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ANALYZING RFID DATA FOR THE MANAGEMENT OF REUSABLE PACKAGING

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Abstract

A common issue that most automotive manufacturers have to face in production logistics is the efficient handling of a considerable number of cost-intensive pallets, trays, boxes and similar reusable packaging goods. As empirical studies show, deficiencies in monitoring, controlling and optimizing packaging material are widespread within this industry. In this contribution a case study is used to investigate the potential of supporting these managerial tasks with a combined use of RFID infrastructures and Business Intelligence (BI) infrastructures. This includes a derivation of relevant RFID reader locations, the identification of further relevant data sources as well as crafting concrete analysis and reporting scenarios based on the paradigm of multidimensional data modeling. The results are used to design a concept for a BI and RFID based system architecture. They highlight the need to include data management systems that bring data integration capabilities and that are capable of tracking historical data – as a possible component of a wider BI infrastructure for manufacturing and logistics.

Keywords: *Business Intelligence, Radio Frequency Identification, Manufacturing, Reusable packaging*

1 MOTIVATION

In production logistics of automobile manufacturers, reusable packaging is mainly used for the transport of components. The high specificity of many goods, cost-intensive special pack trays, pallets, baskets, and boxes are used and their sheer number entails the need for a systematic packaging management (Lai et al., 2008). In general, the relevance of packaging management increases proportionally with the value of the goods to be transported. The following statements are taken from an empirical study on packaging management carried out in the year 2005 (Hofmann et al., 2006). The majority of the participating enterprises are from the automobile industry.

- More than half of the industrial enterprises classify the package use cycle as a critical or very critical process.
- Essential challenges are seen in the acceleration of the processes, the reduction of damages in transit, the increase of the reliability as well as an overall cost reduction.
- Already three quarters of the questioned enterprises monitor and control the package use cycle, though mostly based on error-prone and inefficient manual data capturing and administration processes.
- A considerable automation potential is seen in the automation of object data gathering, with Radio Frequency Identification (RFID) technology as a central constituent.
- The introduction of RFID into the package use cycle is not only driven by pure automation gains but also by expectations for an increasing transparency.

The use of RFID in the packaging management will undoubtedly lead to a significant increase of the amount of data. The efficient handling of large volumes data for purposes of decision support, its integration with data from various other sources, the provision of mechanisms for keeping track of historical data, and the aggregation and enrichment of data are functions that so called *Business Intelligence* infrastructures are designed for. Business Intelligence (BI) denotes integrated approaches to decision support with integrated and logically centralized data hubs in the form of Data Warehouses (DWH) in the centre (Baars et al., 2008, Inmon, 2005; Kemper et al, 2009).

This contribution aims at investigating what possible applications might benefit from or be enabled by a combined use of BI and RFID in the realm of packaging management. All results are based on real business needs as derived from the results of an in-depth case study. This encompasses the definition of the necessary RFID reader locations and the identification of possible analyses that are deemed relevant. With the analyses come requirements to feed in complementary information from additional data sources and therefore a need for data integration functionality. All results were developed and evaluated in cooperation with representatives of the responsible IT and production departments. It has to be emphasized that the enterprise in discussion already brings in experience with RFID from pilot applications in production. However, the respective data is at present only used in a decentralized fashion within separate production cells.

In the following sections, fundamental concepts of packaging management and BI are introduced as well as an overview of research results on the subject packaging management. After a short introduction to the company and the applied methodology, the processes in discussion and the conceived RFID reader infrastructure are outlined. This is followed by a detailed presentation of the analysis scenarios. The results are discussed with respect to consequences for a possible BI data management and further implementation steps. Also, the limitations of the research are discussed and options to widen the scope of the solutions to other areas in the realm of production and logistics are outlined.

2 FUNDAMENTALS OF PACKAGING MANAGEMENT AND BUSINESS INTELLIGENCE

2.1 Contents and challenges in packaging management

For applications in a industrial production environment, *packaging* can be defined as materials that serve the purposes of protecting goods that the company will transport or store, of permitting an effective use of transportation space, of facilitating ease of handling and using and of providing information (Coyle, 2006; Northern Ireland Environment Agency, 2008).

