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WHITE PAPER

The Role of the Auto-ID enabled Product Information in a Product's Usage: A Maintenance Example

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ABSTRACT

This is the second white paper that investigates the role of product identity in a product's lifecycle. The preceding paper [Parlikad et al. 2003] examined how Auto-ID technologies can be used to obtain lifecycle information associated with a product and thus enhance end-of-life decision making. Here, the same model is applied to decisions made in the usage (middle-of-life, MOL) phase of products. The lack of unique product information often causes economic losses for companies. This paper examines, with maintenance as an example, how explicit product information on individual products can improve the management of the product-lifecycle. On one hand there are potential benefits of efficiency gains in the maintenance process itself, such as efficiency gains due to a higher data accuracy and less manual mistakes. On the other hand the collected data during maintenance can also improve future product lifecycles: quality improvements or simplified variant management becomes possible.

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Biographies

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WHITE PAPER

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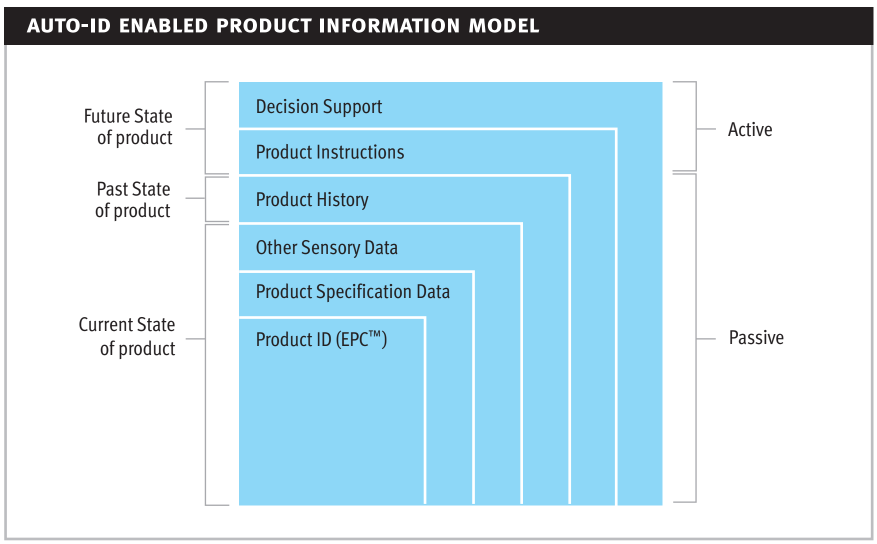
Contents

1. INTRODUCTION

Today there are trends which force companies to rethink their decision making in the lifecycle of their products such as the "Proposal for a Directive on Waste from Electrical and Electronic Equipment (WEEE). WEEE makes producers responsible to pay for taking back and recycling their own products by 2004. By now there are 6M tons of waste each year, a rate which is expected to double by 2010 [The Economist 2003]. Due to lack of infrastructure, excessive costs, and lack of necessary information, products are often not recovered at the end of life in an efficient and environmentally friendly manner [Parlikad et al. 2003]. This paper examines whether the same obstacles due to information in-transparency exist for Middle-of-Life (MOL)-processes as well, especially to maintenance, which is part of the usage phase (middle-of-life, MOL) [PROMISE 2003].

Figure 1 shows the Auto-ID enabled product information model. The model enables a comprehensive representation of the current and past states of a product and provides the capability to influence future states. With appropriate information infrastructure, this model forms the foundation for product information transparency throughout the whole product's lifecycle [Parlikad et al. 2003].

