Smart.NRW—RFID as Enabler for an Intelligent FMCG Supply Chain

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Abstract RFID is a key technology for an increase of transparency in logistic networks and can serve as a solution for unsolved problems in FMCG industry like excessive inventory levels, inefficient capacity utilization and poor service levels. The research project Smart.NRW studies the application of RFID on case level as well as the interorganizational demand planning. The project goal is to integrate high resolution information into the planning and control processes to maximize the on-shelf availability of consumer goods in the wholesale market. The research project includes three major work packages. The first one aims at the definition of the suitable product-specific RFID transponder and its position. The objective of the second work package is to develop a manufacturing process providing cardboard packaging of FMCG articles with RFID transponders. In the third work package real-time data driven methods for adaptive planning and control in the supply chain are developed. To validate the project results two field trials have been carried out,

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for which an RFID infrastructure consisting of reader gates and handheld devices has been installed at several points along the supply chain. This contribution reports in detail about the results of Smart.NRW, by describing the process of RFID application in an FMCG supply chain.

Keywords Supply chain management · RFID · Collaborative planning · Fast moving consumer goods

1 Introduction

Companies belonging to the fast moving consumer goods (FMCG) industry face a high pressure to decrease costs and to secure a high service level in a heterogeneous range of products (Geißdoerfer 2009). In addition, a delay in the flow of information between supply chain partners often leads to strongly increasing stock levels, inefficient capacity utilization and decreasing service levels. The information exchange in supply chains is still limited (Bottani et al. 2010).

This paper focuses on the question how supply chain partners can continuously improve the flow of goods and information in order to optimize the planning and control processes in the entire supply chain. Based on this, new methods and tools need to be developed to sustainably improve internal as well as inter-organizational logistics processes.

An approach to answer this question is the implementation of new information technologies. One of these technologies is Radio Frequency Identification (RFID), consisting of a chip with an integrated antenna, also called tag, which can be attached to the items. Since unique number combinations are sent to contact free reading points, the challenges mentioned above can be addressed with the application of RFID (Emde et al. 2012). Thus, based on the higher information transparency supply chain partners can exchange more data and intensify the degree of inter-organizational collaboration. RFID technology makes it possible to capture each item at several supply chain stages in a rapid and automatic way and to increase the transparency considering goods and information flows throughout the supply chain (Bhadrachalam et al. 2009). Consequently, RFID technology seems to be a key enabler to increase information density and to integrate real-time data into logistics networks (Gille 2010).

Nevertheless, there are some technical barriers to introduce RFID in a supply chain, especially on case level. Since the physical parameters of each product and each package vary significantly it is important to implement an efficient and quick process to select the right tag and to define its right position. Considering the broad product range existing in the FMCG industry, this step will ensure an effective reading of RFID on case level.

The problem of finding the optimal tag type and position as well as the automated integration of RFID tags into cardboard packages and the development of