Packaging can be divided into the following three types (Chan, 2005): primary (consumer packaging), secondary (retail packaging) and tertiary packaging, with the latter two mainly being used in transportation processes. Tertiary packaging is also called *transport packaging* and the relevant type for this contribution. In the given case the tertiary packaging came in the following variants: pack trays, containers, pallets, reusable dunnage trays, and wire baskets. A further distinction can be drawn between *expendable* and *reusable packaging*. Only reusable packaging is object of the packaging management as understood here (Rosenau et al., 1996; Twede, 1992).

Ascription and reuse tasks are essential components of the design of material flows (Wildemann, 2005). The elementary tasks of the packaging management encompass the specific use and the administration of the packaging units, i.e. the monitoring and control of the package use cycle. This covers all tasks related to the logistical supply and the maintenance of the packaging units.

One possibility of increasing the availability of packaging units is the introducing of central pool systems. In a *pool* unused packaging units are collected so they are immediately accessible when a supplier submits a release order. A sufficiently high incentive is necessary to ensure that empty packaging units are brought back to the pool as promptly as possible to curb lead times. An option for such incentives is a use-depending renting system. Enterprises typically hold a buffer inventory (increased stock) to prevent out-of-stock situation which ties a considerable amount of capital – particularly in the automobile industry with its various special cost-intensive packaging units (Buitenhek et al., 2002).

The current discussion on packaging management is dominated by contributions on the optimization of individual packaging units activities, technologies for the automated handling of the packaging units, questions for the standardization of a single packaging unit, as well as a discussion on the possibilities of employing RFID technology. The respective literature includes some noteworthy results:

The mentioned standardization efforts primarily address the *physical* design of packaging units, especially by aiming at the compatibility with packaging handling equipment (Wehking et al., 2006). In parallel, technical solutions are developed that allow for an improved handling of the packaging units at production work stations and that improve the physical interfaces between packaging units and trailers, floor conveyors and the like. Also new materials, such as light building materials, or new designs of special packaging units are studied as well as their effects on the transport process (Wehking, 2007). With respect to RFID technology, a relevant challenge is posed by the necessity to achieve a reading rate of nearly 100% - in a production environment. Some solutions have been developed and currently evaluated, e.g. by utilizing redundant transponders or by optimizing the positioning of the objects with respect to RFID readability. More business oriented studies have so far focussed on issues of shrinkage, the availability of packaging units, or on the accumulation of packaging unit inventory. It has been shown that a fundamental lack of transparency is prevalent in many enterprises and that they need to be tackled with a better IT-support. The tracking and tracing of packaging units, the recording of the packaging unit movements, the inventory control as well as a purposeful performance measurement system are of particular interest (Lange et al., 2007).

In the discussed case, RFID technology has been chosen as an identification technology by the logistics department due to the inherent possibilities of the technology to further automate data capturing in near-time and to thereby more directly link material and information flows (Wehking et al., 2006). The discussed processes are part of a closed system. This type of application RFID is widely discussed. The reuse especially increases the cost efficiency of the transponders (Peter Jones, 2005).

One of the most pressing issues in context with RFID technology is its cost efficiency. It has been repeatedly emphasized that a cost-benefit-analysis should go beyond the evaluation of the measuring events and take the distribution and usage of RFID data within into the IT-landscape of an enterprise should be considered (Baars et al., 2008).

So far, existing solutions only partly address the packaging management issues: Manufacturing execution systems (MES) provide some basic resource management functionality but are only focussing on *operational* issues and thereby lack the management support aspect. Advanced planning systems (APS), primarily cover the *planning* side of complex good movements but do not address the provision and analysis of actual data for immediate decision support. Sometimes, RFID middleware like the "Auto-ID Infrastructure" (*SAP-AII*) or Oracle *Fusion* is mentioned in the context of RFID, but those systems are primarily designed as data hubs between diverse enterprise systems and the readers (as well as associated "edgeware", e.g. the nofilis Crosstalk software, for basic data filtering tasks). The middleware at best provides rudimentary functions for the support of operational processes. (Bornhövd et al., 2004; Chawathe et al., 2004; Floerkemeier et al., 2005; Kim et al., 2005; Park et al., 2004). As none of those solutions is specifically geared at the packaging management, they do not provide comprehensive solutions to the discussed problems.