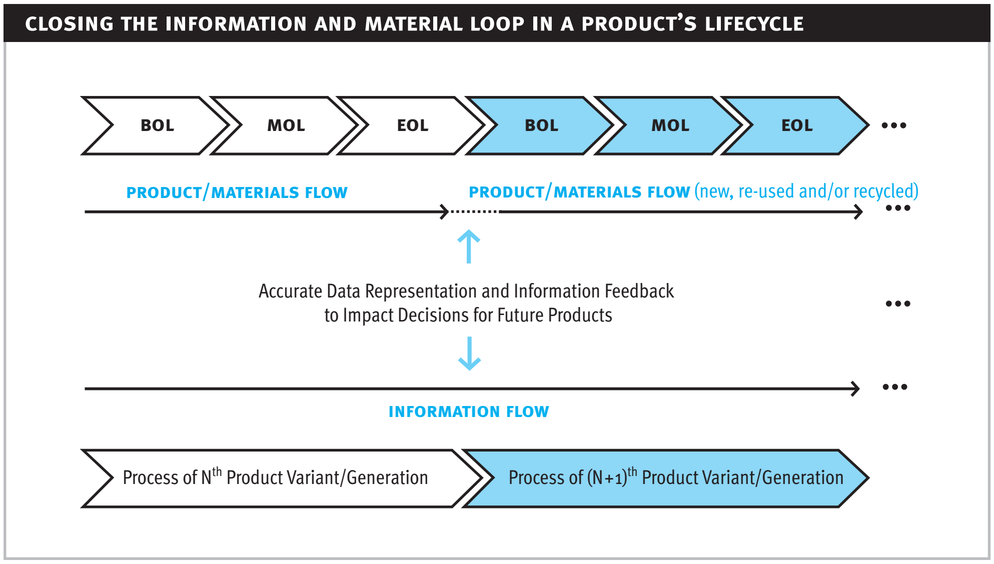
Figure 1: [Parlikad et al. 2003]



The aim of an Auto-ID enabled product lifecycle management (PLM) system is to integrate complete and transparent product information fully and automatically into existing IT-systems. Also, it shall be possible to decide automatically on further actions. Figure 2 shows how the vision could be integrated in a product's lifecycle. The Auto-ID enabled product information model is seen as the key enabler of the vision. Unique product identification enabled by the Electronic Product Code (EPC™) and the Product Markup Language (PML) allows storage of information associated with each product across all stages of the product lifecycle in a consistent and standardized way. Thus, the information flow along the product's lifecycle and the integration of experiences with current products into future products is secured. The Auto-ID enabled PLM system has to ensure that every trading partner is receiving the materials and product information, that he is interested in. For instance, the car manufacturer tracks the car history and knows which parts often need repairs and why so that he can improve the next parts generation. The Auto-ID technologies also ensure data accuracy and consistency between the real and the virtual world. The car manufacturer would know how many parts are exactly in the market so that he can plan an optimized spare part management. The material loop can be closed by using the information attached to products or product parts. The information could specify the responsible recycling company and hence contribute to an optimized reverse supply chain.

Figure 2:

BOL: Beginning-of-Life
MOL: Middle-of-Life
EOL: End-of-Life



The purpose of this paper is to evaluate the role of product identity in one process: at the example of maintenance in the product's middle of life. The examination of all MOL-processes is beyond the scope of this paper and subject to further research. However, the maintenance process must be seen as part of the vision shown in Figure 2.

The outline of this paper is as follows: chapter 2 concentrates on current economical trends and highlights the problems arising from these trends. Many of the described problems derive from missing information for producers or customers. For instance, cost deriving from product and system complexity gets reduced if the composition of a product is precisely known. The information requirements and potential benefits of Auto-ID will be examined in chapter 3 for the case of maintenance. Then, the authors investigate how the roadmap to Auto-ID enabled product information model in MOL might appear and provide some case studies in the area of maintenance. Finally, chapter 5 summarizes the findings and gives an outlook on further research.

2. PROBLEMS IN MOL

Many companies are coming under increasing pressure today due to trends in competition and markets, sustainability demands and regulations (chapter 2.1.). This pressure is directly related to the products offered by the companies. For each industry and partner of the value chain, there are different perceived problems (chapter 2.2.). They also depend on the MOL-activities. Sample activities are ([PROMISE 2003], [Zollikofer-Schwarz 1999]):

- Reclamations,
- Spare Part Management,
- Hotline/Enquiry Line,
- Training,
- Inspections,
- Preventive Maintenance,
- Repairs.

2.1. Trends

On one hand markets are changing from supply-dominated **markets** to demand-dominated ones. This forces companies to shorten their innovation and production cycles in order to fulfill their customers' demands. This leads to an increased number of product variants in the market, for which the producer has to provide after-sales services. On the other hand customers demand a longer product lifespan for certain products, especially for durable goods. This results in a number of problems. Particularly the producer has to keep all imaginable spare parts in stock. This alone is reason for huge cost blocks as storage costs or logistic costs [Schuh/Schwenk 2001].

