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Establishing A Process to Enable Improved Product Life Cycle Management

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Metropolia

At this moment. Writing this text feels rewarding. The long journey of this program is almost over, and it is time to look back. All started from the willing to understand better why businesses runs as they run and to learn more how to provide better sustainable product services to customers. There were remarkable stages on this journey where I learnt a lot about service business and industrial management. There was a doubt that do I manage to meet the goal of this journey. Now, I would say warm words to following people, which make this journey possible:

The colleagues at work. These people offered me the time and their support, although there was sometimes limited time for discussions. This thesis would not be the same without our debates at work. I thank the colleagues which offered their opinions for the thesis and special thanks Project Manager and Controller to their guidance in proposal building stage.

The professors and visitors in the Metropolia University of Applied Sciences. Special thanks to Zinaida Grabovskaia, PhL Head of IM&LOG Master's Programs, for her support and strength to guide us through our studies. Thanks to my Thesis instructor Dr. Thomas Rohweder for his lessons and support to build this report. I thank all the others which make this possible.

The classmates. I am thankful for get known these people. They make the atmosphere into the classroom where it was fun to learn things together. These people were professionals, and I learnt from them, too.

I would also thank my family. They understood my priorities in this journey. Special thanks to my partner, Ira Karlström, for her support. She made this possible by running the daily actions at home, when I was studying and working long hours. Her valuable comments led text to the right direction when I was struggling with the report and needing her presence.

This journey is almost ended and now it is time to look ahead. New challenges are waiting, but… It is time to enjoy this achievement.

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This thesis focuses on establishing the product life cycle management process at the case company. The objective is to create immediate and transparent product identification and traceability for a manufacture company of power supplies. The study discusses the topic from a perspective of after-sales services.

The study based on the action research methodology, which has similar study methods as a case study methodology. The action research notifies the influence of company business and individual aspects to the topic, where biases of the interviewees and author himself was reduced interviewing several stakeholders of the case company during CSA and proposal stages.

This study revealed challenges of the product management. The product information is not supporting the product life cycle assessment or product structure identification in a product maintenance process; therefore, product data management is investigated over products life cycle process and business process. The result of this study indicates the meaning of good process design, where once created process data can be directly utilized in other processes to achieve cost efficiency in products life cycle.

The PDM / PLM process is described for the case company. It is recommended to develop product life cycle management on the business processes. The company is operating in the business area, where product information is well instructed by regulations and standards. The outcome of this study provides an order of subprocesses in perspective of product life cycle. It defines parameters and tools to the product traceability in a customer service and product maintenance in cases of product crisis. A knowledge about the employees' responsibility in product traceability process is worth to increase throughout the company processes, where this study can be used as reference.

Keywords	Product traceability, Product management, Product life cycle

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Acronyms

BPM	Business Process Management
CPU	Central Processing Unit
CSA	Current State Analysis
EOL	End-Of-Life
ERP	Enterprise Resource Planning
PDM	Product Data Management
PLCC	Product Life Cycle Costing
PLM	Product Life Cycle Management
PVA	Product Value Analysis
QFD	Quality Function Deployement
R&D	Research and Development
SME	Small and Medium Sized Enterprise
TCA	Thematic Content Analysis

1 Introduction

One of the objectives of product manufacturers is to create a product which fulfils the customer expectations. These expectations are achieved through co-operation with the customers, when new product sales, deliveries, technical support or maintenance services are needed. Compared to traditional organizational-oriented processes, a customer-centric strategy directs the company vision more to customer services.

A product management system helps companies maintain their products until the products' end of life. Product traceability is in a significant role in after-sales services, where the company maintains product's installed base and creates value for customers through such service attributes as a technical support and product warranty. The industry sector sets also certain requirements for the companies depending on the role definitions of the companies.

This thesis focuses on product management in a power supply manufacturer. The study discusses product life-cycle management within company operations. It is vital to understand that the industry sector, where the company operates, has requirements for product traceability at every organizational level from components to final products.

1.1 Business Context

The power electronic industry has moved to countries, where manufacturing costs are low and the production is near the markets. A Finnish power supply manufacturer has outsourced manufacturing and a part of the maintenance services, but has product development projects, where the purchased material is processed forward to final products and maintained until the outsourcing processes.

Product traceability is required by the Finnish legislation and EU, European Union, directive, and therefore the company must prove its ability to trace the products delivered to customers and to suppliers. In addition to the general product manufacture, product co-development with the customer challenges the product life-cycle processes. For instance, this is seen in product sample batches, which are dispatched to customers in connection with product development projects.

1.2 Business Challenge, Objective and Outcome

The current product management process enables individual product deliveries to be followed-up only on a serial number basis, but not in terms of specific product version. This results in major product life-cycle management problems in company's Maintenance Service Unit in cases of service requests from customers, returned products. This is because Product Life Cycle Management does not have a formal / well-established good way to act at the case company. The challenge is magnified by the fact that the company is strategically moving into a business area, where product version transparency becomes even more important.

The objective of this thesis is to establish the product life cycle management process and to enable access to immediate and transparent product version traceability information.

Accordingly, the outcome is a partially improved product data management process for the case company.

1.3 Thesis Outline

The scope of this thesis focuses on the stakeholders' touchpoints and product traceability throughout the product life cycle, where the case company has a role in the actions. This study excludes outsourced processes provided by other companies, which work independently.

The study is conducted by interviewing the inner stakeholders and investigating the information in the databases such as a product database and an enterprise resource planning database. The case study supports the conceptual framework research after the current state analysis has determined the product management system's strength and weaknesses. The thesis outcome in this sense is an established product life cycle management process in the company operations.

The maintenance service team receives service requests. Customer services - technical support, claims and repairs - deal with the data which is created in earlier processes in a product life-cycle. Customers expect fast actions when solving technical problems on-

site or even the product repairs in a repair center. Time-consuming data-mining processes cause delays and inefficiency in the maintenance services. Even though the objective is in the maintenance services, the thesis outcome provides a more informative tool and/or a procedure for tracking case company's installed products.

The introduction is written in section 1. The method and material are presented in section 2, while the section 3 provides an analysis of the current state of the product management system. Best practices are studied in section 4 based on the challenges identified in the current state analysis (CSA). The results of the CSA and Literature are used to improve product management process in Section 5, where stakeholder feedback is collected for a final action plan in section 6. Conclusions of this thesis are discussed in section 7.

2 Method and Material

This section describes research approach, introduces the research plan and data collection method for the study, which are used in analysis.

2.1 Research Approach

The thesis approaches the topic through interviews and investigating available information. Yin (2009, p. 8) defines the case study methodology through questions: what? why? how? These questions are important in this research, and this thesis answers to the technical definitions of case studies (Yin, 2009, p. 18).

In this study, an action research methodology is chosen because of the nature of the thesis outcome. Blichfeldt & Andersen (2006, p. 4, 7) discuss similarities and differences between the case study and action research methodology. They define the case study under both research methodologies, but this thesis point of view has a difference, which agrees with action research. That is business. The economical and human resources at the case company affects to the final solutions.

This research utilizes the case study methodology for investigating stakeholders' data sharing and personal knowledge, but the objective is to answer the research questions and fulfils the practical need instead of the attempt to create universal knowledge. The final proposal of the action research can be the best practice in the individual case based on the knowledge and resources (Kaplan, 1998, p. 94)

2.2 Research Design

This research design follows the action research methodology. The action research bases on the process development, where innovative practices are discovered and articles and books are written before management and organizational phenomena (Kaplan, 1998, p. 98). This thesis discusses the ideas through case study. Yin's suggestion for the first step was a literature review and posing of research questions or objectives (Yin, 2009, 3). The research stages are introduced in Figure 1.

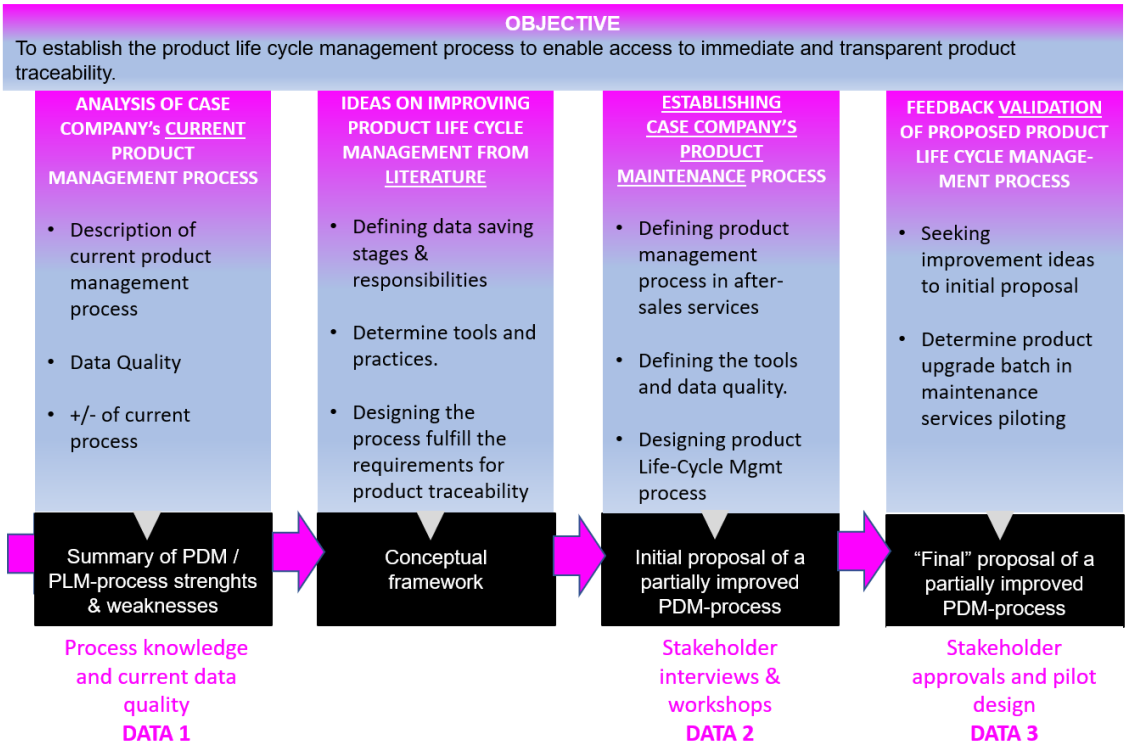

Figure 1. Project Design.

As seen in Figure 1, this study uses the objectives as a starting point. Data 1 consists of the questions about the topic in general and the data-mining process, data 2 deeper knowledge with recognized challenges after the literature review, and data 3 the agreement for the proposal for the action plan. The logic consists of four steps, which have their own particular outcomes.

First, the objective of this study is described in processes where an execution of product management is playing a part. The objective is to enable access to immediate and transparent product traceability which is announced to the stakeholders' representatives.

Second, a current state analysis is executed by interviewing the stakeholders and investigating the product management system with the help of the company tools. The stakeholder's wishes and requests are investigated, and how they are executed in the case company. The CSA reveals the stakeholder's expectations for improved product management system. These expectations are taken into account in suggestions of improved product management processes.

Third, best practices are researched from the literature. Data collection of the analysis of the current state, company tools and requirements, which the case company meets in its business area. These are studied with the general knowledge. This research stage creates the conceptual framework as output for the process development stages.

Fourth, an initial proposal is built for the improved product management process, where recommendations for improved product traceability is introduced to the inner stakeholders, employees in operations. The workshop approach with interviews and notes in test database creates the feedback, data 2.

Finally, the final proposal is introduced to the executives in the company. It includes corrections and additions agreed with the inner stakeholders' feedback.

2.3 Data Collection and Analysis

Product data in this study is a collection of the case company's own process data related to the Product Life Cycle Management (PLM) process. Maintain the products before their End-Of-Life (EOL) may include product upgrades to the newer product structure or module replacement to another individually traceable product. The product maintenance service unit collects customer feedback and product quality data.

This study draws from a variety of data sources. First of all, the interviews are conducted and people's personal opinions are collected during this study. Secondly, the product management and product traceability tools are studied and data quality evaluated based on the received information.

The interviewees represent sales, quality, logistics and product development departments. The author of this study is a representative of the product maintenance services. These people are interviewed face-to-face or by questionnaire as shown in Table 1.