This contribution follows the design science paradigm (Hevner et al., 2004). Based on an evaluation of the business needs in the packaging management cycle, it derives a concept for a refinement of RFID based packaging data for a management support solution. The developed concept is further explored and fleshed out based on an explorative case that provides insights into the difficulties of the data integration and reveals levers for the development of a solution concept. The contribution particularly addresses the options of supporting packaging management with a Data Warehouse Architecture for data integration and processing. It concentrates on issues of data integration, tracking historical data, and data management that allows for flexible reports or analytical systems.

2.2 Business Intelligence and Data Warehousing

In principle, Business Intelligence denotes integrated approaches to management and decision support (Baars et al., 2008). The main pillar of BI infrastructures is formed by an integrated data pool pertinent for managerial support – the so-called Data Warehouse (DWH). According to Inmon, a DWH is a subject oriented, integrated, time-variant, non volatile data store (Inmon, 2005).

The data is accessed by a variety of different analytical systems. Most prominent are reporting, OLAP and Data Mining systems. Reporting systems allow for a preparation and presentation of the data from the DWH according to a pre-defined layout with limited degrees of freedom regarding the user navigation. Data Mining refers to algorithmic pattern recognition in large amounts of data (Han et al., 2006; Hand et al., 2001) while OLAP (Online Analytical Processing) systems enable the user to flexibly navigate in so called “multi-dimensionally” data structures. These data structures are built by a combination of key performance indicators ("facts"; e.g. sales volume, costs, number) that are described by various dimensions (e.g. customer, branch office, product). The dimensions are the basis for aggregation paths along defined “hierarchies” (e.g. branch office, postcode, country, region, world). Nowadays OLAP and reporting systems grow together as both are based on the same multidimensional data structures (Laudon, 2007; Thomsen, 2002).

A current trend in BI is the utilization of DWH infrastructures for operative and tactical decisions which in consequence leads to a storage of integrated data on the granularity of single transactions and the data provision in near time ("real time") (Nelson, 2004 ; Raden, 2003). These infrastructures are also used for the automation of decisions in so called "Active and real time data warehousing" (Hackathorn, 2002; Thalhammer et al., 2001).

BI systems based on real time and active DWHs are of particular interest in the realm of logistics, as logistics by definition spans across different locations – and in turn often systems – and thus presupposes some sort of near-time and integrated data storage.

3 METHODOLOGY AND CASE DESCRIPTION

The novelty of the combination of applying BI on top of an RFID-based packaging management made it necessary to address the subject qualitatively. To ensure rich insights and to justify the theoretical concept, the design of the case study was chosen. Data gathering and validation took place in the first half of the year 2008 and was conducted in several iterations.

The various activities were structured by the framework shown in Figure 1: The foundation of the research are insights into the various packaging management tasks (packaging planning, packaging disposition, further tasks) which support the identification and understanding of possible weak points of dealing with the tasks traditionally (business needs). By scrutinizing which weak points could and should be addressed with management support a set of analyzes scenarios can be derived that need to be supported by adequate data structures. The data structures are here organized as multidimensional data models (cubes). The cubes lead to the data sources – including RFID readers. The compound result determines the relevance of BI solutions.