Customers and legal regulations demand **sustainable products** today. The goal is to maximize value by minimal ecological damage. It is not sufficient anymore to close material loops to ensure the economic success of a product [Becker et al. 2002]. Hence, in order to achieve higher resource productivity, companies have started to formulate new product usage strategies such as re-usage and sharing of products, leasing, multiple usage, usage cascades, prolonging of the usage duration and the replacement of products by services.

The European Union issued a number of **regulations** related to end-of-life of products during the last few years such as the Directive on Waste Electrical and Electronic Equipment (WEEE) and the Directive of the Restriction of the use of certain hazardous materials in electrical and electronic equipment (RoHS). The previous paper [Parlikad et al. 2003] examined the potential benefits of Auto-ID technology with regard to the two directives. There are other regulations that demand traceability of products in order to comply mainly to security issues, as in the case of food traceability [European Parliament and Council 2002]. The regulations also protect producers: products without an EPC™ may be stolen or faked.

2.2. Impacts

One of the issues faced in the usage phase is to ensure the **customer's loyalty**. The challenge today is not "just" producing the right product at the right time for the right customer, but also to fulfill the users' requirements during the usage of each individual product. The customer has to be content with the product and the related services. Producers especially fear third party producers which also provide spare parts or after-sales-services.

Spare part management consists of problems in various fields such as supply chain management and inventory management for spare parts. The role of product identity for these processes is already examined in previous white papers such as [Strassner/Fleisch 2002], [Alexander et al. 2002].

One other problem is the high cost of **recalls**. The number of recalls has probably increased due to shorter innovation cycles. High cost can result if companies have to recall the whole product line instead of individual products [Strassner/Fleisch 2002]. Producers and customers suffer alike from insufficient individual product information.

Also related to product identity is the problem of **product liability**. Often insurances have no evidence why individual products caused a loss or damage. On the other hand it is difficult to receive context information about the environment such as temperature data in the cool chain of food, which lead to lost and damaged products.

Today producers have to provide **manufacturing solutions**, not just products and machines. The products and machines must guarantee a certain level of performance to avoid problems such as compensation demanded by customers for production losses caused by failure of manufacturing equipment. Also, the products and machines have to be re-configurable and recyclable in order to meet the challenges of mass customization and tighter environmental regulations [Lee 1998]. The knowledge and experience in maintenance and associated services is often a main differentiation feature amongst competitors [Hohwieler et al. 2001].

For the customer, Products and machines cause re-occurring **costs during maintenance** and support for the customer. For instance, in the mining industry in North America, the cost for maintenance is about 30 to 50 percent of the total cost of mining. The cost is composed of spare parts, personnel, supply and service providers. Hidden maintenance cost such as production losses due to downtime, cost for maintenance equipment, storage room for maintenance equipment and an increased maintenance workforce are not included in this figure [Lewis/Steinberg 2001]. The most expensive repairs are specialist works and special makings, which can just be done with special equipment, or has to be done with programming. The producer has to keep track of his maintenance equipment in order to have it available for emergency repairs of breakdowns. Other cost factors are the distance from the service center to the customers' site, the cost of material, maintenance and repair friendliness of the products or machines, and complexity of the disassembly process.