Table 1. Details of interviews, workshops and discussions, in Data1-3.

	Participants / role	Data type	Topic, description	Date, length	Documented as
	Data 1, for the Current state analysis (Section 3 or 4)				
1	Respondent 1: Vice President, Sales Manager	Face to face Interview	Sales items and product traceability	Jan 2018, 1 hours	Field notes and recording
2	Respondent 2: Buyer	Questionnaire	A use of item codes in purchase and inventory processes.	2 pages	Field notes
3	Respondent 3: Technician	Face-to-face Interview	Product Manufacture and inventory	Jan 2018, 45 min	Field notes and recording
4	Respondent 4: Logistics Coordinator	Questionnaire	Product Deliveries and Inventory	2 pages	Field notes
5	Respondent 5: R&D Project Manager	Face to face Interview	Product Structure and Product Upgrades	Feb 2018, 1 hours	Field notes and recording
6	Respondent 5: Quality Manager	Face to face Interview	Process quality and product claims	Feb 2018, 1 hours	Field notes and recording
	Data 2, for Proposal building (Section 5)				
7	Participants 4-5: --	Workshop/ discussions	Proposal building	May 2018, 2 hours	Field notes
	Data 3, from Validation (Section 6)				
8	Respondent 2: Respondent 3 Respondent 5:	Group interview/ Final presentation	Validation, evaluation of the Proposal	May 2018, 2 hours	Field notes

As seen in Table 1, data for this project was collected in three rounds. The first round was conducted for the current state analysis. The challenge of this study is located inside the case company, and its product management process, and thus the first step is to improve the in-house processes before outsourced processes such as product manufacture and maintenance services.

The narrow scope of the study limits the workshop participants / second interview round to the case company premises. The interviews and/or workshop is easily organized and

conducted alongside daily work. Data 2 is a collection of the interviews and minutes of the meetings based on the data mining demos in the product management system.

The final feedback was collected from the management team for the final action plan. The process managers' feedback was used for priorities of improvements for the product management processes.

The CSA includes also the investigation of the product management processes. Found documentation is introduced in Table 2. The documentation is analysed using Thematic / Content Analysis (TCA) (Anderson 2007). The internal documentation such as procedure instructions, Excel spreadsheets, Enterprise Resource Planning System, Product Structure Database are in data mining processes.

Table 2. Internal documents used in the current state analysis, Data 1.

	Name of the document	**Number of pages/other content**	**Description**
A	Case Company's ERP	Since year 2006	Operational Processes, Sourcing
B	Monthly Report, Maintenance Services	1 diagrams	Diagram for case company's product maintenance services.
C	Product Structure Database	Since year 2014	Product Structures. Component items
D	Procedure Instructions		Work instructions in data-saving processes

As seen in Table 2, this study analysed the product management documentation. Examining documents gives a holistic picture of where and how the product management topics are stored. Other documentation can be revealed by the interviews, which is studied alongside Table 2 documentation. The following questions of data saving process is recommended to keep in mind: Do the processes use the same information or create their own trace in the product management system? Do the processes communicate with each other? These questions are discussed in Section 3 to establish the current state of the product management processes.

3 Current State Analysis of Product Management Process

This section discusses the CSA of the current product management process at the case company. The CSA focuses on both employee's personal knowledge about the product management systems and data-mining process based on the given information.

3.1 Question formulation

The CSA strives to collect the knowledge regarding the product management process. Process knowledge was seen as an important topic for the first interview round, and therefore all department were heard how they understand the product management and traceability.

A questionnaire avoiding leading questions was designed, so that employees can answer by their own words and according to their knowledge. The interviewees represent different section in a product life cycle and company processes. The interviewees had knowledge on being part of the product management process, product traceability and Product Life-cycle Management (PLM). This helps a workshop approach when the process development starts.

The questionnaire template can be found in Appendix 1. The results are discussed in a subsection 3.2 'The Product Management Process'. The interview focused first on the tools such as databases and people were asked about the use of these tools. The final topic in this interview round was the wishes and observations of the interviewees regarding the development targets. The interview revealed three databases. The product management in the case company has spread to separately working databases or even the employee's personal files.

Since these tools and procedure instructions were not mentioned in the questionnaires, the interviewees defined their own tools and practices. Similar answers reveal the common defined processes and inconsistent answers reveal needs for describing the process.

3.2 Current product management processes

The interviews were conducted as face-to-face meetings or sending out the questionnaires in electrical form. The employees had a chance to decide what method was suitable for them.

3.2.1 Process knowledge

The interviews showed that there are no common processes working together. Departments have their own procedures. The logistics and sales departments feel that product management belongs to the Product Development Department (R&D), not them, and that for them it is not necessary to know more than product type and the serial number. The R&D department and buyer found difficulties to handle the product structures in deliveries and purchase, because they work with prototype products, i.e. unfinished product structures. They still had the best understanding how the product management process works and how the product structures are designed, because the product traceability under the project deliveries are based on the product structures in product design stage and created by them. Customer services use several datamining sources for collecting all information for returning products, where quality processes are creating statistics only for the product type level, not the product version level where the product structures are identified.

The company focuses on the product development projects. The product management process is only about creating product structures, not the PLM process. The company's core competence is product designing and the product management process has been developed from that perspective. PLM in maintenance services has been handled case-by-case by the service team, which were also interviewed in this CSA.

Product traceability is built on serial numbers and the dates. The serial number defines the individuality, and the delivery date defines the product structure which is dispatched to a customer. The sales team is always selling the newest product version. Product spare parts and replacements units are the newest product structures from the product manufacture. The purchase orders to the module and product suppliers are the newest product structure at the time of the purchase. The product designers see that the product has to be updated when the earlier delivery has been done within the project sales. The

quality team, on the other hand, is recommending to use only the repairs for earlier product structures due to expensive update procedures.

3.2.2 Working methods and responsibilities

The working methods are also unique within the departments. The responsibilities are shared between everyone. The procedure instructions have been discussed inside the department case-by-case within the project deliveries and process quality notifications, but the problem is these instructions are not strictly followed.

The differing working methods stem from different responsibilities. The responsibilities are divided to all employees who have access to the product management tools. When there is missing information, the procedure instruction is to ask for help from the responsible party – contacting people of the partnership companies or the responsible product designer. Sometimes the project manager, who is an administrator of the product data management database, adds and refines the product information on behalf of the product designers.

Employees have created their own Excel spreadsheets for product management and traceability. These spreadsheets support their own job where the information is up-to-date, where databases have been left outside or are in a minor role in the product management process. The files are fulfilling the needed information which is removed/not in use in their database tool.

3.3 Data-mining process and data quality

A current process description was studied as a data-mining exercise, where all findings were checked and confirmed with the tools mentioned by the interviewees. The product management process has mainly three different tools: The Product Data Management Database (PDM), Enterprise Resource Planning database (ERP), and Network drives. Available information from these data sources has been investigated in following subsections. Product types and user information are concealed in the name of business security. The recognizable item codes have been replaced with general text ‘ITEM’ and ‘ITEM MOD’ to represent the product and spare part modules respectively.

3.3.1 Product Data Management Database

The electrical product data management system (PDM) is the core of product management. Product items, documentation and work instructions have been collected to this database, where the information is available for everyone.

The PDM system opens the product structures and defines the product versions in all levels of product structures. It links the items to each other, and therefore the product structures are traceable from module to the final product. The product structure is created from the item codes in a product structure feature. It is also mentioned in the item's description fields, and the product structure is empty. The item status indicates when the item is created, checked, accepted and not-in-use.

One of the three search parameters for determining the product structure is the items' creation date. Firstly, several interviewees answered that this date links the products and the product structures together. Secondly, the service engineer found that the product structure can be a product structure published in the supplier-site, not the newest created structure at the delivery time. Thirdly, products are updated before project deliveries. Finally, the prototypes may not have the product structure in the database, when they have dispatch as a sample to the customer. The product structure data is created afterwards.

The company delivers two types of products. i.e. Battery Charger Systems and power supply modules such as converters, chargers, controllers etc. The system's product structure is presented in Figure 2, where the product structures are separate items linked to each other.

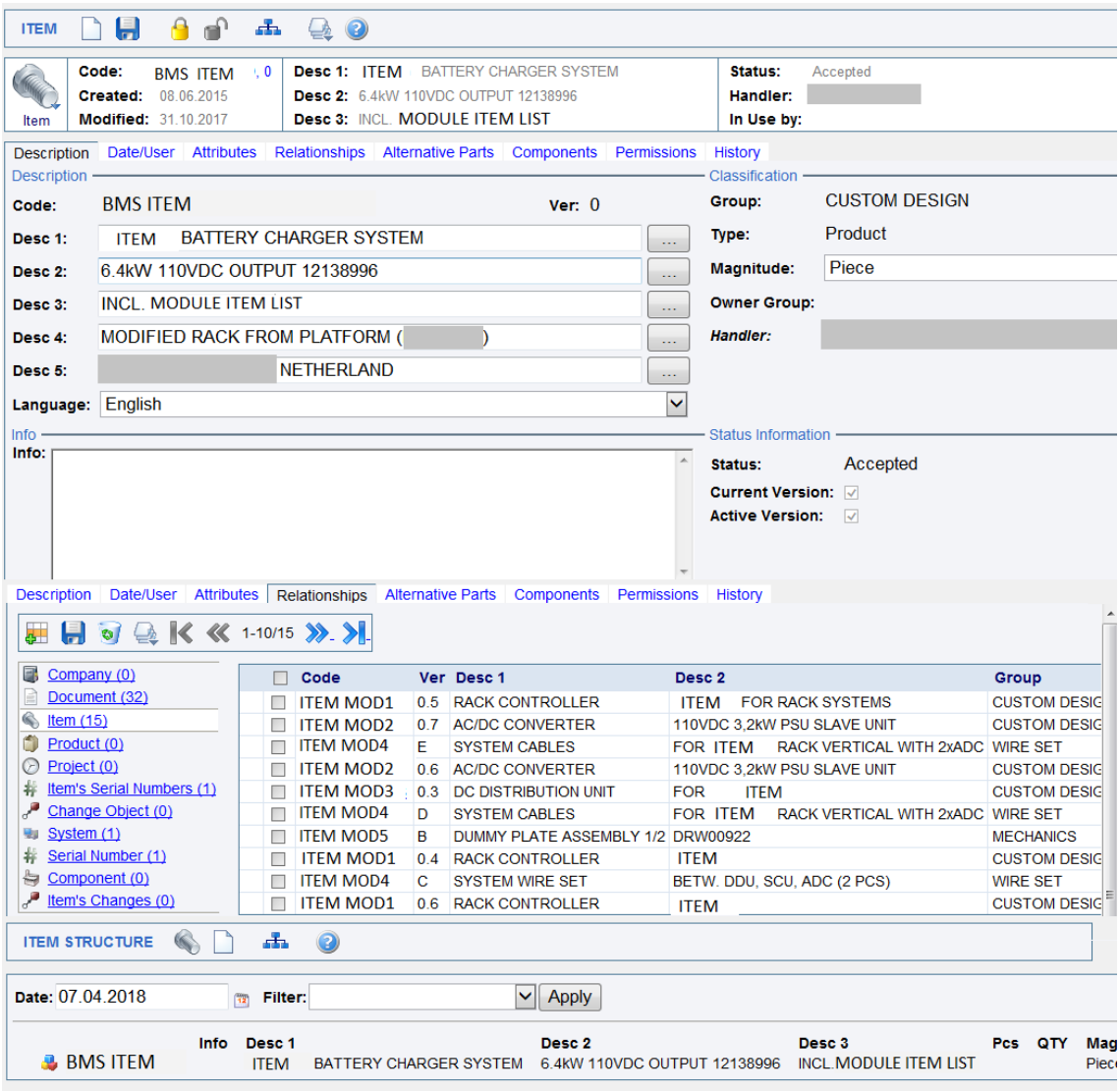

Figure 2. System product structure.

As seen in figure 2, the Battery Charger System has a module information in a third description field (Desc 3) and relationships under Item, where the list includes 15 items with version different version information. It mentions all accepted module devices in the items, not the exact product structure. The product structure tree is not in use for system products as seen in the bottom side in figure 2 – the character '+' in front of the item code indicates that there is a substructure under it, which is missing from this item code. The system product structure is defined as Version 0, which does not change according to the module versions in relationships.

