Combining RFID Technology and Business Intelligence for Supply Chain Optimization – Scenarios for Retail Logistics

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Abstract

"Radio Frequency Identification" (RFID) and the related EPC standards promise to enable an automatic collection of supply chain data for optimization purposes. While extensive research has been done on applications for operational supply chain optimization, there is still a lack of insight into the requirements and benefits of further processing the data within integrated management support infrastructures (Business Intelligence infrastructures) that allow for sharing, integrating, and analyzing RFID data. This paper discusses respective scenarios which were elicited from a transcontinental retail supply chain case. It addresses data collection and integration on the one hand and the relevance of the enabled analyses on the other. The results indicate that the role of Business Intelligence components should not be underestimated when preparing a business case for RFID.

1 Introduction and Motivation

Automatic Identification Systems based on the so-called "Radio Frequency ID technology" (RFID technology) are expected to become an enabler for substantial improvements in cost-efficiency within transportation and warehousing processes [1] [33] [17] [20]. RFID systems enable a contact-free bulk identification of objects on pallet, box, or even item granularity.

The heart of an RFID system is the "RFID tag" which encapsulates an integrated circuit and a transponder for data storage and transmission. The tag can be attached to an object and be read out with a reader hardware either in the form of a hand-reader or a RFID gate [22] [3] [4]. For applications in logistics, the dominating RFID standards come from the EPCglobal consortium. EPCglobal defines characteristics of RFID hardware, the structure of the stored data, and the middleware for data exchange across corporate borders [11] [22] [3].

Next to an identification code, some RFID tags can also store additional information, especially data that is collected by integrated sensors. Further potential stems from the possibility to combine RFID and the Global Positioning System (GPS) for world wide tracking and tracing scenarios [21].

An option for sharing RFID data across company borders is the EPCglobal Network approach, which is built on the idea of interlinking decentralized data storages with RFID data. The coordination between the different locations is facilitated by a central directory service, the Object Naming Service (ONS) that refers to local information systems called "EPC Information Services" (EPCIS) [11].

A small but growing number of enterprises have already picked up on the technology, and there is a widespread expectation among decision makers that RFID based systems will significantly gain in relevance in the mid term future [21] [26].

The dominating stream of current activities focuses on increasing local efficiency gains by implementing a more efficient handling of items or pallets or a reduction of processing times [3] [21]. These applications do not yet take the full potential of RFID data into account: Substantial benefits are expected to result from sharing and processing RFID data of various sources along the supply chain [25] [3] [33]. However, such an approach requires integrating, enriching, and analyzing RFID data for the purpose of supporting decision makers – preferably based on systems explicitly designed for these types of tasks: Business Intelligence systems.

In this paper the term "Business Intelligence" (BI) denotes integrated infrastructures for management support. Such infrastructures currently encompass components for data transformation (ETL – Extract, Transform, Load), data storage (data warehouses, data marts, and/or operational data stores), and for data analysis. The latter include (among others) reporting platforms, "Online Analytical Processing" (OLAP) solu-

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tions for a multidimensional navigation in data, and “data mining”, i.e. pattern recognition tools [28] [19].

Recently, BI infrastructures have grown both in scale and in scope and are increasingly used to support all managerial levels – down to the operational real-time steering of business processes [10] [12]. The respective capabilities match the requirements that arise when pursuing a purposeful utilization of shared RFID data in logistics.

This paper discusses the results of a case study in the retail industry. The focus lies on the deduction of concrete scenarios that require data integration and analysis components. The aim is to enhance *decision support* rather than *decision automation*, so experts will still be responsible to derive decisions based on their additional background knowledge.

Special consideration is given to the discussion of the business relevance of the proposed analyses. The aim is to gather insights into the business value of applying BI infrastructures on top of RFID-based logistic processes.