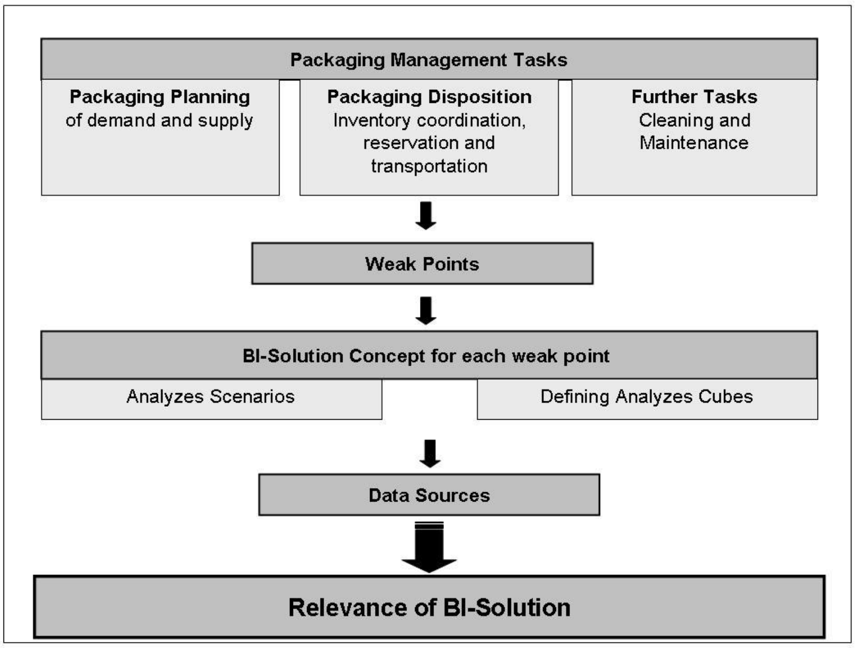

Figure 104: Applied instruments in the case study

Figure 2 illustrates the various applied instruments of the case study and their interplay. The case study based exploration is understood as a first significant cornerstone in the investigation of this topic that lays the foundation for upcoming quantitative and qualitative research activities.

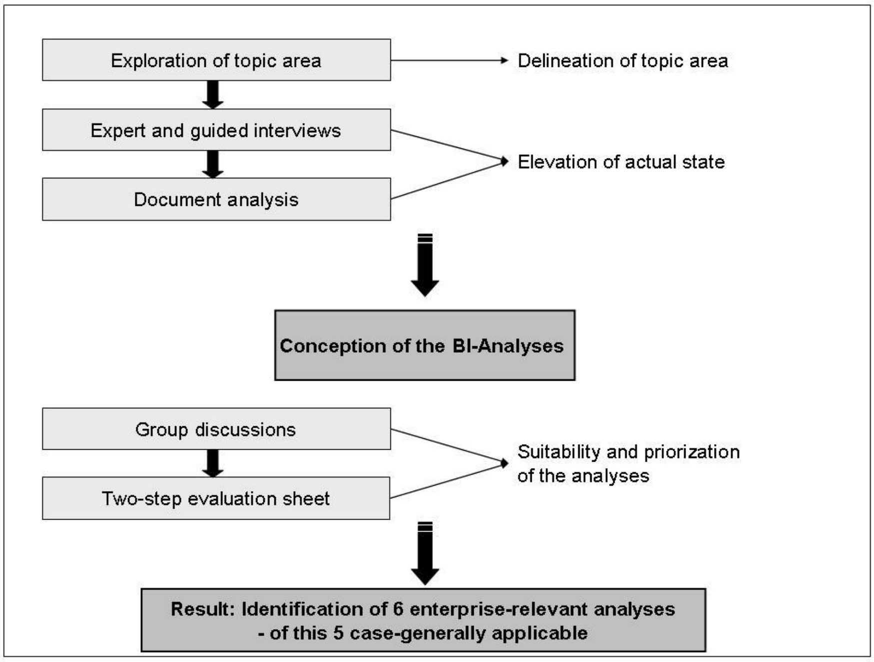

Figure 105: Methodology of the case study

In preliminary talks, two relevant process settings were identified and then discussed in-depths in five qualitative interviews of two hours each with representatives of the BI and logistics units of the concerning production department (expert and guided interview). In the interviews, the current situation and the relevance of RFID were elicited. This encompassed aspects of process structure, geographical distribution, partners, locations for RFID readers, key performance indicators and challenges. Based on the interview results and a parallel analyses of project and technical documentation, eleven OLAP- and Data Mining based analyses were derived. Afterwards, workshops were held for validation and substantiation of the results. This included the evaluation of suitability and a prioritisation with respect to economic potential. The profit estimation was carried out by the use of a two-step evaluation sheet. Altogether, the use of the proposed analytical applications is expected to have relevant positive effects on logistics performance.