A reference date for the product management process is found on the main tab, the upper section of figure 2. The product structures are following the creation date in the

PDM system compared to the product delivery dates in the ERP system, which is discussed in the next section 3.3.2.

The power supply modules have a different way for product data management. The sample item represents a product version 0.7, which is an accepted product structure. This product can be recognized without questions.

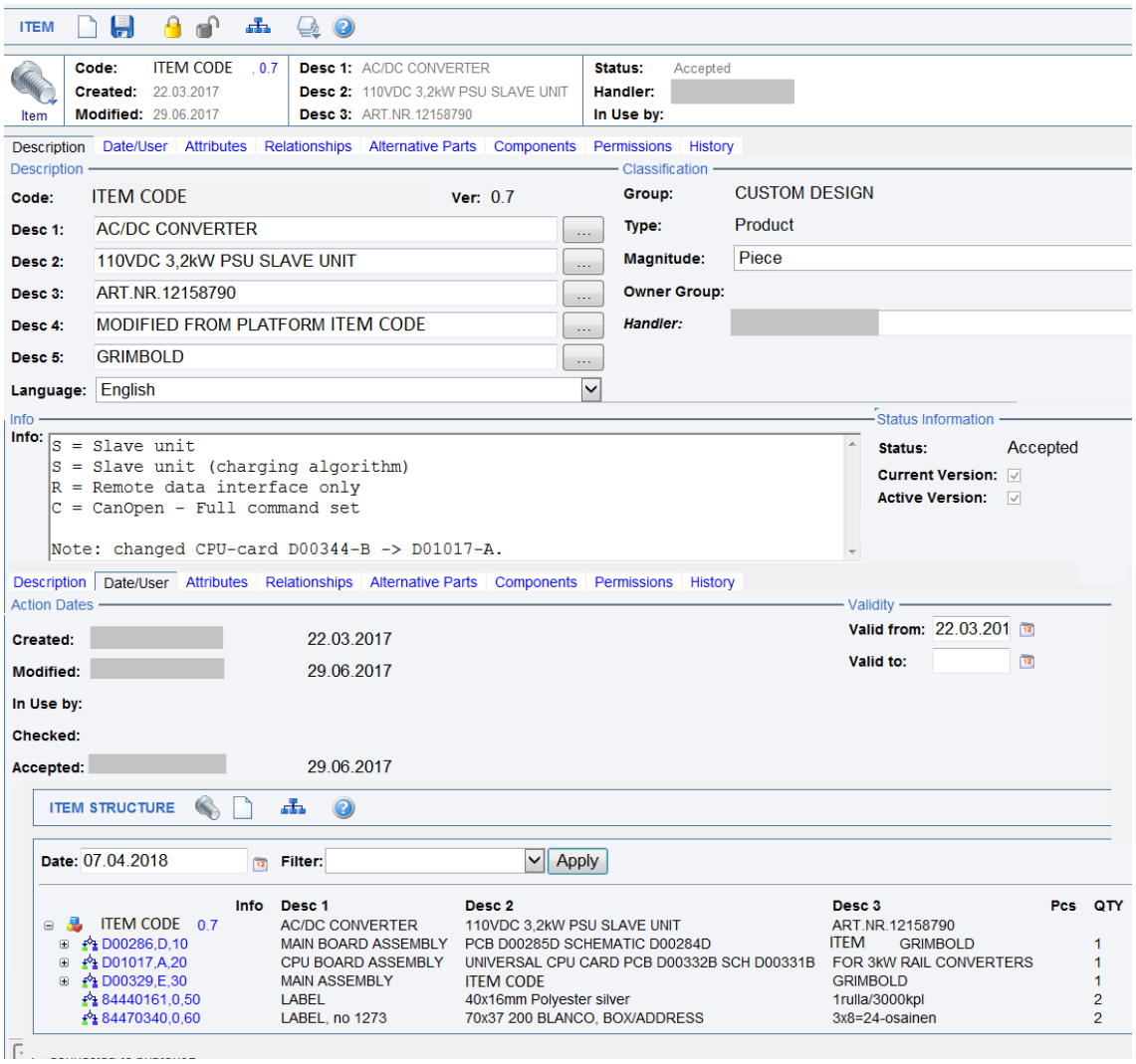

Figure 3. Power supply structure.

As seen in figure 3, the converter module has the product structure tree in use. The text field Desc 3 has other information compared to the system product items. The product data is the same, but the information is in different places compared to system products. The product structure has been dismantled from the component level to the final product, where every item has version and parent level information. The sample data shows the

user's personal data saving method: there is a product change note in the text field called 'Info'. The item has been modified and accepted after the creation date.

The product information type in figure 3 represents the most of the sales items, which are available for customers. There are product maintenance cases, where this database cannot help to solve the product structures. The sales team can agree with the customers and offer product repairs to the old unit or at least the fault analysis services without checking the possibilities to fulfil the expectations. The unit can be several years old and the product data is not saved into the PDM system. This case is discussed in section 3.3.3 Network Drives.

3.3.2 Enterprise Resource Planning Database

The business has been run through Enterprise Resource Planning database ERP where PLM is created by following the serial numbers. The individual product has a card in a machine registry, where the data is saved by entries created by the order processes such as production orders, warehouse inventory, sales orders and maintenance orders.

The product structures have been created in the beginning of the work order process with the available information at that time. The sample data is taken from the current PLM process, because the data quality varies from time to time. When the company had its own factory, the production orders had product structures and product structure information for manufactured products, which are in use in maintenance services even today. These processes came to the end after the case company ramped-down the factory processes and focused only the project deliveries directly from the product development unit or products are manufactured by other company. The result of the order processes is shown in figures from 4 to 8.

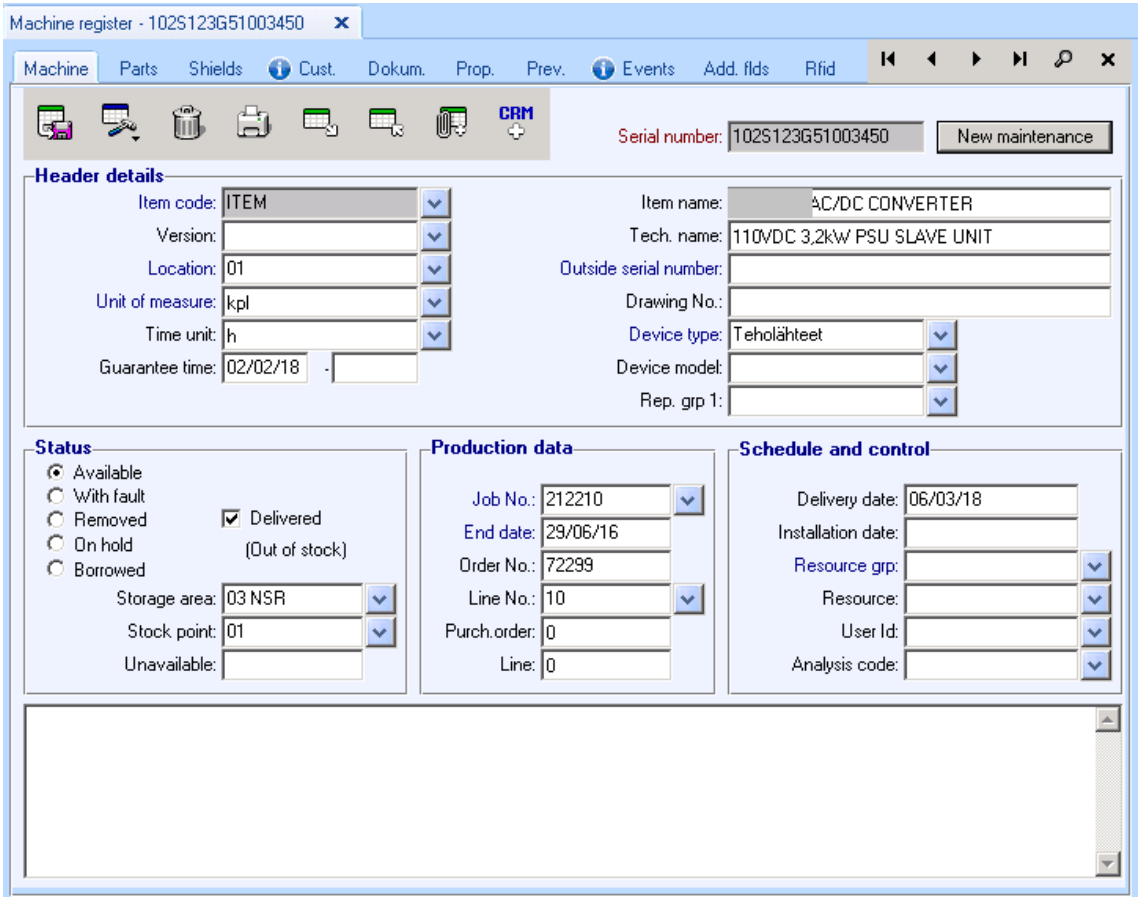

Figure 4. Product information created by production order in a machine registry.

As seen in figure 4, the product structure cannot be identified directly with the serial number. The product management in customer services uses three parameters in the ERP systems: Serial number, Item code and Delivery date. which are saved on the main tab in the machine registry. The text field, which indicates the product version - just below the Item code in the upper left corner - is empty. This is as a result from a decision to move product management to the PDM system, which was introduced above in section 3.3.1. The case company offers the product warranty, which starts from the delivery date. The machine card includes also that information in different text field: Guarantee Time. Data is stored under the delivery process, but not always updated. The production order number to the manufacturing information is also visible in this tab. A difference of manufacture date and delivery date is 21 months, and warranty start date is 20 months after the first system delivery on 08/07/16.

The product traceability and management for the sales item is executed through the events saved by the employees with their best understandings. The history of the project

delivery item is shown in the figure 5. The events reveal missing, wrong or skipped procedures in the product's life-cycle.

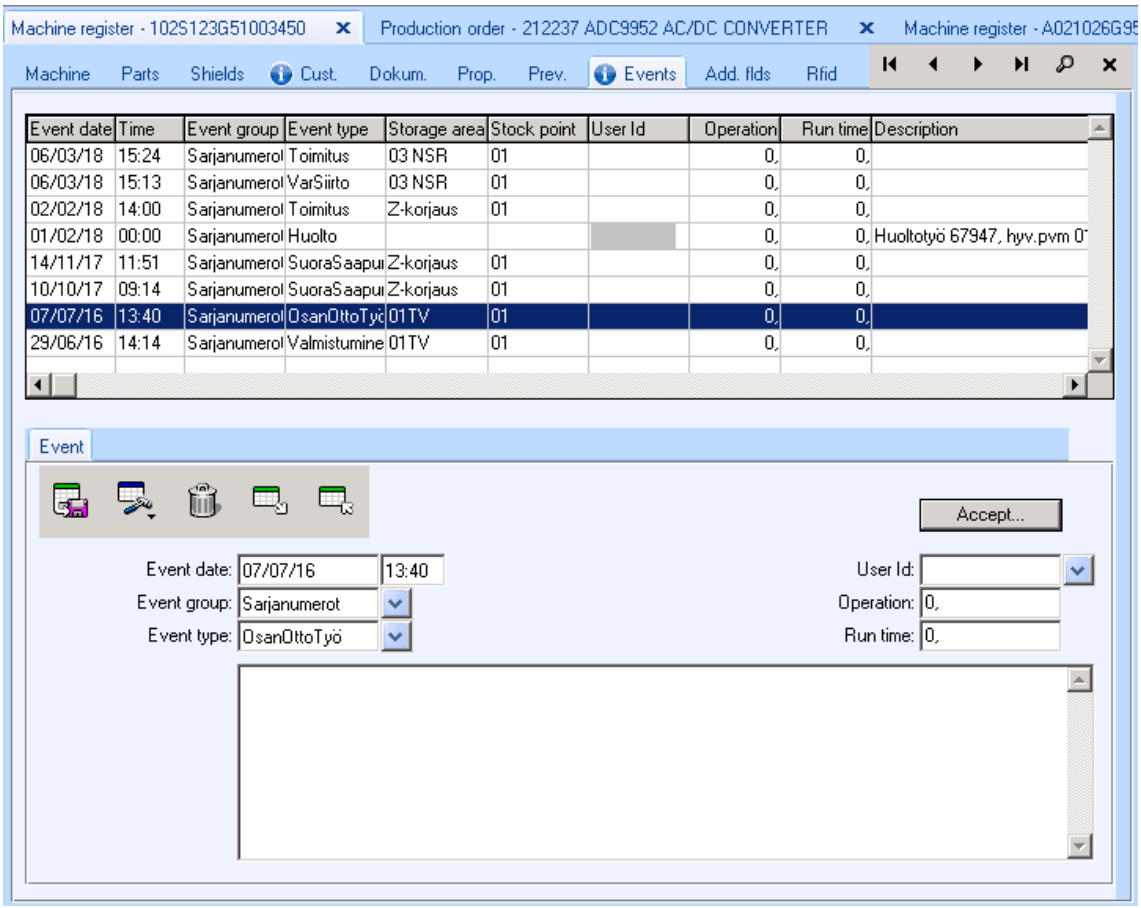

Figure 5. A product history according to the process events.

