total number of delayed units with the manufacturer's site p. a.
p	average price per unit
γ	approx. loss in sales due to incomplete fashion lines
c_S	costs for subsequent deliveries
c_P	costs for contract penalties
c_T	costs to compensate the delay

Due to competitive reasons, we are not able to use genuine data (prices, costs, etc.) to illustrate the calculation. Nevertheless, we present realistic assumptions.

For our example we presume that a company is able to detect around 90 % of all supply chain events by conventional technologies like telephone or e-mail and that by utilization of the EPC network it is expected to increase that by 9 %. We assume that the company has the opportunity to switch from standard to express transport mode (for instance, from sea to air transport) in seven out of ten cases. The annual number of produced garments is the same as applied in our simulation: 2,497,599.

For lost sales and contract penalty it is necessary to set an average price for a unit, which for our cause is 50 \$. In the case of an incomplete fashion line we assume a loss in sales of 5 %. In our scenario, a retailer is permitted to request a discount of 10 % relating to the price. As for the expenses for a subsequent delivery, we assume additional costs of 2 \$ per unit for all additional administrative, handling and transportation processes.

As a rule of thumb, costs for air transport exceed those for carriage by sea by a factor of 5. Nevertheless, cargo rates always vary due to the fluctuating demand and supply ratio or oil prices. As a simplification, we assume the same price difference for all other transport mode alterations. The savings resulting from the utilization of the EPC network in combination with SCEM systems can be determined as follows:

$$B(E_1) = (99\% - 90\%) \bullet 70\% \bullet 99{,}525 \bullet \left[(50\$ \bullet 5\%) + 2\$ + (50\$ \bullet 10\%) - 0.80\$\right] = 54{,}549.65\$$$

Although this sample calculation for the case of E_1 alone marks considerable potential savings, it is to be reminded that our calculation encompasses only three exemplary benefits for one sole type of event and that it is based on a 10 times smaller volume as it is the case in reality. Though, fulfillment of target processes in the supply chain is jeopardized by a multitude of potential events. Hence, we see a much higher return when all of a company's most critical events are considered. As for RQ_3, we illustrated a way how the benefits of an early detection of critical supply chain events can be determined.

7 Conclusion

In this contribution, we presented a simulation based on results from a case study with seven fashion companies and data directly from Gerry Weber. We designed the EPC network for future fashion industry supply chains and, based on this, developed a simulation model in the factor of 1:10. The simulation results were presented in detail and they are available online for future researchers and their investigations.

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