2 Related Work

There have been various research activities carried out that address the business potential of sharing data across the supply chain – both regarding data in general [16] and RFID-based data in particular [23] [25] . The results suggest that the business impact of attaining supply chain transparency can well surpass that of harvesting direct operational gains.

The literature also provides a few studies on pilot RFID implementations: Loebbecke and Huyskens discuss an RFID project in the fashion retail industry [27]. Holmqvist and Stefansson examined warehousing applications in an automotive supply chain [15]. Dighero et al. describe and discuss a RFID based system implemented to enhance data collection and sharing between an IC manufacturer and an OEM [9]. Similarly, Wamba et al. evaluated the business potential of collecting and sharing RFID data in a beverage supply chain case [31].

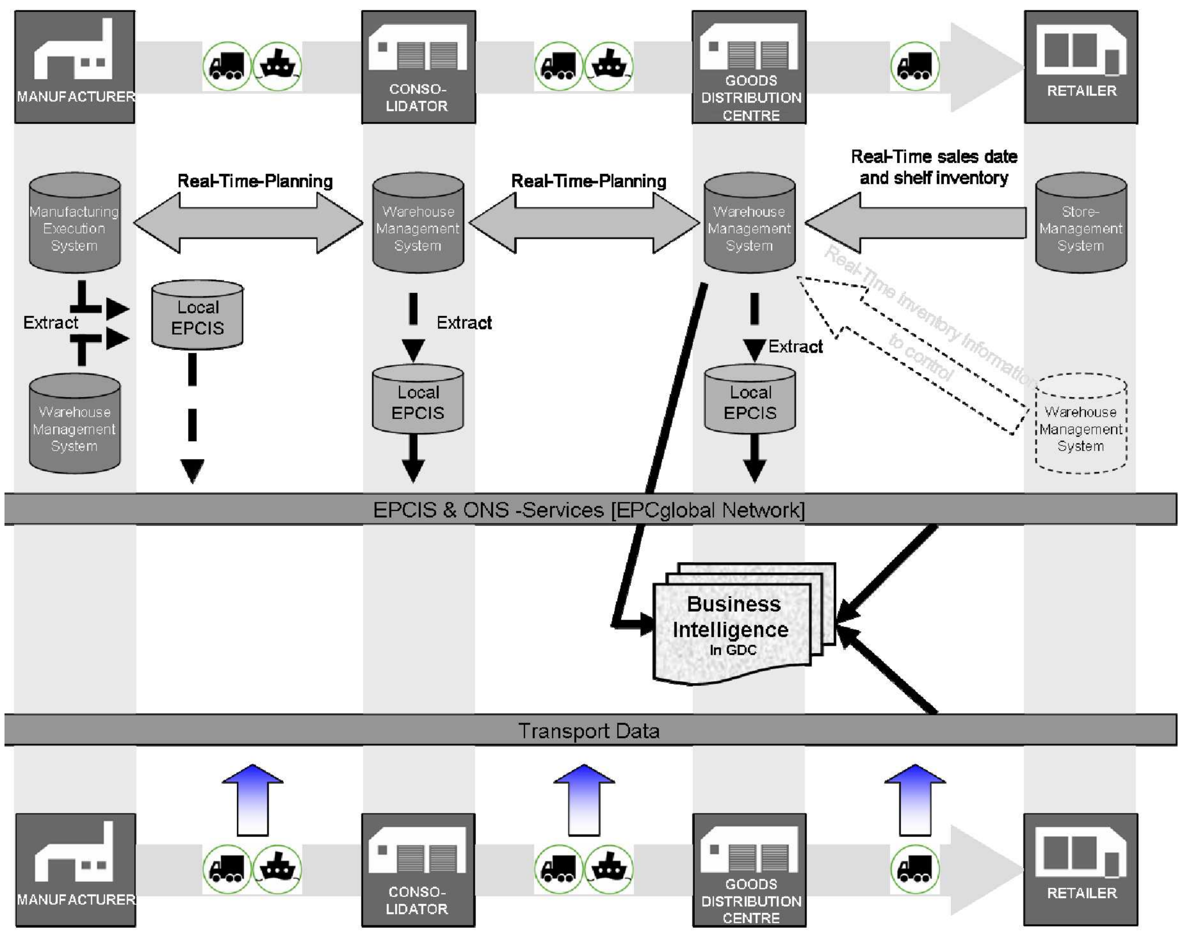

Figure 1: Concept of the decentralized Data Management in the Supply Chain

These cases illustrate the feasibility of implementing the technology, highlight real world business potential, and uncover implementation challenges.

The combination of BI and RFID has been addressed by Gonzales et al., who discuss consequences of storing RFID data on transactional granularity in data warehouses and deduct approaches for handling the resulting data volume [13].

However, there is still a lack of research that links RFID data collection, BI based data integration and analysis, and business value.

3 Scenarios for Combining RFID and BI in the Supply Chain

The following research was accomplished within a logistics project of a leading European retailing group. Applied methods were observation, workshops, and narrative interviews. The scenarios reflect actual business demands, envisioned applications, required data, and possible benefits of the concrete analyses.

The chain in discussion includes Chinese **manufacturers,** a **consolidator** located in China (responsible for the bundling and the shipment of goods from different suppliers in containers), a **Goods Distribution Centre (GDC)** in Germany (handles the goods transfer to the individual retailers), as well as **retail outlets** across Europe.

In the given case, the involved retailing group is the driving force behind the introduction of RFID. Because of its buying power, the retailer can enforce an implementation of the technology across the supply chain.