As seen in the figure 5, the faulty unit has been assembled into the system product on the date 07/07/16. The system delivery date is not seen in this product history, but the first maintenance order has been completed about 1,5 years later when the first delivery date is saved on the machine card. There are actually two warranty periods determined in this product history, i.e. the product warranty for the system product delivery and the service warranty for the repaired unit. It is easy to recognize the business challenge of PDM / PLM process at the case company. The same product is received twice before maintenance order has been completed. The product has been moved from the stock to another after it has already delivered.

The system product has a module structure on the part tab in the machine registry when the product card is created through the production order. These four modules are seen in figure 6.

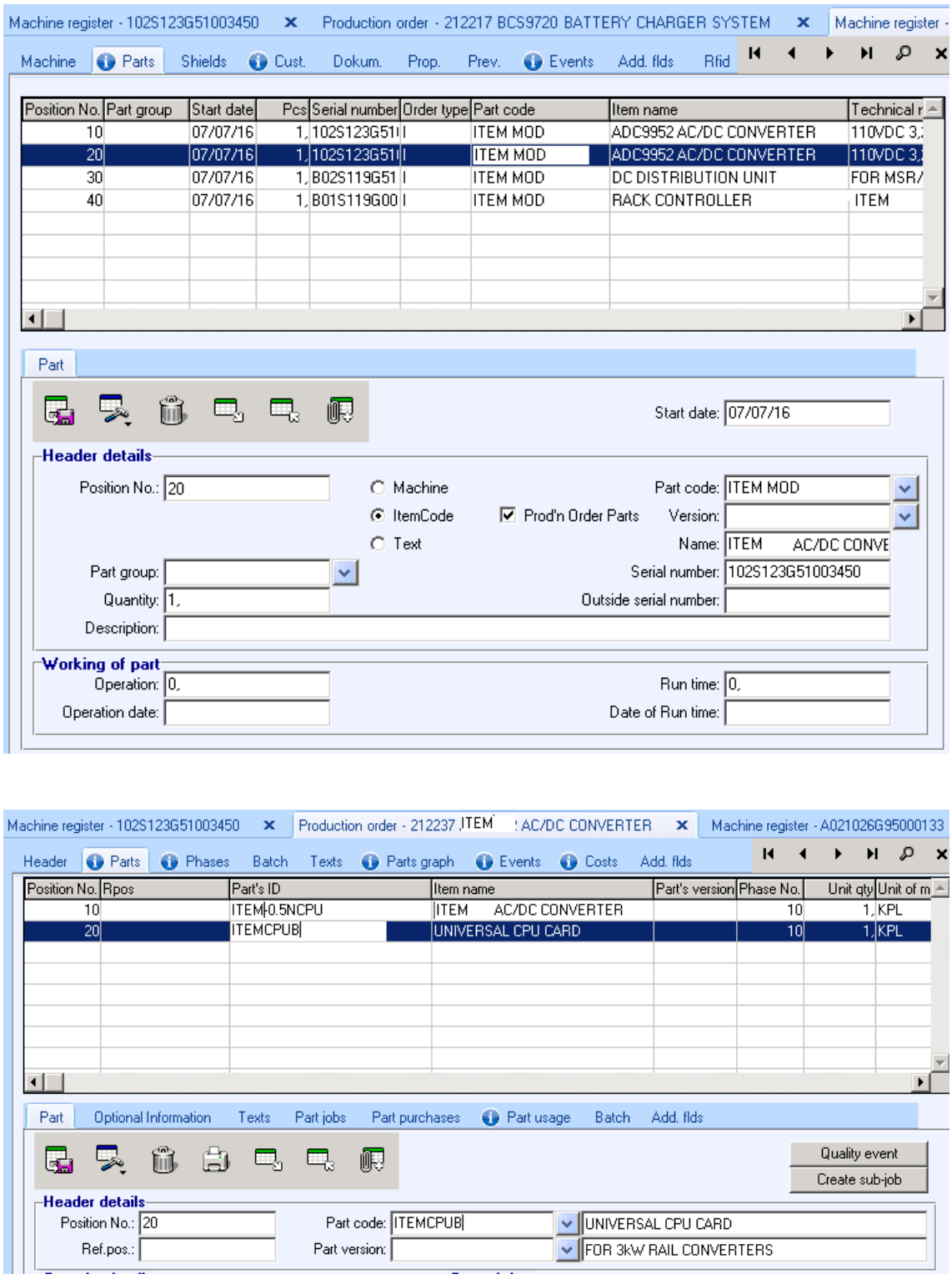

Figure 6. Product substructures created by production orders.

As seen in figure 6, the system modules are identified as individual products in maintenance services. Customers can replace the module products by themselves and return only defective units to maintenance services offered by the case company or its service partners. The challenge of maintaining system structures is that module information cannot be replaced under the system serial number without changes in product history. Firstly, over-writing the Serial number changes the module information in a production order. Secondly, a maintenance order requires the product structure behind the item code, but module lists have been built manually on the production order. The module lists include only the product traceable by serial numbers.

The lower window in Figure 6 is taken from the production order of power supply. The production order uses items, which are not from the product structure. The prototype manufacture of the case company has created own material items between the purchase and sales items, so that project deliveries manage to follow the material flow in the case company. Product structures are recognized in case company material stock with item code extension, which is later removed from the product traceability. This picture reveals the version handling method for spare parts and subassemblies in processes and material inventory at the case company premises. The Universal CPU card, Central Processing Unit (CPU), ITEMCPUB represents the item version B. The version information is constant part inside the ITEM code as the extension -0.6NCPU. The material is also divided to components which does not follow the module structure, because the purchased material includes further manufactured items than they are.

The PLM process confronts the biggest challenges with purchased products, which are manufactured by contract manufacturers. The products' substructure is missing from the purchased material. This product structure is shown in figure 7.

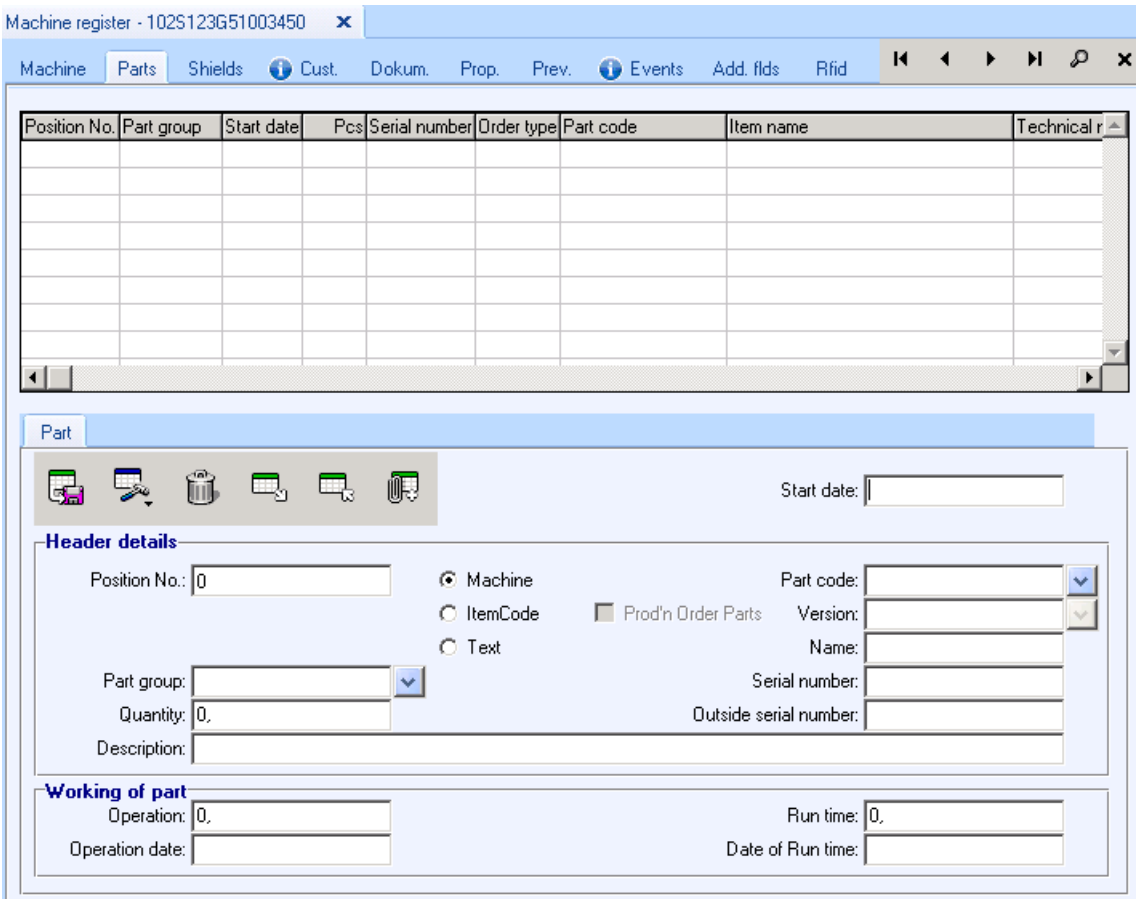

Figure 7. Products substructure for purchased items in ERP system.

As seen in figure 7, the module items are missing from the suppliers delivered products together with non-existent product version (See Figure 4). A product structure management for the manufacturing processes is handled by the material supplier. The product version and components are not in use in the documentations, because they can change during the manufacturing process – instructed by engineering change orders. The decision is based on the product development processes, where product structures are evolving. The suppliers have been instructed to deliver only the newest product structure, when purchase orders have been completed.

The product version management is removed from the ERP system for the sales item, which is later handled by the maintenance services, technical support and claims. When the product has been manufactured into the stock as a sales item, all product versions look the same without the specified product structure as presented in figure 8.

Item group	Item header	Version	QC	Location	Storage area	Stock poiBatch	Quantity	Unit	Value
PN1030	ITEM AC/DC CONVERTER			01	03 L-4353	01	1,	kpl	
PN1030	ITEM AC/DC CONVERTER			01	03 L-4354	01	3,	kpl	
PN1030	ITEM AC/DC CONVERTER			01	03 NSR	01	14,	kpl	
PN1030	ITEM AC/DC CONVERTER			01	03 ZwenZwoka	01	7,	kpl	
PN1030	ITEM AC/DC CONVERTER			01	Z-korjaus	01	5,	kpl	
	****** Stock total						30,	kpl	

Figure 8. Product inventory situation for sales items in ERP system.

As seen in figure 8, there is an empty space under the heading ‘Version’ on the inventory list. It does not tell which product structures are available in storage areas. There is number of units on the customer-site and the direct product version information is as figure 8 shows in the inventory. These products are not yet delivered to customers, and the delivery date determines the product structure.

The product information inside the ERP depends on the time when the card is opened in the device registry. The procedure for investigating the product structure goes through the delivery date. That date is checked the PDM system which product version is the latest at that time. This is not enough, because the product upgrades under the after-sales services does not follow this process. The claim process is not followed in the database because it is handled in the supplier premises according to their processes. The claim documentation is provided by the suppliers and stored as an attachment under ERP system’s claim section. The maintenance services create an event through the process order. The product upgrade and repairs can be found by browsing the product history.

3.3.3 Network drives

The product structures for old products are in a network folder. The files have been saved there before the current PDM system has been used for the product documentations. The network drives are still in use for personal files and process documentations.