3. Maintenance & Potential Benefits of Auto-ID

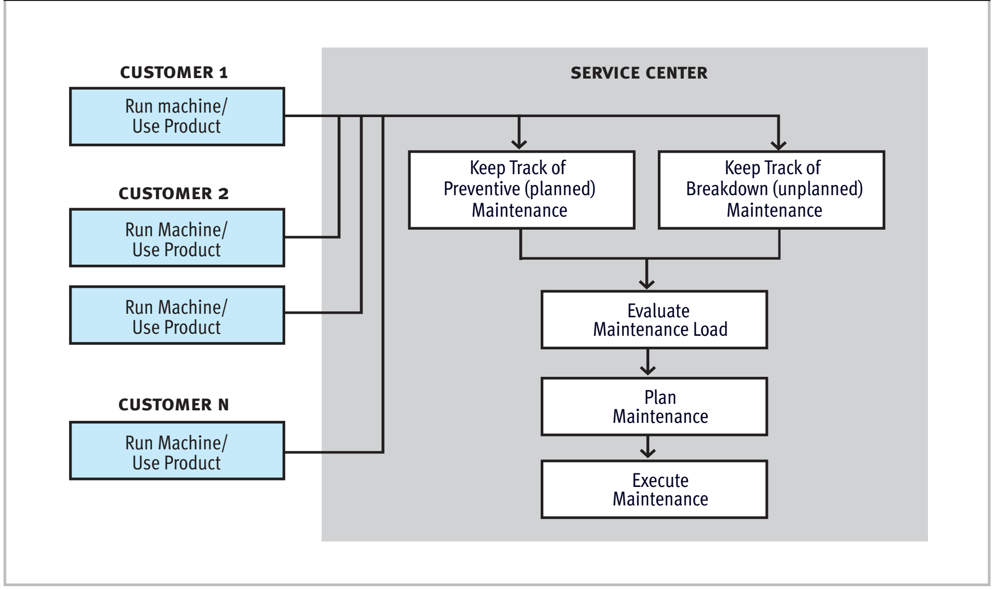
The focus of this chapter lies on maintenance-intensive products such as cars, elevators or production machines. The trading partners in the value chain are the producer of the product, and the customer/user of the product. Maintenance and repair can be carried out by the customer, the producer, or a service center (which can be run by the producer or a third party).

3.1. Process Description

A typical maintenance process is shown in Figure 3. Usually, companies prefer preventive maintenance to breakdown maintenance. Breakdown could result in serious tangible and intangibles such as operating expenses, penalty, decline of brand image, and future business opportunity losses. Unexpected breakdowns also result in a sharp rise of maintenance cost and reduce customer satisfaction. Preventive maintenance can be time or condition based. They usually involve rules of thumb concerning inspection and replacement cycles. Other approaches include the Taguchi methods, which take the average lifetime of a part into account [Yamashina/Otani 2001b]. Maintenance planning also determines the cost of maintenance for a manufacturer or the service center. It includes activities as work order planning, scheduling, dispatching and execution.

Figure 3: adapted from [Duffuaa et al. 2001]

SAMPLE MAINTENANCE PROCESS

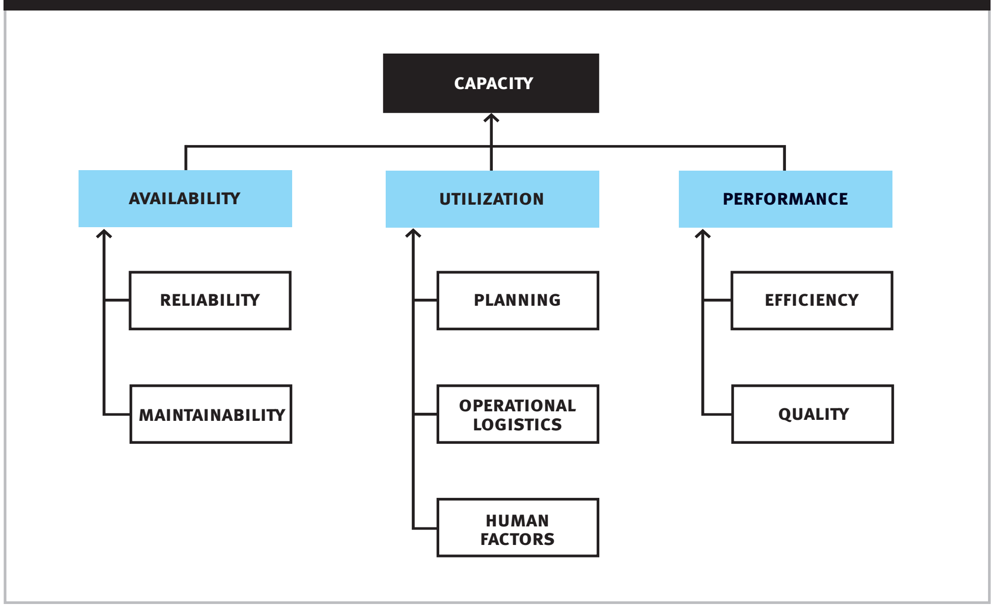


3.2. Process Goal and Requirements

The goal of the maintenance process is to maximize the capacity of products, as in plant engineering, construction, or car maintenance and repairs. Figure 4 shows the factors that contribute to the capacity of products ([Strub 2003], [Lewis/Steinberg 2001]).