This study discusses different options for RFID data analysis from the perspective of the GDC. Because of its central distributional function, the GDC keeps contact points to a considerable number of other partners in the supply chain and has significant influence on the overall flow of information and goods. The GDC is therefore a natural starting point for a discussion of supply chain effects.

Chapter 3.1 introduces a concept for the collection, enrichment, and exchange of RFID data. It is the foundation for the derivation and evaluation of two scenarios (Chapter 3.2) that observe different sections of the supply chain. Both scenarios include a discussion of the current state, an analysis of the different BI based RFID-data analyses, relevant data for those analyses, and a short evaluation of the expected benefits. The benefits are mapped to performance attributes from the Supply Chain Operations Reference-model (SCOR) model, a common standard for evaluating supply chains [18] [30].

The results reflect the information needs deemed critical by the involved experts. They need to be understood as a first iteration in the development of a concept for a company-spanning data exchange and analysis infrastructure.

3.1 Data Management in the Supply Chain

A commonality among all the analyses in this paper is that they require the integration of data from various organizationally and physically distributed partners. Figure 1 depicts a bird’s-eye view on the derived infrastructure concept for the collection and management of all needed data. It presupposes that the middleware from the EPCglobal Network has been implemented and that all RFID related challenges arising on hardware level have been dealt with (cf. [4], [9]). For each partner in the supply chain potential measurement locations and relevant complementary data sources have been identified. The results can be summarized as follows:

By the use of RFID-EPC, **manufacturers** enhance their capabilities to gather and store product related data such as production or transportation dates. The RFID data is enriched with additional information from local information systems, especially on product descriptions, inventory and transportation conditions, or on date of expiry. All data is uploaded to the local EPCIS.

As soon as goods arrive at the **consolidator**, they are identified at the consolidator’s gate via RFID. The respective data can be stored both in the local transaction systems and in the EPCIS.