The document tree is different. In project management, where can be essential information about the products, the folders have been named as product type. The product management have the same document tree only for the newest product structure and older product structures in subfolders named according to document type such as folders of manuals, pcb layout, pcb schematics or testing. The documentation does not tell,

when the earlier product structures are accepted and when not from the maintenance point of view.

The documentation can be so old that they cannot be opened with the current software versions. There is no process to maintain the electrical document archive. Usually this happens with over 15 years old products, but the products are not in their end of life. Comparing to the PDM documentation; the document name has a logical string of characters. It consists of numbers based on the products and its customer specific version and product revision.

3.3.4 Product binders

A product history goes beyond the computer time used in company processes, where product documentation was hand-written on the paper. Customers could have a service request for the product created in that time. The case company policy is to provide at least technical support and failure analysis, if the customer decides to return the unit. Then the only data source would be the product binders and their hand-written paper documents.

The service requests for these products are so rare that this archive is left out from this research. These products have been handled case-by-case, so the product management process does not get more value, when these documents are saved to electrical form such as pdf files. The value can be created from the work time in declining the product support after products' EOL.

3.3.5 Corrective/Extra tools and practices

Employees have created their own Excel spreadsheets for product management and traceability. These spreadsheets support their own job where the information is up-to-date, and databases has left outside or in a minor role in product management process. The product maintenance service uses the Excel spreadsheets in monthly reports, where all data is collected from the ERP database. The table of PLM parameters from the monthly report of maintenance service unit is introduced in Appendix 4. The data on the service report is collected from the maintenance orders and machine register in ERP system.

The current price list for the sales items is outside the ERP, because the sales is based on the sales offers. There are only spare part prices which can be sold to the customer detached from the product. Fixed modules do not have the sales price, because their prices depend on the purchase prices, therefore the repair price is determined case-by-case based on the real costs.

The product returns in claims are handled outside the ERP. Those are followed by the quality manager in his personal files. The database report shows only the information which is stored in the database fields in the beginning of the claim process. The claim is documented on the text document and saved as attachment file on the claims, when the information field in the ERP system are used in different purposes. It depends on the user's accessibility whether he or she can open the files behind the links.

The project schedules have the file where the delivery information for the prototype batches have been saved for future use. The prototype structures are not always in the ERP or PDM databases when the customer wants the prototype samples, the project manager keeps record for these delivery batches.

The material inventory has its own serial number tracking before the final production has been completed. Since the product structure is built from the final production point of view, but product testing does not belong to the outsourced processes, the determined serial number traceability cannot be used for this kind of material in the ERP. The non-tested products have their serial number traceability created by the technician.

Embedded software, bootloader and device specific software, inside the products can be upgraded by the customer, and this is why this information is missing from some product structures. The product's software database is maintained by the software architect in his own network folders, where he is publishing them to the programming procedures. The automated production testers allow tests only for the products with the newest software. When there are hardware upgrades required by the newest software, it could lead to the mismatch in products under repairs. The hardware and software combability is checked to recognize the installed modules, but not the all module revisions.

Final data source of product management is the product itself. A responsibility to handle returned products is appointed to the service team, which use reverse-engineering to determine the product structure. The unit does not have any official item labels where

the product version is mentioned. The product version is missing from the purchase orders, and there have been claims for product upgrade, the reverse-engineering is the only possibility to confirm the real product structure on the repair table.

3.4 Key Findings from the Current Product Management Process

The analysis of current product management process faces the fact that undescribed processes and a supremacy of one stakeholder creates unwanted processes for other stakeholders. The supremacy of R&D department causes the challenges in product life cycle management process. These challenges are shown in Table 3.

Table 3. Key Findings from the Current Product Management Process.

Product Maintenance Services operate with a zero-based-budgeting.
Product version is dropped out from product information in ERP system.
The responsibilities of PDM is appointed to R&D department
A search method for determining the product structure cannot be validated.
Sometimes the order processing neglects the product structure and the product updates are only mentioned through the spare parts items.

As seen in Table 3, the maintenance services operate with a zero-based-budgeting, where the service engineer determines the spare parts, needed product upgrades and sales offers with help of the other departments. When these are not described or instructed, the costs estimation of the product maintenance would be challenging in products' life cycle.

The product management process continues in a PLM, where maintenance services needs information created by earlier processes in products life-cycle, but the product version is dropped out from the product information. Product data related to the order processes is described in Figure 9. This documentation describes the general product life cycle process, when the company provides product maintenance services to customer.

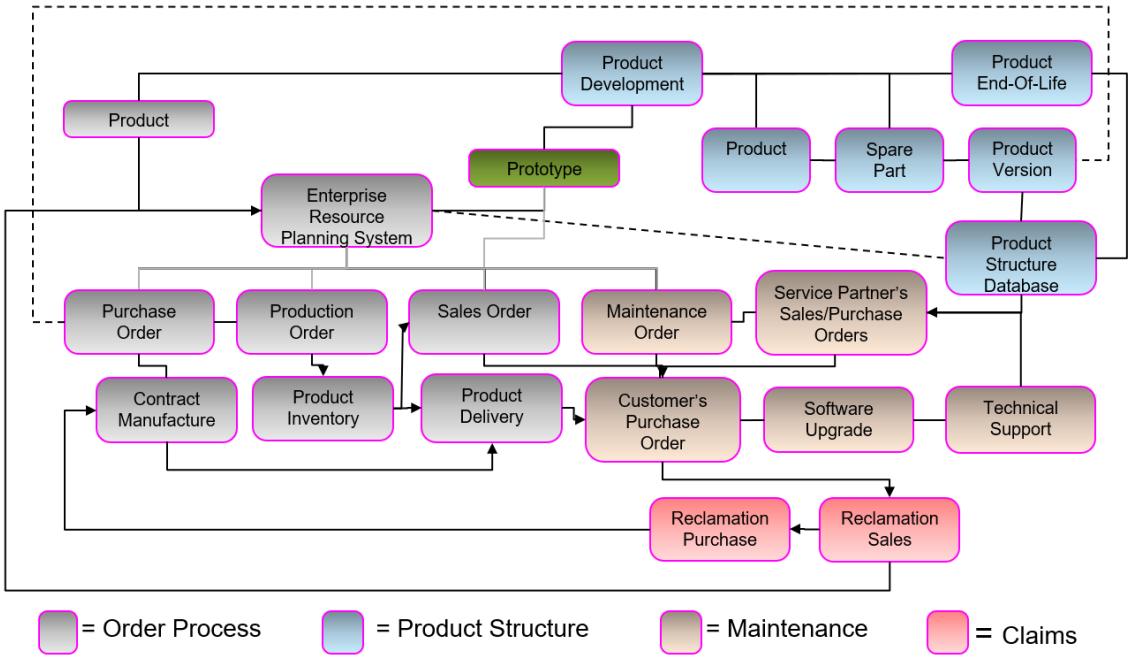

Figure 9. PDM / Order Process Documentation at the Case Company

As seen in Figure 9, the documentation on the left-hand side are related to products' value-chain. The manufacturers business, sales and purchases, runs through these boxes. The supporting documentation such as claims and product documents are on the right-hand side. The continuous line between boxes describe the connections between the documentation and dotted line the ability to utilize the database feature from supporting documentation to the order process.

The current product management process is designed for the product design services and assimilated with product structure management. The process is designed for the unfinished product structure, which is continuously changed by product designers under their R&D projects. This is facing new requirements in products' life-cycle management at the case company. Earlier the unit cost was so low that the defective units were easily replaceable – the manufactured product version was enough for product traceability. Nowadays, the most expensive system products costs almost 10 000 euros and power supplies around 1500 euros per unit, and this is why product maintenance gets more attention.

The product management is under the responsibility of R&D department. During this study some product designers are appointed to the product manager, whose responsibilities would be the PLM alongside their new product development projects. The sales

and logistics team's main objective is to have all product items similar in their work, because they do not need the product version information. They see as the R&D that product management is handled in the PDM system and the delivered product version is not important in the ERP because of the serial number traceability is based on the delivery dates.

The challenge in the product management process is in the maintenance services and the technical support. A search method for determining the product structure cannot be validated. The product management process does not notify the storage periods or product upgrades during the processes. The original instructions to compare delivery dates is not valid, because the date is later than manufacture or purchase date. The manufacture-to-order keeps the stock rotation fast and minimum, although the unit can be in process several weeks before customer delivery - caused by challenges in material handling or manufacture. The earlier product return process changes the delivery date information to the latest one, so product life cycle must be checked before any conclusions of warranty interval.

The claim process does not create an event on the machine registry or the claim numbers cannot be searched by serial number, therefore it is recommended to ask for information directly from the quality manager. Sometimes the order processing neglects the product structure and the product updates are only mentioned through the spare parts items. it tells the updates only for the people, who can recognize the product changes from the item code. If the product upgrade process is run by another company, the spare part items may not be found behind the serial number information. One sample of product upgrade information is mentioned in Figure 3. The CPU card is updated to another item code, not the newer product version.

3.5 Summary of key strengths and weaknesses of PM process

The current Product Management process has strengths and weaknesses, which are seen differently inside the case company. The management team focuses on the company's core competencies, i.e. project deliveries. A tight delivery schedule and resources in business cause undefined working procedures, which is problematic for the PLM point of view. The strengths and weaknesses of the current PM process are listed in the table 3.

Table 4. Current State Analysis for Product Management in the case company.

	Strengths	Weaknesses
Product Management Process	The case company sees the business value only on the new product sales.	Customers expect even 30 years maintenance services for these products.
	Product information is not created or followed by the case company in a products' LCM after the manufacture and service processes are outsourced.	Data is scattered or missing.
	Several products are maintenance free because of the production costs.	The company is strategically moving into a business area, where product version transparency becomes even more important.
	Product Management Process has tools for building a product management and a product traceability.	Employees do not use the tools as instructed.
	Product management is designed for the product development process, which is case company's core competence.	Products' LCM does not exist.
	Order processing in a customer services uses only one item code which is not depended on the product version.	Product information is not 100 % sure.
	Employees have their individual way of working.	The working procedures do not meet to each other. Next process stage fixes the information from the earlier stages
	Every case is an individual case and do not need to go back after the solution.	Statistical tools are almost impossible to use.
	Product data is in the PDM system	Order processing uses different product data in ERP system.
	Prototype information is not seen in sample deliveries.	Prototypes and production structures get mixed in the maintenance services.

As seen in table 4, the strengths of the current product management process are in the prototype manufacture. The purchased material can be changed without changing the

purchase order in the system. The delivery notes and the products do not inform the product structures. This means they can be anything. A required product information for the sales reclamations does not use product version traceability.

The weaknesses of the current product management process are listed in the right column in Table 4. One common weakness throughout the company processes is a lack of information in customer services and in a product quality, where customers expect 30 years maintenance services for their products. The statistics of the updated units is time-consuming process, when all individual data savings have to go through, and ask for more information from the suppliers and service partners. This is true even if the customers have informed the case company, how many units have already been updated.

The CSA-analysis consists of the product-management process in the case company. The focus on the process development is to get rid of the product repair services, where the product upgrades change the manufacturing information. The same issue is found in the claim processes where the product structures have changed in a supplier site. This product life-cycle is recognized as a challenge in processes, tools and product quality in figure 10.