Figure 4: [Lewis/Steinberg 2001]

MAINTENANCE AND REPAIR CRITERIA



To reach this goal economically, the customer and/or the service center must ensure that the maintenance resources are used efficiently. The resources are: manpower, materials and spare parts, tools and equipment, and standards and procedures. The requirement is thus [Duffuaa et al. 2001]:

– Optimal manpower needed for each trade,
– Effect priority levels on scheduling, and
– Effect of spare parts policies on down time.

3.3. Current Solutions

Current solutions include e-maintenance tools, which try to evaluate the current capability of machines and products without human intervention. Some of them also influence the machines automatically [Hohwieler et al. 2001].

There are several remote diagnostics techniques that collect data from customers' products and plants remotely. This information is used to perform remote machine monitoring and troubleshooting, and to provide service instructions for the service personnel. The e-maintenance systems assess the behavior and degrading level in order to prevent unexpected breakdown. In the case of a breakdown, the history of a component helps in a quick recovery of the machine. All collected information is shared with other user sites in order to transform the collected information into knowledge about the machine. Also, some tools provide multimedia based features for collaborative maintenance assistance, such as smart helmets or gloves [Lee 1998].

E-maintenance systems usually possess interfaces to other applications such as spare parts management or ERP systems [Hohwieler et al. 2001]. The interfaces connect the organizational unit, which is responsible for maintenance, with different functional areas, require specific information, and use different business information systems (BIS), cf. Table 1.

Table 1: Sample interfaces to business information systems (BIS) (adapted from [Strub 2003])

FUNCTIONAL AREA	MAINTENANCE SYSTEMS INFORMATION INPUT	MAINTENANCE SYSTEMS INFORMATION OUTPUT	BIS
Purchase	Notification of receipt of parts	Request purchase of parts	Procurement System
Human Resource	Hourly rate for maintenance personnel	Certifications, licenses earned by maintenance personnel	Human Resource System
Payroll		Hours worked by personnel	Human Resource System
Cost Accounting	Value of repair parts for maintenance costing	Cost of maintenance by product/machine part	Accounting System
Inventory	Availability of repair parts	Confirmation of parts consumed for repair	Inventory System
Warehouse	Warehouse transfer	Warehouse transfer	Warehouse Management System

3.4. Potential Benefits of Auto-ID

Unexpected breakdowns must be avoided in order to enhance the capability of products. At the same time, service centers are interested in increasing maintenance intervals and avoiding unplanned assignment of maintenance personnel due to failure. Preventive maintenance scheduling based on failure characteristics of individual parts, maintenance records, and real-time data about the depreciation state of individual parts are expected to result in the best efficiency gains [Yamashina/Otani 2001a], [Yamashina/Otani 2001b]. Today, often diagnostics is done by analyzing the error codes instead of analyzing the history of each product component. Table 2 shows how product information of the Auto-ID enabled product information model (cf. Figure 1) could enhance preventive maintenance scheduling and maintenance processes.

Table 2: Potential benefits with Auto-ID enabled product information

PRODUCT INFORMATION	ACTIVITY	POTENTIAL BENEFIT
Product ID	– Automatic part identification with RFID	– Less mistakes than in manually written maintenance reports; easy identification in dark and harsh environments (such as dusty warehouses)
Sensor Data	– Product state information collection such as operational, degree of depreciation or broken per part in real-time [1]	– Unexpected breakdowns can be minimized; inspection intervals can be maximized for “good” parts
Product Specification Data such as Configurations, Material, and Catenation as well as Product Related Data such as Planning Data, Logistics, etc.	– Automatic lookup and interface to spare parts and material availability and spare part management	– More efficient process due to process and data integration
Product History	– Automatic maintenance scheduling by checking maintenance equipment and tools availability	– Sounder decision making about priorities and working schedules and planning
	– Quality management	– Easier control of quality and shorter reaction times
	– Closing the information gap to customer relationship management e.g. by updating CRM systems when the customer has complaints and/or positive feedback	– Better understanding of customer requirements and reclamations and thus better ability to bind the customer
	– Closing the information gap to product design e.g. by informing design teams about frequent failures or special combination of product features in a product’s history which leads to failures.	– Better products and product variants for the next generation
Product Instructions and Decision Support	– Guided execution and documentation of maintenance	– Less errors, better documentation e.g. electronic instead of paper-based, given categories