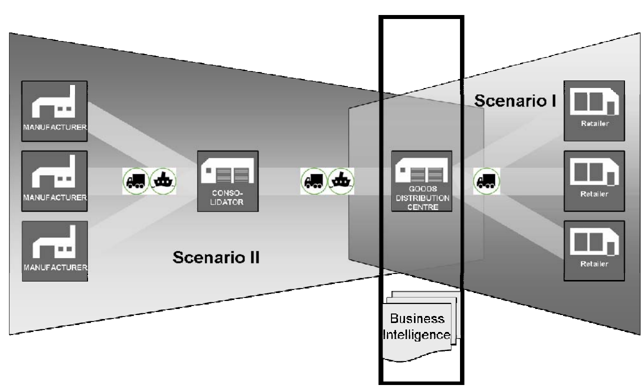

Figure 2: Overview of the Scenarios

A consolidator also adds individual attributes, especially on repacking processes (by combining the product-EPCs and the EPC of the transportation unit), container loading activities (by relating the EPC of the package to the SSCC, the "Serial Shipping Container Code"), or on the actual shipment events (by feeding in data on dates, ship IDs, place of the containers etc.).

In a similar fashion, the **GDC** stores supplemental data in his local EPCIS. The respective information is complemented by external data from transportation service providers, especially position and navigation data.

For some of the analyses it is further assumed that the GDC obtains real time data from its retailers, for example on sales volume and shelf inventory. In return, the **retailers** get access to the Warehouse Management System (WMS) of the GDC. This data is used to control data redundancy in the Store Management Systems. Besides mere logistical figures, the retailers can also provide additional customer and sales related data, e.g. on customer complaints.

The Object Name Service (ONS) provides a means for the GDC to capture and share the discussed product and transport data across the whole supply chain.

After ETL-based transformation and harmonization steps, refined and enriched RFID data is kept in an integrated (real-time) data warehouse of the GDC and can thereby be accessed by the GDC's analytical applications.

Regarding the necessity of data harmonization, it needs to be stated that although the EPC Code provides a consistent identification scheme, harmonization issues can still arise, especially as a result of inconsistent aggregation hierarchies or deviations in the calculation of business measures and ratios.

3.2 Data Analysis Scenarios

The **first scenario** demonstrates possible efficiency gains at the downstream end of the supply chain – between the GDC and the retailers.

In the **second scenario**, the section of the chain that encompasses the manufacturer, the consolidator, and the GDC is subject to the discussion.

The focus of both scenarios lies on efficiency improvements for replenishment processes, lead times, and processes dealing with unexpected events.

The scenarios are based on the following assumptions:

- In discussion are nonfood articles that are shipped by sea. Both standard and promotional goods are included in the discussion.
- Vendor Managed inventory (VMI) can be implemented [7]. In the given case, respective reorganizations are facilitated by the power concentration on the retailer's side.
- The RFID tags are attached on item level by the manufacturer. It is assumed that active RFID tags with sensor capabilities can be attached to logistical units like pallets or containers.
- The data management concept introduced in section 3.1 is already fully implemented. Thus all relevant data of the manufacturers and of the consolidators can be accessed and prepared for data analysis purposes.
- An appropriate BI Infrastructure exists at the GDC. This BI Infrastructure provides various reporting and analytical applications, and offers closed-loop functionality, i.e. it can feed back analysis results into operational systems.

For a systematic appraisal of the derived analyses, the expected benefits will be mapped to the framework of the SCOR model. The discussion is based on the impact on key indicators performance attributes on the first level of the model (cf. [18]).

3.2.1 Scenario I

Scenario I focuses on logistic processes between the GDC and the retailers.

Current State

Currently, the retailers determine the sequence of deliveries (pull strategy, [7]). The GDC coordinates all incoming orders and – after reaching a minimum order quantity – requests the goods from the manufacturers. Decisions on how to handle defective items are made by the individual retailers. If necessary, renewed orders for the replacement of improper goods are sent in by the retailers.

Overview of the Scenario I

In Scenario I, the order process is changed to Vender Managed Inventory (VMI) [7]: Articles available at the GDC are distributed to the retailers depending on stock levels and real-time sales volume.