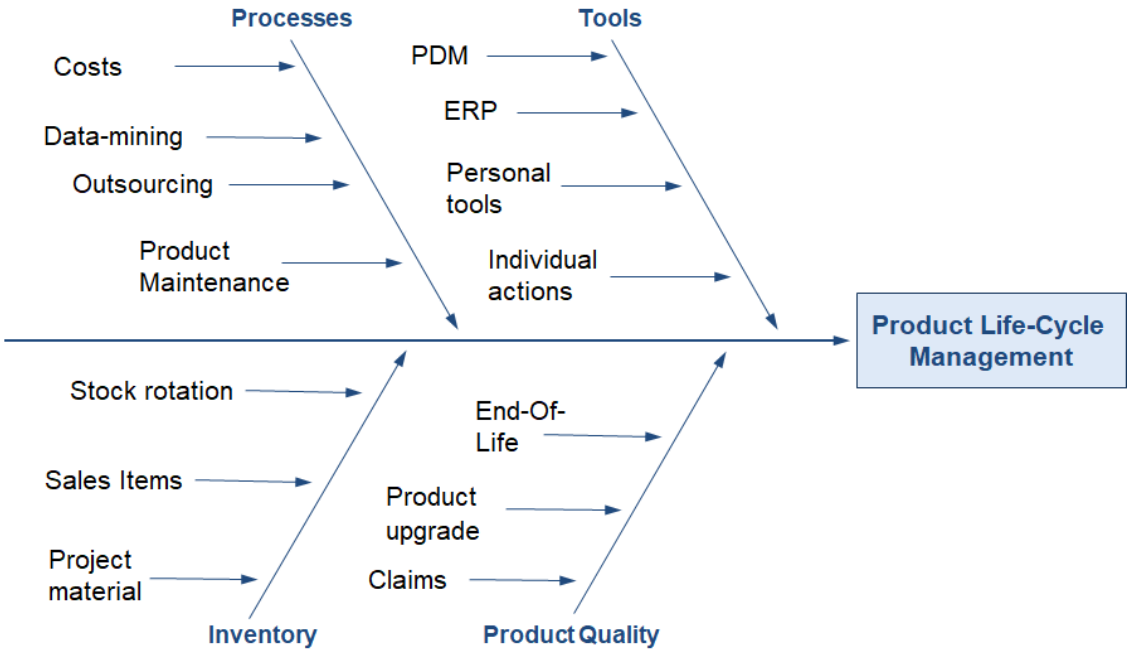

Figure 10. Challenges in PLM.

As seen in Figure 10, there is only a few terms of PLM, but these are collected from the maintenance service point of view. Terms related to this PLM process are costs and data-mining, tools related databases, inventory related new material and the last product quality. These together maintain the product life cycle in product maintenance services. The product repair process is planned to be outsourced, thus the challenges are chosen for supporting this company strategy:

The first challenge is to improve product version recognition, so that contract manufacturers, service providers and inner stakeholders can find the needed information fast and easy with the available tools.

The second challenge is to improve product pricing. Product maintenance services can use database information to determine the individual service prices in sustainable level of business processes.

The third challenge is to establish the PLM process, where claims and service statistics provide better data quality from the products' installed base. A material handling is improved process for product structure identification in product crisis situation and product life cycle assessment.

The best practices for better PLM, order processes and product maintenance services are studied in the next section 4 'Existing knowledge for the Product Data Management and Traceability'.

4 Existing Knowledge on Product Data Management and Traceability

This section discusses best practices in product data management and traceability. First, it discusses the product data management and product life cycle in Section 4.1. After that this section discusses cost efficient product maintenance process in Section 4.2 before discussions of the process development in section 4.3 and the conceptual framework of this thesis, which is introduced in section 4.4.

4.1 Product Management Processes

This section focuses on the product identification and traceability. It describes the obligations and processes in the case of product crisis.

4.1.1 Product Data Management

Product Data Management (PDM) is one of the key aspects for business efficiency. PDM is closely related to PLM and actually is a core pillar of PLM (Otto 2011, p. 274/ Gmelin & Seuring 2014, p. 172). PDM system typically controls all basic data from the product design to product EOL (Kropsu-Vehkapera et al. 2009, p. 770). PDM can consist of several interconnected software systems, which all have their individual purpose.

Kropsu-Vehkapera et al (2009, p. 770) highlights the PDM during product design and development. PDM systems are supporting these purposes through integration of surrounding systems such as product design tools and ERP system. PDM includes also documentation, order process, product traceability and data sharing functionalities. (Otto 2011, p. 275.) Products confronts the essential requirements of the applicable legislation, which directs implemented business processes. In the global markets and standards of individual business processes have their own requirements for PDM (Otto 2011, p. 288/ Campos & Miguez 2002, p. 533). A notification that components, spare parts or subassemblies may be regarded as finished products and their end-use may be the assembly or incorporation into a finished product. (European Commission 2014, p. 16).

PDM process development helps companies to fulfil the essential requirements throughout the product life-cycle with co-operation of the manufacture and service providers. PDM process efficiency arises from the easy access into product data and available data

quality. The earlier the data is created, the more value it provides to manufacturer and service providers. Number of data is also essential to recognize in the PDM process to avoid an unnecessary data hoarding.

4.1.2 Product Life-Cycle Management

PLM is a business concept which expresses the engineering point of view of the product and integrates the aspects of people, processes, and data (Gmelin & Seuring 2014, p. 166). It is about the systematic integration of product sustainability to improve products and services while enhancing the overall sustainability performance of business and its value chains (Sonnemann & Margoni 2014, p. 8, 12, 206).

PLM is a cross-functional work. It interconnects with a new product design and environmental and social provisioning. Neto et al. (2015, p. 462) determine that decentralization of service divisions and alignment of the product design and manufacturing processes are necessary. It involves top-management to streamline processes, which is essential for not losing time and money due to poorly defined process steps (Gmelin & Seuring 2014, p. 174). Products goes through each PLM stage only once, although the product will go through downstream phases of value chain repeatedly (Clinton & Graves 1999, p. 25). This is evident primarily in maintenance services, where there is product recalls and tracking mechanisms in each information system for product crisis (Lei & Xiao 2011, p. 373, 375 / European Commission 2014, p. 52/ Kumar & Schmitz 2011, p. 236). To satisfy the lack of product information, a ubiquitous product recovery management system PRMS was developed (Um & Suh 2015, p. 174).

An integration of product traceability connects the product information to a customer information. As Lei and Xiao found in their study (Lei and Xiao 2011, p. 275), the recall management information system includes product and customer related information. The business process efficiency is based on the product traceability where products are followed through high-quality data of streamlined processes. The manufacturer's obligations have been shared wider in recent legislation, which answers better to questions of responsibilities in outsourced processes. Company's top-management is recommended to participate in process development, where process data quality is in high priority between the company and service providers, when the tangible goods are only handled by other company. Product life cycle analysis is concerned with the costs during the entire product life cycle.

4.2 Cost Efficient Product Maintenance Process

This section focuses on the costs of product maintenance services i.e. manufacturers ability to foresee the costs related to the delivered products in the customer service.

4.2.1 Product Value Analysis and Life Cycle Costing

Total costs of the products can be determined by using Product Value Analysis (PVA). It links the strategy and performance evaluation with specific products. Product life cycle and value chain analysis examine a sequential progression of activities over time in interaction with and consideration of suppliers and customers (Clinton & Graves 1999, p. 22-23).

A large part of these costs (over 70 %) become defined already in the design stage (Vlachy 2014, p. 205). Koh & Simpson (2005, p. 649) defines the advantages of ERP system in meeting delivery performance in SMEs to conquer the uncertainty in manufacturing systems. Poor communication or lack of process harmonization causes fails to capitalize from collaboration (Gmelin & Seuring 2014, p. 168). Bad data quality causes costs in data-mining processes but can be reduce two-thirds of measurable costs through steps for top-management in the company. A focus is recommended to be on hidden data factors such as wasted time and risk of failure (Redman, p. 2, 5). The figure 11 represents how product volume and value chain is integrated each other.

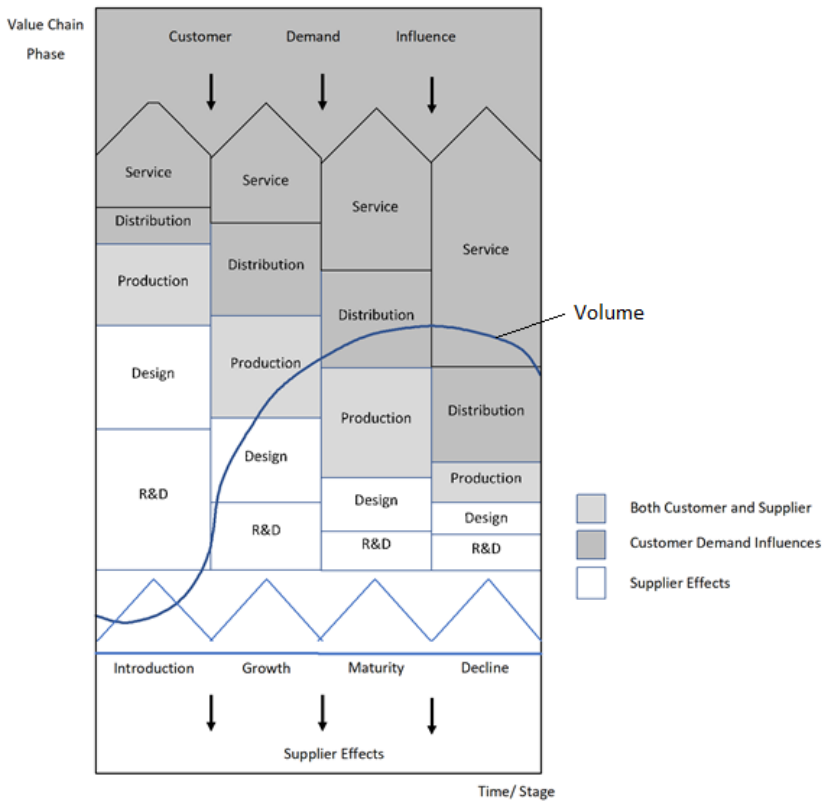

Figure 11. Integrated PLC and Value Chain. (Clinton & Graves 1999, P. 24)

As seen in figure 11, new product design and product manufacture have bigger role in introduction and growth stages, where new product design creates value for every stakeholder, but the product goes through all stages in its life cycle. This means that distribution and maintenance stages will increase their share of the PLM. A good product design will ultimately reduce the number of recalls and the risk to consumers when a recall takes place. The sustainability aspect of product development helps the company to improve its business processes with suppliers and customers as well as with other parties (Kumar & Schmitz 2011, p. 236, 249).

PVA and Product Life Cycle Costing (PLCC) offer basis for business process development. PVA takes into account the product maintenance costs during the product life cycle, where the product volume is high compared to the manufacturing batch in a specific time period. Products' installed base consists of several product structures developed during the time and has different costs left until the product EOL. Vlachy introduces Cost Type Breakdown in his study, which includes five different costs: direct, indirect, contingent, intangible and external costs (Vlachy 2014, p. 207), to which Gmelin and Seuring also recommend focusing on the product design phase.

4.2.2 Product-Service System in Aspect of PLM

Traditional product manufacturer focuses on their products and cost efficiency related to the product manufacture. Sustainability and customer centricity is changing this point-of-view from the product to the services which company provides to customers during the product life cycle. Services can be co-design processes of custom made products, technical support and maintenance services offered by the manufacturer or other stakeholders such as supplier and service companies.

Roach (2011, p. 706) researched the relationship between product management and firm performance, where he found out that the proposed measures of product management provide some insight into company performance. In a product-oriented culture, product maintenance services are thought as costs. Process development focuses on reducing costs to achieve better company performance with tools such as Zero-Based Budgeting (Hueter et al. 2018), Build-To-Order (Holweg & Pil 2001) and Value-Based Management (Koller 1994). Demands of these tools are flexibility and data quality in measurements. In other hand, the flexibility and data quality are limited by legislation. Certain requirements guide the way of product management, where manufacturer response time to the technical risk, behavioural risk and delivery competence risk play own part in company risk management process (Reim et. al 2016, p. 668). Data ownership is typically defined based on business responsibilities where a data is created or maintained (Kropsu-Vehkapera et al. 2009, p. 770). Hong & Huo (2010, p. 850) brings up a Quality Function Deployment (QFD), which they see as an effective method for Quality Management in a collaborative consumption of both products and services.

The services may represent also the barrier for manufacturers with a product-oriented culture, when the longer product life cycles delay the customers' need to buy a new product (Neto et al. 2015, p. 464-465). Company performance in aspect of PDM/PLM is depended on the cost-efficient processes. The company can outsource the product maintenance services to another company or divisions, but it does not remove the obligations of product identification and traceability in their own processes. Because service providers have different perceptions regarding the manufacturer's value proposition, changing from the product-centric approach to the service-centric approach often creates problems for the companies. Small and Medium sized Enterprises (SME) may not

have PDM / PLM processes centralized under one department, and therefore a management team must turn to the general requirements of PDM / PLM in their responsible business area.