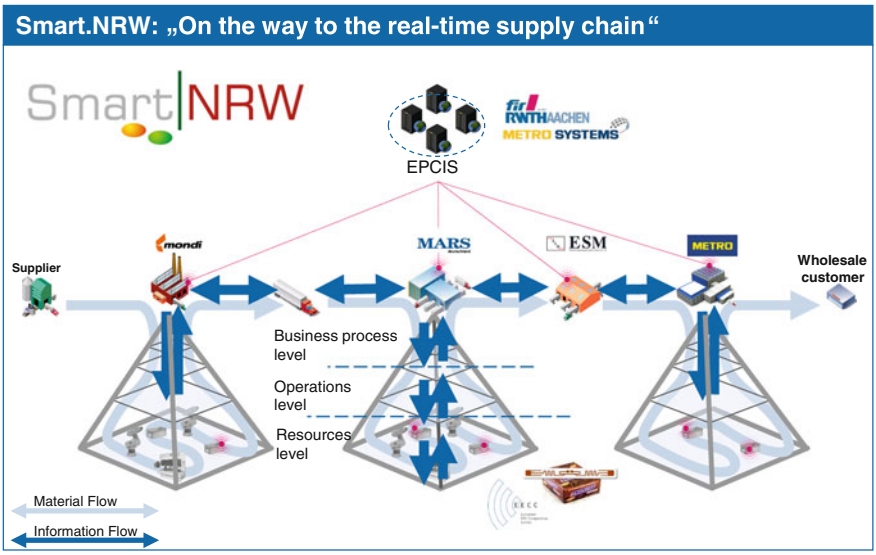

Fig. 1 Smart.NRW supply chain

adaptive planning and control algorithms based on real-time data belong to the main targets of the research project Smart.NRW. The Smart.NRW supply chain consists of Mondi (manufacturer of cardboards), Mars (confectionery manufacturer), ESM (logistics service provider) and METRO Cash & Carry (wholesaler). Besides, the European EPC Competence Center (EECC) develops a procedure for the Optimal Tag Type and Position (OTTP), while METRO Systems provides software solutions for implementing developed algorithms and supports the construction of an RFID infrastructure. The Institute for Industrial Management (FIR) at the RWTH Aachen University coordinates the project and develops methods to optimize the supply chain planning (Fig. 1).

In the next section, the results of the technical work packages will be described. Subsequently, the benefits derived from Smart.NRW are summarized for each supply chain partner. Finally, both field trials and further research needs are discussed.

2 RFID Application in a FMCG Supply Chain

In this section, the development of the research results regarding the OTTP, the implementation of a supply chain platform as well as the development of a manufacturing process will be illustrated.

2.1 Development of the OTTP by the European EPC Competence Center EECC

The FMCG market is characterized by a large variety of packages (Clarke 2008). Since the purchase decision of customers at the point of sale is determined to a large extent by the package (which hence is an important marketing tool), product packaging is undergoing changes continuously. This poses challenges for the UHF-RFID based product identification on case level. The package form and content as well as the RFID transponder position operating in the UHF band strongly influences its performance (Regattieri and Santarelli 2013). After package revisions, the type, position and orientation of the transponder often need to be redefined to ensure a reliable reading.

Due to the large number of FMCG manufacturers, products and product variants and rapidly changing outer packaging, determining the optimal tag position with the conventional method in an anechoic chamber is not feasible. The lack of specialized laboratories that can perform the measurements and the high costs associated with measuring different tags on different positions of an FMCG case creates the need for an innovative and new tag finding procedure. In the future more and more FMCG cases will be equipped with UHF-transponders. Thus, an economic method is needed to find the right transponder and the right transponder position in an automated way.

The optimal tag type position (OTTP) procedure should solve this problem. As part of the Smart.NRW project the EECC together with METRO Systems developed a method to decide upon the right position of a tag without measuring it attached to the product. About 150 UHF labels were measured on eight reference materials with a distinct permittivity. The permittivity as a measure of how an electric field affects, and how it is affected by a dielectric medium, is the main parameter influencing the performance of UHF-RFID tags.

Mathematical Model From these measurements, a mathematical model has been created to predict the performance of each tag on materials with permittivity values different from the ones of the reference materials. With this model on hand, a way had to be found to automatically predict the read range of UHF-RFID tags on different positions of the FMCG package. A permittivity map of the tagged consumer goods was the missing link to realize the OTTP.

The EECC developed a new permittivity probe, designed especially for the needs of using it on FMCGs. It can measure the complex permittivity with both components, the real and imaginary part, and scans an area of size similar to the area which affects the performance of an UHF tag. The real part of the permittivity leads to a “detuning” of the transponder, whereas the imaginary part stands for the absorption of energy by the material, what leads to a direct decrease in read range.

The probe was attached to a positioning system with the ability to automatically scan the surface of different FMCG packages of any size in a pre-defined raster. At each point of the raster the permittivity is measured and connected with the coordinate.