All goods are ordered proactively by the GDC from the manufacturer. This approach allows a more efficient order processing as well as storage space reductions on the GDC's side. The real time information sharing also enables the GDC to coordinate the distribution of goods *among retailers* in order to maximize product availability. Furthermore, the GDC will become responsible for decisions on recalls of defective goods. The enriched data enables to pursue a more focused approach which limits recalls to defective batches only.

In conclusion, the new role of the GDC transcends that of a provider of pure operational distribution services. It grows to become the core decision unit for all types of distribution related activities.

Analyses in Scenario I

The first analysis in scenario I aims at maximizing shelf space utilization – a well known challenge in retail [6] which also has been stated to be relevant in the given case. Because of its capability to capture availability data in real time and on item level, RFID technology is in general expected to have an impact on the optimization of shelf space allocation [1] [25] [32].

Data items deemed relevant for gaining insight into the current self space situation are listed in Table 1. Note that data from three involved parties needs to be integrated.

Table 1: Scenario I – Analysis 1

Scenario I – Analysis 1		
Analysis	**Location**	**Data**
Maximization of shelf space utilization	Retailer	Allotted shelf space per item
	Retailer	Shelf inventory per item
	GDC	Stock level per article type
	Manufacturer	Item size

The anticipated benefits of increased shelf space utilization can be mapped to the indicators of the SCOR-Model as follows: decreasing payment cycle times, reduced supply times, and increased capital turnover. Taken together this leads to reduced capital expenditure.

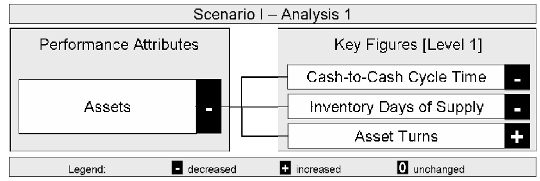

Figure 3: Result Scenario I – Analysis 1

Not charted on this list of benefits is the possibility to browse through *historic data* in the data warehouse to trace the effectiveness of these measures, and to calibrate them if needed, for example when out-of-stock situations arise because of too tightly calculated inventory levels.

Out-of-stock-situations are in general considered to be a widespread issue in retailing [2]. Since a shortage of goods on the retailer's side usually can't be balanced by the GDC, it becomes essential to enable **goods transportation among the** retailers to solve the out-of-stock problem. To be able to deal with such a situation, the inventory information of the retail stores must be collected as soon and as accurately as possible, so the demanded goods can be transferred between the retailers in time [25].

Core data fields for the respective analysis are listed in Table 2.

Table 2: Scenario I – Analysis 2

Scenario I – Analysis 2		
Analysis	**Location**	**Data**
Relocation of goods between retailers	Retailer	Stock level per article type
	Retailer	Shelf inventory per article type
	Retailer	Minimum stock level per article type
	Retailer	Sold items per day

The resulting measures should lead to an increase of the indicator "perfect order fulfillment", an enhanced delivery performance, and to a more efficient handling of erroneous deliveries.

The bottom line is an increased delivery reliability – but it comes at the price of higher distribution costs. Since no counterbalancing factors come into play, total costs will rise.

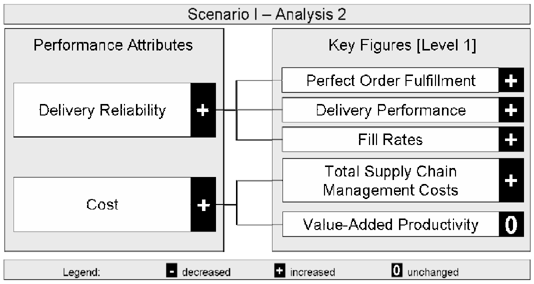

Figure 4: Result Scenario I – Analysis 2

The cost effects aggravate the need to closely monitor the actual outcomes of respective transportation decisions – again by taking historical data in the data warehouse into account.