4.3 Process development

Processes related to the PDM and PLM is recommended to be examined on a more detailed level where required resources are allocated to each task, because product information is essential for efficient product maintenance processes already in product design stages. So that the process implementation provides better results, it is beneficial to describe the tools and information required in the tasks. (Martinsuo & Blomqvist 2010, pp. 14)

Lean production is usually seen as a manufacturing concept. Any concept that provides customer value can be in line with a lean strategy and can utilize (or not) Lean tools such as Kanban, level scheduling, or take time (Hines et al. 2004, 1006/ Swank, C.K. 2003, 129). Products or services can be plotted with regards to their relative cost-value proposition to the customer. Value is created if internal waste is reduced, as the wasteful activities and the associated costs are reduced, increasing the overall value proposition for the customer. Hines et al. introduces four stages of lean thinking, which are related to the stages of development of organisational learning. It can be defined as the process of improving action through better knowledge and understanding. (Hines et al. 2004, 997, 1000)

The production line at the premises of the case company manufactures product structures, which may not have product type approvals, but the products are still sent to customers as sample products. The Lean process faces challenges during the process loops-backs and process may be further complicated by the employee’s choices concerning which tasks to do when. Product designers can decide to change the prototype structure in the middle of the process. The objective of the process improvement is that all steps in the process is located close to one another (Swank, C.K. 2003, 125).

4.4 Conceptual Framework of This Thesis

Based on the findings in previous sections, the improved product management process has legislative requirements and business process aspect. The product management is in a close relationship with a product life cycle management and company performance.

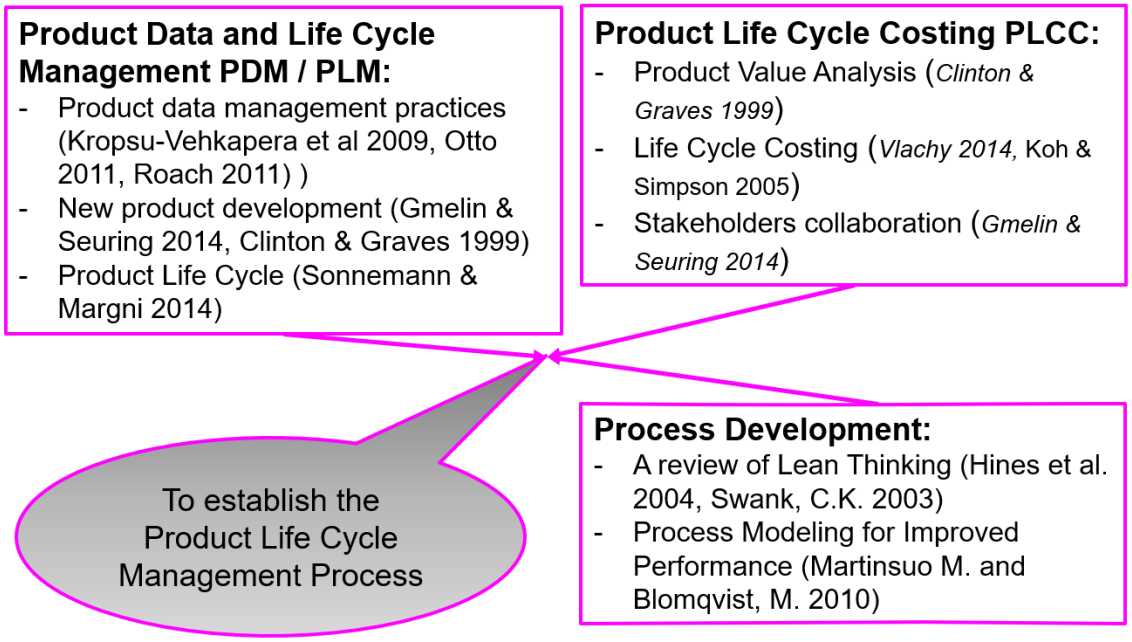

Figure 12. Conceptual Framework for Improved Product Management Process.

As seen in figure 12, The established product life cycle management process focuses on developing the product management and product life cycle costing by using the Lean tools.

The first element of the conceptual framework is PDM / PLM, which determines the minimum obligations of the product manufacturer and other stakeholders in a product value chain. It also defines the product data interconnections between different software systems such as PDM and ERP systems. The PLM has a part in new product design, where proactive company creates a product recovery management system for cases of product crisis and product recalls. This element also focuses on the collaboration between companies during the product life cycle, where data sharing and data mining processes runs without handling the tangible goods.

Second element of the conceptual framework discusses about the LCC. To fulfil the manufacturer's obligations and finding the PLC stages where the product information is created and shared with others. This element defines the tools and practices for product value analysis and process efficiency in company performance.

Third element of the conceptual framework discusses process development at the case company. Product information is essential for efficient product maintenance processes already in product design stages and continues later in products life cycle where other company processes change the product information.

The conceptual framework of the established PDM / PLM process offers best practices for a SME processes. Process improvements of the case company performance are studied in next section 5.

5 Building Proposal on PDM / PLM for the Case Company

This section merges the results of the current state analysis and the conceptual framework towards the building of the proposal for PLM process for the case company.

5.1 Overview of Proposal Building Stage

The proposal building stage aims to establish a product life cycle management process to offer better product identification and product traceability in customer service. The basis is on the findings of CSA interviews, where employees had individual expectations for the product management process. It focuses on the product life cycle management and data quality in PDM/PLM systems.

First, a data quality of product information is determined based on the general requirements. The required product information defines parameters for the product management process, where process owners are obligated to respond general requirements. This stage creates the minimum level of product management process.

Secondly, a data transfer from data creation process to another is utilized in the product life cycle. The proposal of improved product management process has statistical tools for PLM and PLCC created from the data creation steps to products EOL. This stage was conducted with help of the employees which have administrative accessibility to the PDM and ERP databases.

Thirdly, a workshop was set up to develop the initial stage of the PLM process. The result of the workshop is the first step in establishing a PDM / PLM process in customer service. The proposal of the PDM / PLM process includes data saving tools which share the product information with less effort to manual work. The workshop creates the material and product traceability through the project deliveries.

Finally, the parameters of PDM / PLM process are utilized in after-sales services, where Service Engineer, Controller and Supervisor of Electrical Works describe the Product Maintenance Process at the case company.

5.2 Findings of Data Collection 2

The data collection 2 shown in Appendix 3 is limited to the product version handling. The two other proposals in Business Process Management (BPM) and PLCC did not get any respond in the discussions with R & D project teams or logistics. Therefore, the proposal of the improved PDM / PLM process revises the case company processes through its project deliveries. It determines the product information data used in the order processes after the product manufacture or purchase orders has been completed and products are dispatched to the customer.

CSA revealed Database Tools that can be used for data mining of product information. It also revealed the different objectives of the process outcomes. Employees have their own ways to handle the product data. All available features of the ERP system have not been used, because those have been seen unnecessary in earlier stages of the product life cycle - before product maintenance service.

The suggestions of the product management system take into account changing product structures in order processes. They diminish the time in data-mining process. They can also offer real-time statistics for company performance and product life cycle assessment. In this initial proposal stage the product management is described as a process throughout the product life cycle.

Table 5. Key stakeholder suggestions for proposal building (Data 2) in relation to findings from the CSA (Data 1) and the key elements Conceptual Framework.

	Key focus area	**Suggestions from MSU**	**Description of the suggestion**
1	Process Description	PDM / PLM process is defined and followed by every process	Buyer, project manager and Service Engineer suggested that the process flowchart has been built and maintained according to the material and product traceability and transparent product identification.
2	Product Structures in ERP system	a) Link the product structures directly from PDM System b) Use the module structures to define the spare part assemblies.	a) All agreed that product data are managed in one system, which share the information automatically to other systems. When all items can be traced individually in PLM. Differences of their opinions were found in level of the product structures. b) The Buyer, Logistics Coordinator, Project Manager and Service Engineer suggested that product structures are saved on the ERP system only in a module structure level. In case of product upgrade or module replacement, the product structures can be upgraded on the module level.
3	Product revision visible in sales items	Use the product version feature in ERP system.	Service Engineer and Buyer suggested that product version is visible directly on the product card in Machine Register. The product structures are identified directly with a product identification number. The item inventory is also possible when LSA and estimate of PLCC is needed.
4	Documented product change info	a) Document the product upgrades. b) Determine the necessary and available product upgrades.	a) Service Engineer suggested that procedure instructions of product upgrades are published with an accepted of new product structure. b) Service Engineer suggested that necessary product upgrades are informed directly on the product version which are not allowed to deliver to customers anymore. There are also several accepted product structures, which have available product upgrades bringing the incomes in after-sales services.
6	Creation of price list for spare parts	a) Save the product price in ERP. b) Determine the product prices and use a percentage reduction for sales quote.	a) Service Engineer suggested that component costs can be determined for a longer time period in sales item, which are handled through price lists. b) Service Engineer suggested that a product or a spare part has a list price, which is determined based on the business objectives.

As seen in Table 5, first four rows are related to the manufacturers obligations. rows 5 and 6 consists of the parameters of business process management related to the product management and life cycle costing.

5.3 Initial Proposal

The initial proposal creates more value of product information and generate new opportunities to build service business with service partners and the customers. It helps also define a product life cycle assessment to product batches in project deliveries.

5.3.1 Product Structures in ERP system

A Product Structure defines the material which is used in a manufacture of the products. This system feature creates the item lists automatically for inventory and picking lists and allows the module replacements later in a product life cycle.

One item code (product) can have multiple revisions where differences of product structures are informed with the product identification number or string. This system feature is active field on the device register, which is updateable without changing the item code. The feature has also own column in several places inside the ERP system, so the product revision follows through order processes and inventories. The product traceability continues in products' installed base and product recall processes can based on the product revision. The maintenance service unit can use old and new product structures as a spare part or a replacement unit. Stock material can be picked up and scrapped without changing the statistics of approved products if the product version is no longer used when developing the product.

The version information offers the possibility to valuate different generations of the product. The manufacturer or service providers have the LCA for different product revisions, which can be used in estimate of material and human resources. Some earlier product version needs more attention than others. Product samples in product development projects may be products, which have not passed the type testing. They are visually marked as samples and are not belong to warranty repairs in maintenance services. Required product material varies also in product upgrade. The final product could be same, but products need different kind of work and parts to achieve the final product structure. The

product version information tells the status of the current product structure and the need of product changes.

5.3.2 Product Change Info in PDM / PLM system

Product Change info determines a nature of product upgrade. It includes needed material items, procedure instructions and is directly connected to the product revision. It informs when the product upgrade is necessary or is only done by request.

The item has a status information field in PDM system. The item status helps manufacturer to maintain its products together with the product change info. This system feature gives the input for necessary product upgrades. The status of the old product structure is set as a history item, and product change info tells the procedure to upgrade the product to the accepted product structure. If the product support is not available anymore, the product change info can be used in information of replacement products.

MSU uses two product management systems. The Product Data is maintained in PDM system by R&D Department. Based on this product information the order processes use the created product data in the ERP system. Both Product Management Systems offer similar feedback for product inquiries, the MSU can maintain products' installed base and create the statistics of product revisions on customer-site. Service business can be developed and maintained based on the product life cycle assessment, which covers the product maintenance costs and sales prices.

5.3.3 Creation of price list for maintenance service

Product and service prices are based on the offers. This is in a high role in product maintenance services, where the service provider handles customer property and the customer satisfaction is more or less depended on the lower service costs and fast delivery times. In other hand, the company pursuing the savings from the service costs.

Service offerings are based on the prices which are determined by company's business management unit, and customers can get the requested cost estimates directly from the service employee after first contact or within the fault analysis without unnecessary delays. The first price offer is based on the product value analysis and profit margins but

offers can be re-estimate through percentage reduction. Total costs can be determined directly form the unit prices and costs are followed in component level, which is needed in breakdown prices, where work and spare parts are informed separately.

The price list prevents the most time-consuming process in cost estimation. It diminishes needed human resources, when service employees can create the cost estimates directly with the item codes. A procedure of cost estimate requires that items have sales prices in ERP system where profit margins of spare parts can also be followed by service statistics. Service statistics are generated from individual cases according to final service offerings, where the cost efficiency have reference numbers provided by default prices.

5.4 Establishing the Process Flowchart

The PLM process utilizes other process data from the product data management, stock inventory and product pricing processes. All stakeholders have separately running processes, but the process quality is improved with stakeholders' feedback.