Both the positioner and the vector network analyzer connected to the probe are controlled by a PC running LabVIEW. LabVIEW retrieves the permittivity measures of the tags on the reference materials from the tag database and calculates the corresponding read range for all tags via the above mentioned mathematical model using a MATLAB plugin. The predicted read range for a tag computed from the measured permittivity deviates only slightly from the real read range values of the tags attached on the same coordinate to the product and measured in the anechoic chamber.

As an outcome of the OTTP development in Smart.NRW it is now possible to determine the ideal type of UHF tag and its position for an FMCG product with a reasonable effort and reasonable loss of precision. It allows an economic tag selection for future use of RFID in the FMCG sector. The selection of tags, performance-, size- and pricewise, for FMCGs is now feasible. The OTTP has removed the obstacles that blocked an economic tag finding.

2.2 Implementation of Planning and Control Algorithms in a Supply Chain Platform by METRO Systems

In Smart.NRW, transactional data for all stations and read points of the supply chain have been gathered and stored. In order to use this new information granularity and transparency, a supply chain reporting platform has been developed which enables its user to perfectly control its supply chain processes and pro-actively react on critical situations.

For displaying and analyzing all relevant information, the transactional event data of all RFID read points along the supply chain had to be transformed into their business representation using the so-called EPCIS (Electronic Product Code Information Services) standard. This business event information represents the necessary KPI- and transactional data for the web-based reporting platform. Possible use cases for the platform include order planning based on stock and sales information as well as process throughput time statistics and the reaction on critical situations like out of stock (OOS) or NOSBOS (not on shelf, but on stock). Situations that require an active intervention can be supported by the notification framework. In that way, the involved stakeholders can get information or actions are even automatically taken in case of certain supply chain KPIs are reported to be beyond their limits.

Methodology Electronic Product Code Information Service (EPCIS) is a global standard for exchanging value chain events between business partners in real time (Zheng and Ge 2013). These events typically inform on what, as well as when and why something has happened. The software implementing this standard is called an EPCIS system with the task to administer all relevant value chain events in a central repository.

The reports which were developed for the supply chain platform have been defined in the platform‘s functional specification. Technically, they are fed by the EPCIS events which are generated for all supply chain processes and stored in the EPCIS repository.

Report Application The report application displays all dynamic business intelligence data. It is web-based and enables an authenticated access for all project partners on all internet-ready devices using a web browser. In a user authentication system all legitimate credentials are stored in order to avoid access fraud by third parties.

Based on the authentication credentials, the individually accessible reports for every user are controlled. In that way, all project partners have access to common reports, whereas company-internal process flows are only accessible for the partners themselves. The list of accessible reports is shown to the user after login.

As a report development framework, the BIRT-API (Business Intelligence and Reporting Tools) was used. When a report is selected, all necessary business intelligence data from EPCIS events are retrieved from the database, processed, filtered, sorted and finally displayed in a tabular as well as graphical representation. The user can manipulate the results using report parameters for time, article, location and some additional optional filters. In all cases, the system already proposes a sensible default selection.

The reports provide an extensive list of analytical functions on the supply chain, specifically concerning the following information:

- Carton and product stock information in every supply chain location
- Sales in MCC stores
- Process order throughput times for cartons and products, inside any supply chain partner as well as across all partners
- Order proposals and planning information based on current stock information and historical process data
- Track & Trace search functions (e.g. locations, time periods, orders)
- Track & Trace for every product instance
- Order process quality (time, quantity, quality)
- On-shelf availability in the stores

Some reports also make use of best before date (BBD) information for each product instance. In that way also product quality (“sellable stock”) can be classified.

Notification Framework In order to optimize the operational process quality, an automatic alert and notification system has been developed so that e.g. minimal stock or BBD situations are actively communicated almost in real-time. This enables direct interventions at the first moment possible.