1 [Green 2003]

4. TOWARDS MAINTENANCE WITH PRODUCT LIFECYCLE INFORMATION

This chapter describes a possible implementation path towards MOL management with product lifecycle information. The first three sections describe examples of companies that have already started to use individual product information in maintenance. They base on literature research. A brief description of the benefits resulting from the availability of product information associated with individual products is also provided. The final section looks at how Auto-ID enabled product information could be integrated into existing PLM-systems.

4.1. Example: Scheduled Maintenance and Security Checks at ExxonMobile Oil Refineries

Oil refineries, which must bring production to a standstill cost 1 million dollars a day. Reasons for a downtime can be tedious scheduled maintenance and safety checks. In order to address this problem, ExxonMobile uses RFID tags as a key to an asset tracking initiative for Equipment Health Monitoring and daily mechanical integrity inspections. With the RFID tags installed, operators make scheduled plant inspections to collect process and mechanical data about equipment using handheld computers. Additionally, low frequency RFID tags are used to ensure that operators properly perform procedures and provide verification that operators are at the correct piece of equipment while collecting data. Also, they have to identify the correct part for changing because spare parts such as valves look very similar. Once inspections are completed, the data is uploaded and synchronized with the plant's Computerized Maintenance Management system over a wireless network. Approximately 30 hand-held computers and thousands of RFID tags (134khz) are used.

Benefits are mainly seen in accuracy and control of the maintenance process: ExxonMobile recons, that it could achieve 40 percent more accuracy than on manual collection methods. The current state of the product helped to identify valves, and the maintenance time and down time could be reduced ([Construction Industry Institute 2000], [RFID News 2000]).

4.2. Example: Miele Washing Machines Management Pilot

The appliances company Miele and IBM Global Services developed the idea of the smart washing machine. The pilot demonstrated the advantages of a virtual washing machine pool control in an apartment house. The accommodation units often have to share common washing machines. The challenge is to optimize the machine's operating time. This includes scheduling of washing orders and immediate action on breakdown. Every washing machine is connected via the internet with the Miele service center. They possess an integrated firewall and are equipped with a GSM transmitter. The renters can book and change their washing times via Internet, via their mobile phone with a WAP browser, or via telephone. If required, the system sends a SMS with the actual status of the washing machine to the renter. Also, the machines perform a self-diagnosis. If maintenance is due or breakdowns occur, they are reported to the warden via SMS and the Miele Service Center by the system immediately. If the warden can perform the repair by himself he gets further instructions. Otherwise the closest Miele service technicians come and repair the washing machine, enter the time and material involved in a program on a laptop and send the reports to the Miele Service Center.

This model provides several benefits that are just possible because unique product information is available: Abnormal behavior can often be fixed in time so that breakdowns can be avoided. Also, service times can be reduced as the washing machine informs the Miele Service Center in advance about the error-state of parts. The efficiency is increased as parts replenishment and repair equipment is ordered automatically via internet. Thus, the supplier can send the needed parts directly to the location of the washing machine [IBM 2001].

4.3. Example: Fire Vents Maintenance SAP Pilot at Frankfurt Airport

Regulations in Germany force airport-operating companies to conduct regular fire vents maintenance. Fraport AG, the operator of Frankfurt Airport, set up a pilot with SAP from December 2002 to November 2003 in order to support the control and maintenance of fire vents at the airport in Frankfurt. The maintenance personnel has to maintain about 220,000 fire vents. Currently, technicians identify the vents by barcode, fill in a three-page paper based report manually. Then, they transfer the report information into the companies computer network at the end of the day. To enhance the efficiency and quality of the maintenance activities the technicians were equipped with handhelds, and RFID transponders were attached to sample fire vents. The RFID chips contain identity numbers and information related to the last inspection. The handheld displays the inspection route for the technicians, reads the RFID information at the fire vent, acts as reporting tool and transfers the collected maintenance information at the end of the day to the central computer systems.