The role assigned to the GDC in the scenario also includes the responsibility to monitor goods returned from the customer and to decide **whether or not defective goods need to be called back**. The information needed for this decision is primarily based on the number of (legitimate) customer complaints per article type aggregated over all supplied retailers. A heuristic for such decisions could be the definition of a threshold number for accepted customer complaints.

Because of the improved visibility of stock enabled by RFID, it is possible to sort out potentially defective selectively, i.e. only affected batches will be taken out of the chain (similar: [2] [31]). The groundwork for this type of decision support is tracking the relationships between items and transportation units at the consolidator's site. This scenario can be expanded by the inclusion of shelf replenishment measures to smooth operations after a callback decision.

Important data for this analysis is shown in Table 3 – it binds together sources from all four discussed partners in the Supply Chain.

To analyze customer complaints across retail outlets and associate them with batches it needs BI tools for flexible data aggregation and analysis, especially tools with OLAP functionality.

As depicted in Figure 5, the proposed reorganization of callback decisions is made in order to increase productivity costs for more targeted product callbacks while keeping guaranty costs at bay. These measures are expected to lead to overall cost reductions.

Table 3: Scenario I – Analysis 3

Scenario I – Analysis 3		
Analysis	**Location**	**Data**
Selective call-back of articles and refilling the shelves	Retailer	Customer complaints
	Retailer	Assortment
	GDC	Threshold of allowed customer complaints per article type
	GDC	Stock level per article type
	GDC	Supplied retailers
	Consolidator	Relation part-transportation unit
	Manufacturer	Batch number

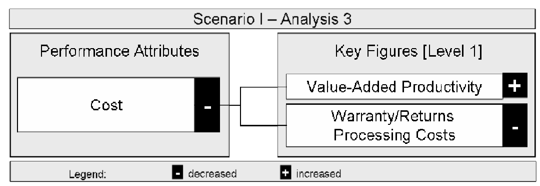

Figure 5: Result Scenario I – Analysis 3

Beyond sorting out defective products, the combination of RFID, tracking & tracing, and sensor technologies additionally enables the **identification and localization of root causes for quality issues** [31]. Sensor data such as abrasion, temperature, humidity, or brightness can be measured automatically for each transport unit and stored on the RFID chip. Relevant data needed for such in-depth analysis of quality is shown in Table 4.

Table 4: Scenario I – Analysis 4

Scenario I – Analysis 4		
Analysis	**Location**	**Data**
Identification of defective articles	Retailer	Customer complaints
	Transport	Tracking & Tracing Data
	Transport	Sensor data (abrasion, etc.)

Again aggregated and historical data from the Data Warehouse makes it possible to identify cause-effect-chains with more confidence, or even to uncover complex patterns, e.g. constellations of travel routes and environmental conditions with a quality impact.

The facilitation of a detailed localization of defects reduces guarantee costs. Moreover liability is to a lesser degree based on subjective judgments (see Figure 6).

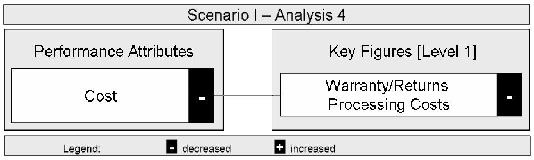

Figure 6: Result Scenario I – Analysis 4

3.2.2 Scenario II

Scenario II examines the section of the supply chain between manufacturer and the GDC.

Current State

Until now, orders from the retailers are collected at the GDC, which aggregates and forwards them to the manufacturers several times per year. After the manufacturers finished the production of an ordered lot, the goods are transported to the consolidators. As the production is on-demand, the manufacturers do not need to keep significant inventories of finished products.

The consolidator receives goods from different manufacturers and sorts them onto containers according to the respective customers. Goods are shipped either by following a first-in-first-out policy or according to prioritization rules which the consolidator defines more or less subjectively.

Currently there is a communication link between the GDC and the manufacturer and between the manufacturer and the consolidator. The GDC has no direct information on the distribution status of goods that are currently passing the consolidator, though, which significantly impedes transparency.