Technically, a combination of database structures, trigger mechanisms and constant script-routines (Cron-Jobs) has been used. From a business data perspective, alert criteria are calculated and continuously updated. In addition, message

Table 1 Key performance indicators

Current details	Event details like timestamp, type × number for articles, order reference
Completeness	Current and historic ratio of order completeness (store-based and global)
Fulfilment	Current and historic order fulfilment KPIs (store-based and global)
Write-off	Number or articles in stock of which the BBD (best before date) residual time is less than 119 days
Reordering number	Number or articles to be ordered as well as the timing of the order (create new order proposal) for target store
Replenishment	Number and location of articles to be transferred from high rack to sales floor
OOS (Out-of-stock)/OSA (On-shelf availability)	OOS event for article type, current and historic OSA figures for article type(s)
NOSBOS (Not on shelf but on stock)	NOSBOS event for article type, current and historic NOSBOS figures for article type(s)
Overstock	Overstock event for article type, overstock ratio and time period (cumulative)
Sales peak	Sales peak event for article type, peak ratio and time period (cumulative)

types and recipients are associated with each notification type. Using Cron-Jobs, every notification is transmitted to the defined recipients in the event of an alert. The Key Performance Indicators (KPI) have been included in the notification framework (Table 1).

2.3 Development of a Manufacturing Process for RFID Case Level Tagging by Mondi

The production process of corrugated cardboards offers different possibilities to apply an RFID tag. In Smart.NRW, the entire procedure to find the optimal technical and economical solution has been analyzed. The following assumptions hold:

- No speed restrictions for the production machines
- Applying without mechanical contact to secure product quality
- Writing of transponders “inline”
- Automatic outplacement of defect transponders
- Separated setup of labeling machine
- Full flexibility considering the positioning

Starting with the corrugator many possible places to apply the tag were found. Applying the tag during manufacturing of the raw corrugated board brings several advantages, especially in terms of flexibility. Both, high pressure (up to 80 bar) and

high temperature (up to 160° steam temperature) at this step cause major problems with the tag. Even after having solved pressure and temperature problems several challenges regarding production numbers and costs as well as resulting waste still exist. For the conversion of the raw board there are three standard ways that are described in the sequel.

Inline Converting An inline machine includes every standard working step into one single line. Since this represents an all in one machine there are some limitations in comparison to separated single steps. Die cutting will never be as perfect as it is with a flatbed die cutter. The biggest challenge for inline machines is the high speed. Depending on the box size modern machines are able to convert up to 24,000 boxes per hour. Synchronization and accurate applying lead to high costs.

Die Cutting Die cutting is separated into the two areas flatbed and rotary die cutting. The first one is a very precise process. The advantages of this method include high precision, high accuracy in scoring and high flexibility considering possible geometric forms. The tool in the rotary die cutting is fixed at an axis and has an opposite axis with die cut rubber. The sheet is moved through and cut by the rotated tool. This process is not as precise as the first one. However, higher production speed and rates as well as bigger sheet sizes belong to the main advantages.

Glueing Glueing and folding are the final steps to transform the open sheet to the final cardboard box. The RFID tag is applied in this step. Therefore, a standard applicator needs to be severely modified. The applying head is equipped with an RFID antenna. Regarding the limited space the entire dispenser with the raw material needs to be positioned much higher so that a longer apply tongue is required. The most critical point is the electrical field. To avoid reflections and writing of wrong transponders in sequence, metal parts have to be reduced to a minimum. As technical highlight, the most loaded parts are made of carbon fiber.

3 Supply Chain Benefits of RFID Case Level Tagging

In this chapter, the benefits to be realized by RFID case level tagging in the FMCG industry are pointed out for each supply chain actor.

3.1 Benefits for the Confectionery Manufacturer Mars

Today, the knowledge of what happens at the point of sale is rather limited. This leaves us with different issues regarding forecast quality, unused opportunities in managing marketing activities and inefficient handling of quality issues.