Some groundwork for the case study had already been laid by the automotive company who followed an RFID strategy that was based on a careful and stepwise diffusion of the technology and the systematic application of pilot studies. In the course of this pursuit, packaging management had already been identified as an application area of utmost importance due to significant deficiencies of the current situation: The data of the package use cycle is kept in a variety of distributed applications. An existing catalogue of relevant challenges revealed a long list of striking weak-points of the established practices. The described research activities were the primarily information base for drafting OLAP and data-mining analyses.

Adhering to the packaging management literature, the package use cycle in the case study included a *central pool*. The packaging unit use cycle starts when the supplier sends the loaded packaging unit either to the supplier logistics centre or the production facility of the OEM (Original Equipment Manufacturer) to the just-in-time production. The *supplier logistics centre* is shared by several suppliers and is located on the factory premises of the OEM. Mostly, there is no real production in the supplier logistics centre but rather an assembly of the products to be delivered. At the supplier logistics centre, the goods are stored onto the packaging units and wait for a release order from production. After the production, the packaging units are transported to the central pool where they are sorted and stored. When requested, the empty packaging units are transported to the corresponding supplier and the cycle is closed (cf. figure 3).

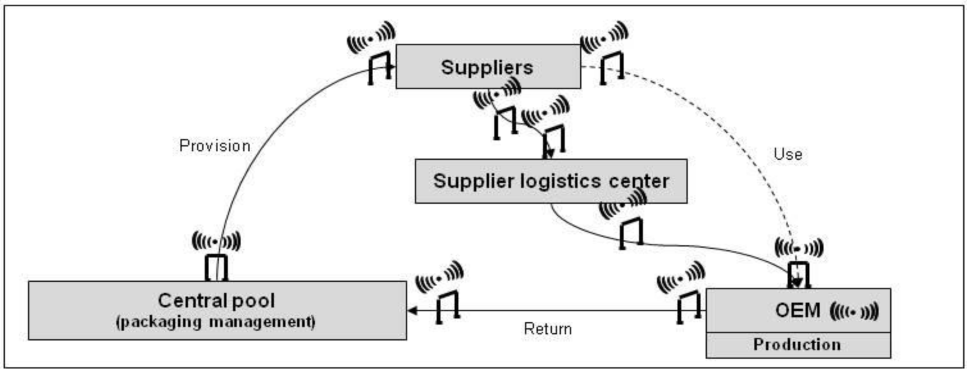

Figure 106: Packaging use cycle

Figure 3 also shows the planned RFID infrastructure with the reader locations. The readers gather data on the amount of crossing packaging units and the corresponding time stamps. In addition, a status "empty" "reserved", "full", or "in the transit" is carried on the RFID tags. The RFID readers are attached to gates which are to be installed at the entrances and exits of each process step. Furthermore, some packaging units will be traced during the transport with a GPS receiver.

4 ANALYSIS SCENARIOS

Each of the analyses introduced in the following section addresses one of the main weak points in the packaging management of the enterprise. For every analysis the required data sources (systems and fields) as well as corresponding data cubes were defined. The cube designs are conceived to be used later for the derivation of a data management concept that includes an integrated data model.

Weak point 1: An essential challenge in packaging management is the occurrence of bottleneck situations which arise when a material planner *does not reserve enough cargo space*. The supply of empty packaging units is currently carried out according to the push principle, i.e. based on forecast numbers which are derived from the master production schedule. The respective planning and transportation tasks for the packaging units are within the responsibilities of the material planner. The packaging unit transports to the supplier are arranged according to his plan. The suppliers have the option to reorder packaging units by themselves.

Solution 1: The material planner can be supported in his planning activities with an OLAP-Analysis that depicts the development of the available packaging units (physically available minus reserved packaging units) over time – differentiated by packaging unit type and in relation to the accumulated demand. The necessary cube for this is defined by the dimensions *supplier*, *packaging unit-type,* and *time*. Based on the historical OLAP-Analysis, trends can be recognized, e.g. seasonal developments. In the workshop it was additionally emphasized that comparable analyses can also be used for the capacity and resource planning of the pool centre (e.g. employee, storage area). Moreover, the described data can also be used to derive some interesting information on the production behaviour of the suppliers, e.g. on lot sizes. If the system provides near-time data, a possible bottleneck can be recognized early.