Once the containers reach Europe, goods are delivered to the GDC. Nonfood goods are kept in average for three months in the GDC warehouse before they are eventually delivered to the retailers.

Overview of the Scenario

The second scenario is dealing with the order and distribution performances between manufactures and GDC. It has to seen in conjunction with the production and distribution planning of the manufacturers [24] [29].

The scenario aims at aligning the flow of goods with the actual demand. The pursued objectives are reducing storage space at the GDC while curbing the risk of out-of-stock situations. In an optimal scenario, goods arriving at the GDC can be directly forwarded to the retailers without stocking (cross-docking [14]).

Analyses of Scenario II

The first analysis in this scenario aims at a more **demand driven order process** which goes along with reduced lot sizes and a higher order frequency. In this case, RFID mainly allows for a more efficient, and precise data collection, while the EPC network forms the necessary communication links.

The decision rationale needs to incorporate production and transport constraints, e.g. manufacturing and distribution times, and consider product variants. The resulting data requirements for supporting respective order decisions are shown in Table 5.

Table 5: Scenario II – Analysis 1

Scenario II – Analysis 1		
Analysis	**Location**	**Data**
Calculation of order quantity and order times	Retailer	Sales figures per product type
	Retailer	Stock level per item
	Retailer	Minimum inventory per item
	Retailer	Forecast retail sales figures per day
	GDC	Stock level per item
	GDC	Minimum stock level per item
	Consolidator	Stock level per item
	Consolidator	Minimum stock level per item

The attained increase in throughput should lead to a reduction of stock levels for the consolidator and the GDC. This has a positive impact on sold product amounts (especially for seasonal products) and in turn helps preventing costly discount promotions. The projected benefits of this scenario are shown in Figure 7.

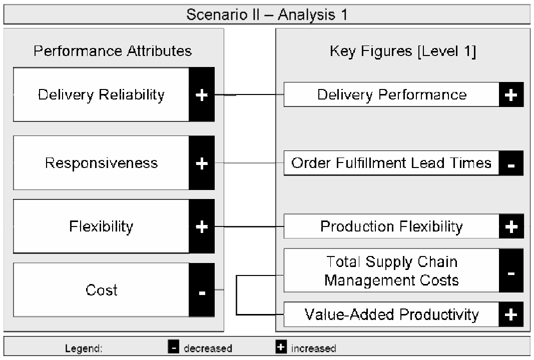

Figure 7: Result Scenario II – Analysis 1

In the second analysis, **goods stocked by the consolidator are sorted by the GDC** based on communicated demand instead of subjective rules. It aims at improving shipping processes (similar to [1]).

Table 6: Scenario II – Analysis 2

Scenario II – Analysis 2		
Analysis	**Location**	**Data**
Prioritization of Deliveries (Consolidator to GDC)	Retailer	Sales amount per product type
	Retailer	Stock level per product type
	Retailer	Minimum inventory per product type
	GDC	Stock level per product type
	GDC	Minimum stock level per product type
	Consolidator	Stock level per product type
	Consolidator	Minimum stock level per product type
	Consolidator	Available container space in ship

Figure 8 illustrates the expected benefits:

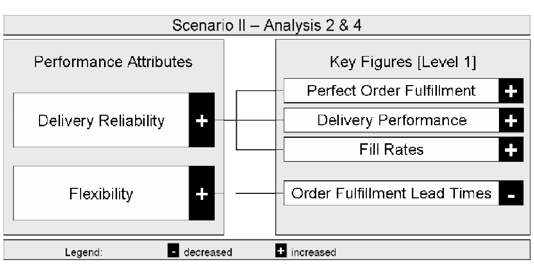

Figure 8: Result Scenario II – Analysis 2 and Analysis 4

Additionally to this, a "**container-loading-list**" can be prepared for the consolidator. It includes shipment specifications such as the loading sequences (heavy units under light units) which can be considered to avoid transport damages. In order to perform such prioritizations the data items from Table 7 are required.