Forecast Quality The goal is to serve all customer orders perfectly. To achieve this, the supply chain will be managed in advance by forecasting the potential demand based on historical data. Unfortunately, this approach still provides an inaccurate forecast of demand, as the real time data of stock in the customers'

warehouses are not incorporated. This results in high inventory levels to respond to unexpected demand or in out of stock situations, as it is no longer possible to respond to large demand fluctuations. With a real-time tracking of products via RFID the transparency and real-time data on sales in the customer stores and on remaining stock levels in their warehouses are given for the first time. Consequently, the forecast quality can be improved by using real-time data that reflects potential future customer demand more accurately. This knowledge facilitates managing the supply in advance and respond to unexpected demand fluctuations faster.

Marketing 2.0 Confectionery is highly driven by impulse business. Most shoppers buy chocolate spontaneously while they pass through the shop instead of having noted it on their shopping list. Thus, placing chocolate products not only in the regular shelves but also on secondary placements is critical to success in this sector. Nonetheless, there is no accurate way to measure the impact of second placements to date. Due to reading points on secondary placements and on shelf in the Smart.NRW pilot stores, plus the RFID case level tagging of the products, we are able to trace if a sold product was taken from shelf or from secondary placement. One step further this also enables to compare the efficacy of different second placements, different promotional displays, or to track the on-time delivery and optimal execution of promotions in store. RFID case level tagging provides a new transparency on what is happening in the shop that leads to a better, more data-driven marketing.

Recalls on Single Item Basis When recalling goods, RFID case level tagging offers two benefits. First, it is possible to capture where and when exactly a certain product went through which production process and might have been affected by a certain quality issue (e.g. misprinted packaging, temperature fluctuations). This enables to tackle a quality issue more efficiently and more effectively by narrowing down the recall to only affected items. The second benefit comes from using real-time data on the location of items. Thereby, locating items affected by a recall is incredibly fast and makes it possible to react immediately.

On-shelf-availability (OSA) FMCG companies in most cases do not sell highly anticipated products for which people make an urgent effort to buy them, wait for delivery for a long time or search shops to find the specific product. When it comes to FMCG products buyers behave differently. If they might not come across the specific candy bar they wanted to buy, buyers most likely just buy a candy bar from a different brand. Therefore, the non-availability on shelf leads to a loss of customers to the competition. If products are out of shelf for a longer time period customers will shift their buying intention to other brands, which is precisely what leads to sustained customer losses. These out of shelf situations can be triggered by low delivery performance or by NOSBOS incidents, where products that are actually on stock have not reached the shelf. To ensure the OSA of certain products, NOSBOS incidents should be avoided by supporting the trade. With RFID reading events on the sales floor and RFID case level tagging, alert functions to detect NOSBOS incidents can be implemented (Sundene and Merete 2014).

In all cases, RFID case level tagging provides real-time data to make a step forward in supply chain transparency. Thereby, it helps to realize a shopping experience in which consumers find their desired product in great quality available in store enriched by a marketing experience tailored to their preferences.

3.2 Benefits for the Logistics Service Provider ESM

The main benefits of the results reached in the course of the research project Smart. NRW for the logistics service provider are summarized to four basic processes in terms of product handling.

Goods Receipt The first focus has been on the goods receipt inspection. Often every pallet is controlled manually. RFID case level tagging improves this essential part. Faster inspections lead to faster handling and availability in the warehouse. As a result of this, a second benefit on storing and taking out of store is noted. That means that the holding area can be entered automatically after the goods receipt inspection.

Commissioning and Shipping Another important part is the commissioning and shipping. It is possible to optimize the system with a better fault prevention.

Service The last benefit which can be realize with the help of RFID case level tagging is to improve the service quality. The handling of returns and reclamations has a great potential. Thus, there is a higher visibility regarding the transport of single goods, which helps to optimize the entire transport and customer support.

3.3 Benefits for the Wholesaler METRO Cash & Carry

Four METRO Cash & Carry stores in Germany participated in the research project Smart.NRW. For them, the value drivers for having RFID technology on case level are identifiable in the areas goods receipt, stock management and write offs, as explained in more detail below.