The benefits of increased efficiency and data accuracy was already seen in the pilot implementation. The pilot currently investigates further process improvements that could be provided by this technology [Quack 2003].

4.4. PLM Systems and Auto-ID Enabled Product Information

Before integrating Auto-ID data into existing PLM systems, companies must first analyze the level that they already support . The levels are product description, current state, past state of the product, and future state of the product.

Existing solutions such as the three examined case studies already implement part of the product information model. Companies should start with the implementation of applications that provide quick wins such as ExxonMobile and SAP. did. For further expansion, the solutions should comply to the necessary standards.

The management of maintenance activities is often integrated into Product Lifecycle Management (PLM) tools, although they are not necessarily called that. PLM tools consist of many modules and it is common practice to implement the modules incrementally. The two main reasons for using PLM tools are process integration and data integration. Therefore, they usually consist of a workflow and a data integration component. The data integration module - product data management (PDM), is highly industry specific: In the heavy equipment industry, the core customer values are reliability and longevity of products and therefore provide mainly functions such as configuration management and spare time management. In the pharmaceutical industry, the core customer value is trust so that PDM tools deal with patents, trials and compliance [Burkett et al. 2002]. Moreover, the tools are also product specific: Computer Aided Design (CAD) applications and simulation tools and their contents highly depend on the kind of developed product [Lindemann et al. 2000].

Companies have to start implementing PLM modules incrementally, although they have to ensure that they deal with complete product information, provided by the Auto-ID enabled product information model. Existing product lifecycle systems often implement parts of the product lifecycle information, but not the complete picture [Parlikad et al. 2003].

The company must also regard the interfaces of the PLM tools and other business information (BIS) systems. In the short term the interfaces contribute to the cost of Auto-ID enabled PLM systems but in the long term they enable a seamless integration of the business information systems.

5. CONCLUSION

This paper shows how Auto-ID enabled product information contributes to higher information transparency in maintenance. This enables the ability for more profound decisions in a product's lifecycle and thus an increase in benefits for both the customer and the maintenance service center. For maintenance, this information transparency results in the following business benefits:

– The ability to identify products and product components uniquely and automatically increases the efficiency of the maintenance process and increases data accuracy due to less manual mistakes,
– Maintenance information is updated in the producer's systems automatically and can be used for an enhanced maintenance planning and for further product generations,
– Standardized product data with Auto-ID technologies increase process efficiencies.

These results can be achieved by (a) providing data accuracy along a product's lifecycle and (b) making the data available throughout the product's lifecycle and future product variants and generations. These two steps allow companies to have access to product data about its current state, about its product history and to influence future decisions. The information is collected for each individual product. This enables the company to perform maintenance with the above summarized benefits: for instance, the technician will have accurate and real-time information about the operation state of a product/machine in order to act in the most efficient way upon it.

It is expected that the concept of product identity also imposes potential benefits in other MOL activities. The Auto-ID enabled product information model structures unique product information data e.g. about reclamations, spare parts, user inquiries, etc. in a standardized way. It could even influence the whole product's lifecycle and result in the adjustments in the processes result in the following potential business benefits:

– Shorter time to market,
– Improvement of quality,
– Simplified variant management,
– Reduction of product cost.

This is done by representing real world actions accurately into the company's virtual data representation and adjusting business information systems in order to deal with the data. So far product lifecycle management concentrates on (a) standardization of product information throughout the products' lifecycle and (b) distribution of product relevant information through business applications such as Supply Chain Management (SCM) or Enterprise Resource Planning (ERP). The Auto-ID enabled product information model uses in addition the Auto-ID infrastructure which represents each product uniquely with the Electronic Product Code (EPC™) and uses ubiquitous computing technologies such as RFID in order to provide product information in real-time and accurately.

This paper and the proceeding paper ([Parlikad et al. 2003]) examined the role of product identity in the end-of-life of a product and for one process in the middle-of-life of a product. Both give a high level overview of the current information gaps in a product's lifecycle and how they can be closed with the Auto-ID enabled product information model. Further research should provide more detailed studies both in EOL and MOL in order to effectively prove the case for product information enabled information systems. The research should also involve the early stages of a product, from product planning to product launch, and examine how the role of product identity influences decisions along the whole product lifecycle.

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