Table 7: Scenario II – Analysis 3

Scenario II – Analysis 3		
Analysis	**Location**	**Data**
Goods distribution under constraints	Manufacturer	Size of item
	Manufacturer	Weight of item
	Manufacturer	Risk classification for the items
	Manufacturer	Production constraints

As depicted in Figure 9 the main effects of the related measures are reduced costs.

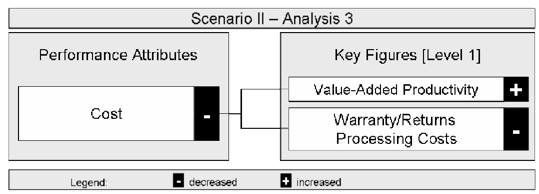

Figure 9: Result Scenario II – Analysis 3

If sensor data and data on damages are added to the set of data, it additionally becomes possible to do an ex-post review of different types of loading decisions.

The fourth analysis pertains to route planning. It has been shown before that route optimization can have significant effects on efficiency [8] [5]. In the given case, RFID, GPS, and sensor data enable the GDC to (almost) constantly monitor the status and the location of moved goods and to be able to intervene as soon as possible.

Such interventions call for functionality to **analyze different transport alternatives** based on target/actual comparisons: The current transport and production status is confronted with the planned date of delivery. If significant deviations between the scheduled and the actual status arise, it is important to be able to prioritize delayed goods and/or arrange for alternative routes. This leads to a demand for the data from Table 8.

Various transportation possibilities, associated prices, transportation durations etc. need to be presented and visualized in an interactive fashion. If possible such an analysis also takes data on the outcomes of former experiences with the considered transportation options into account.

Table 8: Scenario II – Analysis 4

Scenario II – Analysis 4		
Analysis	**Location**	**Data**
Alternative transport possibilities	Retailer	Sales volume per product type
	Retailer	Stock levels per product type
	Retailer	Minimum stock level per product type
	GDC	Stock level per product type
	GDC	Delivery date
	GDC	Minimum stock level per product type
	Manufacturer	Item size
	Manufacturer	Item weight
	Manufacturer	Production status
	Logistics Partners	Tracking- & tracing-data
	Logistics Partners	Sensor data

4 Discussion and Conclusion

This paper presented two RFID-enabled reorganization scenarios that included eight different types of analyses. In all discussed cases, the integration of data from at least two partners was essential. This requires a solid data integration solution – which state-of-the-art BI solutions provide. Besides this, there is a need for the navigation in aggregated and historical data and in some cases for sophisticated data mining tools.

In the given case RFID and EPC make it possible to implement a finely grained and immediate collection of data, which in turn enables more detailed and precise analyses on the BI side.

One branch of ongoing research is aimed at a further validation of the findings with prototypes that implement the BI side of the scenarios. Based on the results of this study, a multi dimensional data model has been derived and realized within an OLAP environment. The data model is built upon the characteristics of the EPC standards and incorporates the presented information needs. It is kept flexible for an adaptation to other business environments and for an enrichment with additional data or analysis logic.

In a second branch of activities, the benefits of a combination of RFID and BI on the manufacturer's side are evaluated. It is assumed that the possibilities to couple BI and RFID to gain detailed and timely insights into intra-company processes, as well as the option to interlink the internal with the inter-business perspective can lead to efficiency gains within production environments. The manufacturer's perspective is understood to be crucial for a transfer of the presented results to scenarios which are not dominated by a single link in the supply chain.

Overall, the results indicate that a connection of BI and RFID has powerful business potential that goes well beyond incremental operational improvements. The benefits and of course costs of a BI Infrastructure for data integration, refinement, and analysis should therefore not be neglected in a cost-benefit evaluation for RFID systems.

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