Weak point 2: Another shortcoming in the current practice is related to *identification of and sorting out faulty or dirty packaging units*. A prerequisite for a smooth packaging management is to ensure that the available packaging units are fit for use – and that means "*in a qualitatively faultless and clean condition*". Obvious, damages must be repaired by the responsible participant. Next to damages, there is wear over time, for example synthetic material abrasion. The even wear and tear is of importance because of the restricted use duration of the packaging units. With the launch of a new car model, the packaging units must also be renewed.

Solution 2: The probability that single packaging units are prematurely worn to the point they have to be sorted out can be curbed by keeping the degree of usage equal among the packaging units. A corresponding analysis can facilitate this task for the material planner, by showing him those packaging units that have so far completed the lowest number of cycles and that are to be reserved preferably. Besides, a maximum cycle number can be defined by the material planner, so packaging units can be channelled automatically to the quality control or cleaning in time. By coupling the cleaning process with the analysis, the cleaning process can be optimized also: Currently, all packaging units are cleaned use-independently week by week. It needs to be emphasized that this sort of analysis does not necessary involve data aggregation and would require an active DWH approach.

Weak point 3: The *shrinkage* of the packaging units supply is a significant and complex problem. A packaging unit consists of several components and is regarded to be available to plan and use only when it can be stored in the pool with all its parts. Bottleneck situations arise because packaging units do not finish a cycle or arrive incompletely. The shrinkage is currently only noticed only during the sorting process in the pool.

Solution 3: An OLAP-Analysis can help to pinpoint the root causes of missing parts with respect to amounts, location and time (that also constitute the cube dimensions). This does not only support the procurement of new packaging units but also the set up of measures to tackle identified problems.

Weak point 4: An *unintentional accumulation of stock* primarily happens in the supplier logistics centre. Although the centre is established on the premises of the OEM, the goods stored there are in the possession of the suppliers. The packaging units, however, which are bound to those goods are the property of the OEM. The OEM has by contract no right to specify the duration for the articles stored in the supplier centre park.

Solution 4: In this case, an OLAP-Analysis which calculates "suggestions" for the needed range of storage (an indicator that show for what production time period the articles stored in the supplier centre park will last). The dimensions "supplier", "article of a packaging unit-type", and the "time" can clarify which supplier bind what packaging unit-types for how long which helps optimizing packaging unit replenishment. The analysis can also be used to decline a packaging unit order if necessary. This way an unwanted built up of stock can be avoided.

Weak point 5: There is an overall *absence of transparency* in the PM with frequent bottlenecks despite an overstocking of packaging units. In the following a kind of control instrument for the supervision of the total performance of the packaging unit supply is introduced.

Solution 5: An OLAP-Analysis that shows the relation between available packaging units to the security of supply represents an indication for possible other causes of the stock accumulations, such as problems in order processing. The security of supply is defined to be the quotient of the delivered and the ordered packaging units. If packaging unit types are identified which show a sufficiently high inventory for planning purposes while at the same time a security of supply below 100%, there is a lack of supply despite a sufficient packaging units inventory. This reveals inefficiencies and their development over time.

The necessary *data sources* for the introduced five analyses are summarized in the following table. It becomes apparent that for all presented analyses data needs to be brought together from several heterogeneous systems. At present, the fields are not harmonized.

Analysis	Facts	Dimensions	Necessary data for the analyses	Data source: RFID-Data	Presetting (1)	ERP-System	Opera-tional Data (2)
Solution 1: Analysis of available packaging units over time	Physically available packaging units in relation to the accumulated demand	supplier, TP-Type, time	Packaging unit inventory in pool	x			
			Accumulated demand of the suppliers per packaging unit type				x
			Reserved packaging units				x
Solution 2: Analysis of even wear and tear over time	Number of package use cycles	Supplier, packaging unit type, time	Number of package use cycles per TP-Type	x			
			Inventory in packaging unit centre pool	x			
			Maximum number of package use cycles		x		
Solution 3: Analysis of shrinkage over time and identification of the 'Bermuda triangle'	Shrinkage	Place, packaging unit type, time	Inventory in packaging unit center pool	x			
			Inventory of packaging units in STP	x			
			Inventory of packaging units at supplier	x			
			packaging units in the production process	x			
			packaging units in transit	x			
			Delivery note, consignment note			x	
Solution 4: Analysis of inventory in the supplier logistics centre	Range of storage	packaging unit type/ article, time, supplier	Inventory of packaging units in supplier logistics centre	x			
			'suggestion' range of storage		x		
			Planned production demand			x	
Solution 5:	Inventory for		Demand of the supplier				x