Goods Receipt "Did we get the orders we requested in the right quality, quantity and within the right time-frame?"

This is one of the key questions of goods receipt. Without the usage of RFID tagged goods, the answer to the question above needs detailed manual checking. After the validation, the goods coming from the producer have to be checked in into the goods management system. This leads to additional manual effort, even when using optical scan methods. RFID on case level helps to reduce the effort spent on checking the goods received and afterwards their check-in into the goods management system (Miragliotta et al. 2009). The RFID tag on each case makes this case uniquely identifiable in the in-store process chain.

Stock Management "Do we have sufficient stock?", "By what time do we have to reorder to avoid an out of stock situation?", and "Where is the stock located?"

In order to fulfill customer needs, it is necessary to ensure that enough stock of a specific product is in store. This may lead to conflicts between the availability of sufficient products on the shelf and the capital lockup they represent.

RFID tagging enables to find the right balance between availability and inventory capital because the information on stock levels and sales is precisely and in real time available (Vlachos 2013). This helps to have an accurate reorder prediction and range calculation, respectively, which helps to reduce the order amount together with avoiding both out of stock and over stock situations.

Another advantage is to know exactly where stock of a specific product is located (Rhensius 2010). RFID based real time information considering the location of a specific product enables to reduce replenishment efforts and to avoid NOSBOS situations.

Write-Off Write-offs are generally unwanted because they have a negative impact on revenues. For instance, in the area of fresh products or ultra-fresh products with a small durability time lag, the risk of write-offs is often very high. With RFID case level tagging it is possible to identify such products quickly and to place them on the shelf in ascending order of their best before date. This reduces the risk of these kinds of write-offs and especially the costs that are caused by write-offs.

4 Conclusion

Before summarizing the main contents of this contribution will be summarized, both field trials conducted in Smart.NRW are briefly described.

4.1 Field Trials

The first field trial aimed at the validation of the OTTP results and the technical feasibility of the concept. Six reader gates, handheld devices and label printers have been installed at several points along the supply chain and connected to several EPCIS instances, one for each firm to avoid the central storage of data. Furthermore, new item codes were developed for targeted orders of test products. The packaging with new codes and RFID tags were qualified and approved by the producer.

During the test, the RFID tags were attached to the cartons and also encoded. ESM used the tagged cartons to repack the test items. At this stage, the RFID tags were read for the first time. Other reading points were located at the outgoing goods area of the logistics service provider's and at the incoming goods area of the wholesaler.

The developed production methods were successfully validated during the first field trial. The chosen infrastructure proved to be suitable for the project objectives.

Significant results were reached in the area of (bulk) reading of the packaging which can be used for the OTTP refinement and the hardware configuration improvement.

The second field trial included additional reader gates, readers integrated into high rank shelves and a larger number of test items. Its aim was the implementation, refinement and validation of the achieved results considering the planning and control algorithms. The second field trial also served as a basis for a possible roll out.

The field trial data was collected in the Smart.NRW platform. It was used by the firms to quantify the RFID based measures for raising the supply chain efficiency. Moreover, individual questionnaires were prepared for each firm for quantitative and qualitative analysis and evaluation of the major aspects of the whole research project.

4.2 Outlook

In Smart.NRW the RFID application on case level in a real FMCG supply chain was analyzed. As a key information technology, RFID is used to solve still existing logistic challenges like uncertainty and lack of transparency. A higher information density in the entire supply chain enables the actors to react faster to fluctuating customer demands as well as to decrease stock levels while improving service levels at the same time (Wang et al. 2011). Additionally, a higher degree of collaboration is simplified by improved transparency. In summary, RFID case level tagging leads to more information quality improving sustainably the performance and competitiveness of FMCG supply chains.

However, research activities in this area need to be continued. Smart.NRW focused on one specific product category. The discussions in the project consortium about a 100 % implementation of RFID case level tagging shows that further logistic potentials can be realized. An important step to future FMCG supply chains has been done by Smart.NRW.

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