Comparison of security of supply and free inventory	planning purposes in relation to security of supply	Inventory in packaging unit centre pool	x			
		Reserved packaging units in pool				x
	time, packaging unit type, supplier	Inventory of packaging units at supplier	x			
(1) defined by material planner (2) of several operational packaging unit systems STP – supplier logistics center, TP-tertiary packaging						

Table 34. Data Demand

5 CONCLUSIONS

The case shows the possible role of BI-Systems for the packaging management that however, presupposes an efficient, fast and precise acquisition of object data. By design, the case study comes with limitations regarding the completeness of collecting all possibly relevant factors and the degree to which the results can be generalized. It needs a larger number of cases to comprehensively grasp the impacts of other factors inherent in the system and organizational environment, e.g. regarding the degree of automation and complexity of manufacturing processes or the diffusion of complementary data integration infrastructures like service oriented architectures. Also, it needs to be observed how the situation evolves when the conceived RFID applications leave the piloting phase. However, as highlighted by the literature review, the problem of the packaging management appears in many industries (Hofmann et al., 2006).

In the case was decided to use RFID. In principle, the discussed analyses can also be based on other Auto-ID-Technologies (e.g. two-dimensional bar code) which, however, are known to subject to various restrictions in production environments (vulnerability to pollution, no possibility to carry additional data as utilized in the case etc.).

Conversely, functions for data integration, data historisation, and data aggregation are pivotal to realize the discussed solution. All analyses bind sources from two to four sources together, in four of the presented solutions it is necessary to access a collection of historical data and two cases require heavy data summation. Besides, open-ended analyses for uncovering patterns in shrinkage or supplier behaviour come with the need of some degrees of freedom and should be adequately supported, e.g. by data mining and/or OLAP tools. All this supports the case to apply BI infrastructures for those tasks. However, other systems or components which come under other labels might equally fulfil all or some of these tasks. Although this would not at all impact the technology-neutral concept, it needs to be considered, however, if it is wise to deviate from the trend to centralize monitoring and reporting functionality in a central DWH infrastructure and under guidance of a specialized BI team – with all advantages regarding economies of scale and scope and the potential to foster cross-departmental applications.

A relevant aspect that needs further scrutiny is a detailed specification of the architecture under consideration of real time and active DWH: RFID enables an undelayed provision of object data. It needs to be evaluated, in which cases it is economically justified to implement a real time and active DWH application. For the discussed case this would be an option for analysis 1 (inventory for planning purposes). By factoring in the development of the inventory situation over time, a potential bottleneck can be identified in near time with the possibility to automatically send out alerts or start counter actions e.g. alternative packing or a new prioritisation of suppliers. The combination of the analysis with automatic actions according to a so-called ECA scheme (event, condition, action) could be realized within the available data management environment of the active DWH.

A further string of research aims at the development of an integrated data management concept for production and logistics based on RFID at sensor data – that is not only limited to the described analyses but also includes requirements from other areas. A respective concept for data management would also allow for distributing the incurred fixed costs. In fact, scenarios with similar requirements can for example be found in monitoring machinery and transportation equipment, tracking components and products – including their assembly, steering and optimizing production flows (e.g. based on an RFID-based Kanban production), reverse logistics, or larger supply chain scenarios. This includes a widening of the scope to other technologies of the field of ubiquitous computing. Especially sensor networks will have an impact that is worthy to be explored early on.

Eventually, the presented explorative – and therefore preliminary – results should be validated and reflected in further studies in order to overcome the restrictions of the chosen research approach case study. For this purpose, further case studies and expert interviews as well as a quantitative study have already been prepared.

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