The process flexibility is developed inside the subprocesses, where the requirements of the process output is fulfilled according to the customer expectations. The holistic PLM process is ground on the Business Process Management (BPM), which meets manufacturer obligations at the customers business area.

An established PLM process flowchart is based on the process parameters described in Section 5.4 and the discussions with colleagues: Controller (Administrator of ERP System), Tester Designer (Supervisor of Electrical Works. Project Manager (Administrator of PDM System) and technician (creates the material traceability in prototype manufacture process). Their opinions are presented in Appendix 2. The discussions support task to establish new product life cycle management process in respond the new process parameters. The new process flowchart in Figure 13 answers better to common subprocesses in case company's business model.

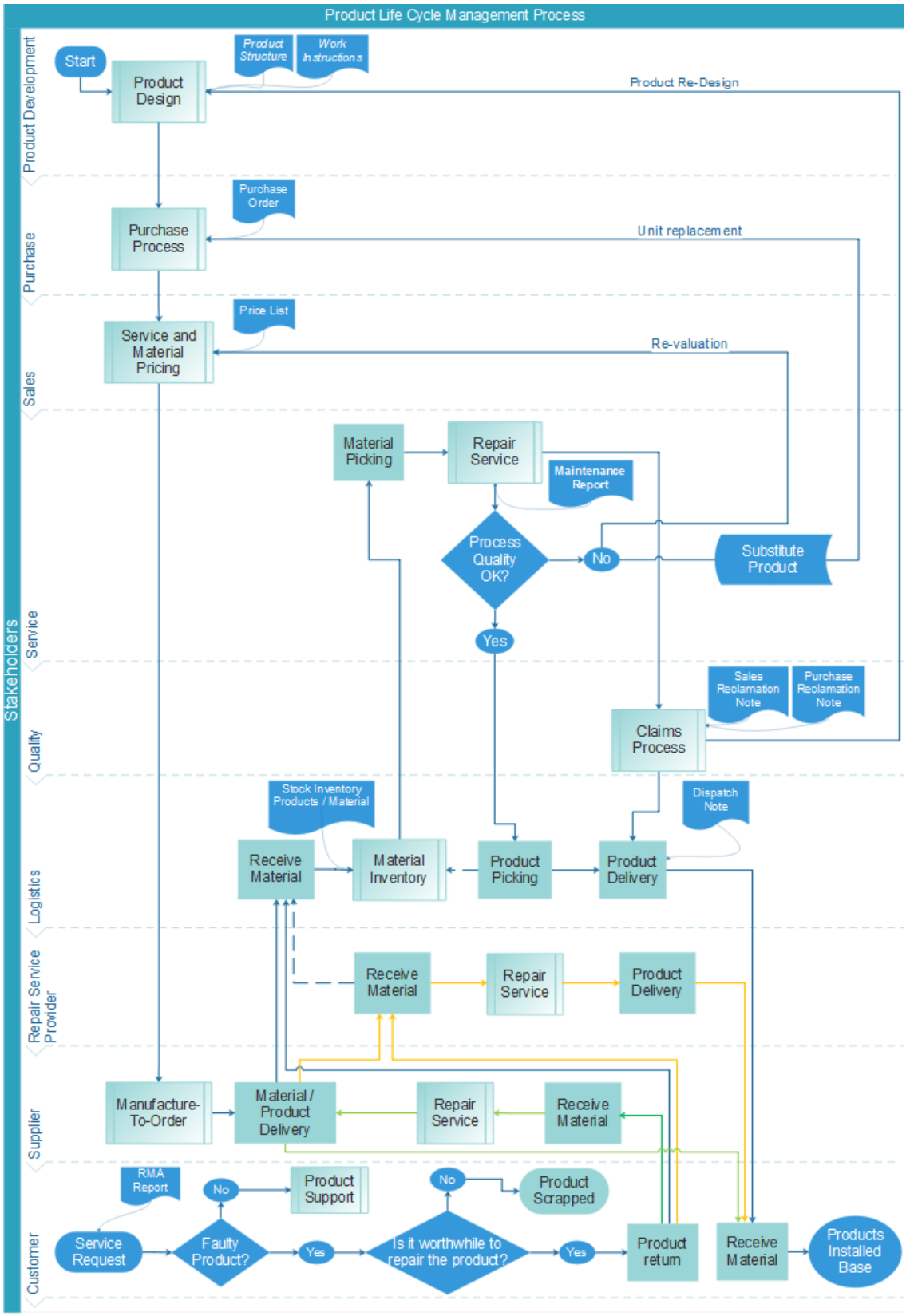

Figure 13. PLM process flowchart.

As seen in Figure 13, the Service Pricing process is next subprocess after the purchase process defined the process costs. The sales prices can be estimated with profit margins and standardize on the price lists of the company. The sales price lists provide the target price of sales offers, but sales prices can be re-valuated in case of bad process quality. Real profit margins of maintenance services at the case company is estimated from the monthly report of maintenance services, when the improved PLM process creates the data from the costs and sales prices at the component (item) level.

Three feedbacks of product and process quality are based on the PLM process after improved product data management suggested in section 5.3:

First, request of product re-design provides a quality data in product structure level, which identifies the product version of returned or scrapped products. The quality of product documentation can also be recorded with help of the requests of product support.

Second, the product structure of the new product or the module is found from the stored data in case of the repair process needs spare parts or replacement products. The product in repair process can have a new generation product model. The product information data provides the substitute product, which can be offered instead of the more expensive product repair.

Third, the process data utilizes the fixed product and spare part prices, but also provides the statistics of real process costs and sales prices after service offerings. The costs and sales prices bring into focus the non-profitable product supports or over-valuated product prices.

The product maintenance service is offered by the case company, suppliers or other repair service companies. They can change the real product structures in their repair process. It is recommended to share the product identification data for individual product without the need of full traceability of process data in earlier PLC.

5.5 Proposal stages for improved PDM/ PLM

The proposal for improved PDM/ PLM process is divided in five steps. Because of the product life cycle and customer information are saved in the ERP system, these improvements are recommended to taken into actions in ERP system, where the data is created case-by-case and enable the statistical tools automatically from the process data. Events in the ERP System create raw data for the process management, where the company performance can be checked with statistical tool such as spreadsheet program.

First, the case company is recommended to develop processes to perspective of transparent product traceability and improve process data of product information. The current description of the PDM / PLM process flowchart is described in section 5.3.1. There are two processes described in perspective of material flow through the company processes and outsourced processes. The PDM / PLM process is strong with parallel claims and repair processes in warranty repairs, but the product traceability is better on the side of maintenance services, which has own order processing tools and linked product information fields to other process stages in sales and deliveries.

Second, the item version in ERP system is in use for new item codes in order processes. This would directly inform the product structures behind the identification number. The version number can be anything which describes the correct product structure. However, it is recommended to use the same identification such as Version number for all product management systems. A version list for one product item of the case company is shown in figure 14.

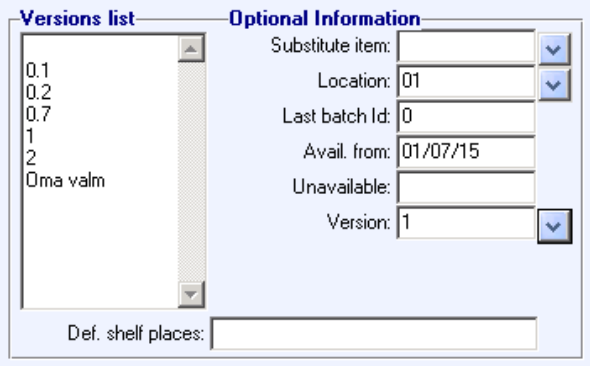

Figure 14. Item version.

As can be seen from Figure 14, the version number follows the general numeric format, where the prototypes are less than one and the production versions over 1. The case company also has one unique product version known as Oma valm. This is not currently being used, but it describes the ability to identify product versions in many different ways. The Version under the Optional Information explains the default setting, which could be used for newest production version of the item codes. The version is saved directly under the Item codes in Machine Register, shown in Figure 15.

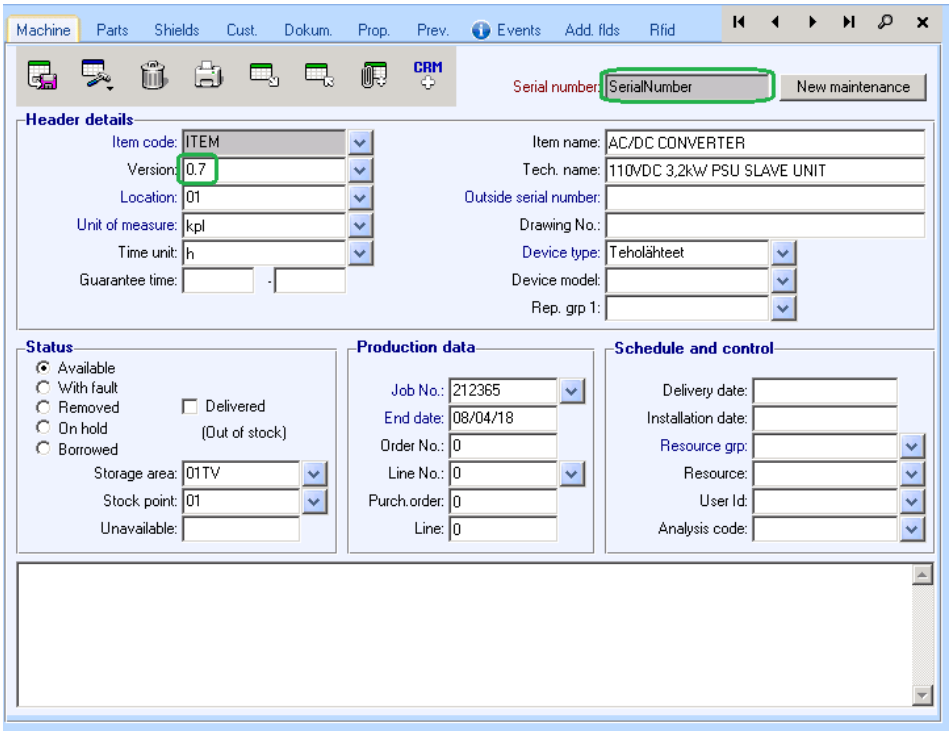

Figure 15. Product Version in Machine Register.

As seen in Figure 15, the time-consuming data-mining process can be avoided. The Version information is available for individual products in upper left corner on the first tab of machine card. The product structure does not need the delivery date information and undelivered products are recognizable. When the MSU needs to check the product structure during the technical support or repair services, they do not have to read that from the product history or compare the data from different data sources. This Version data is following the item codes through inventory and product deliveries.

Item group	Item header	Version	QC	Location	Storage area	Stock	Quantity	Unit
PN1030	ITEM AC/DC CONVERTER		01	01TV	01		1,	kpl
PN1030	ITEM AC/DC CONVERTER	0.2	01	01TV	01		13,	kpl
PN1030	ITEM AC/DC CONVERTER	0.7	01	01TV	01		3,	kpl
PN1030	ITEM AC/DC CONVERTER	1	01	01TV	01		4,	kpl
	****** Stock total						21,	kpl

Figure 16. Inventory List including Item Version.

As seen in Figure 16, the stock inventory reveals that four products represents Version 1. If other products represent restricted product structures such as prototypes, product samples of project deliveries, they can be upgraded or scrapped based on the product LCA. When the upgrade procedure is done, the product represents acceptable product version and is updated on the inventory list. The product lists can be created from delivery or maintenance processes, where the version information reveals directly the product structure in case of product crisis. The individual product can be recall and already upgraded products can be left out from the coming recall process.

Third, modules get their tracking methods available in the order processes. If the item is not followed by the serial number, the suggestion is to use batch number for manufacturing batches. The traceable material can be used from the inventory to the maintenance orders, where material is collected from the inventory and updated to the parts of the final product. Additional benefit is the traceability of the inventory interval. The subassemblies may include aging components such as electrolytic capacitors with limited storage times.

The MSU of the case company uses the database tool, called ‘Maintenance Orders’, where the service employees store the spare part information. Therefore, a level of the final product structure is not enough in product service processes. This can be thought as extra sales items in the manufacturer business. MSU manages after-sales services at the component level instead of new product sales. Maintenance orders are proportional to the new product's bids, where sales items (item modules) are traceable and identifiable on batch level.

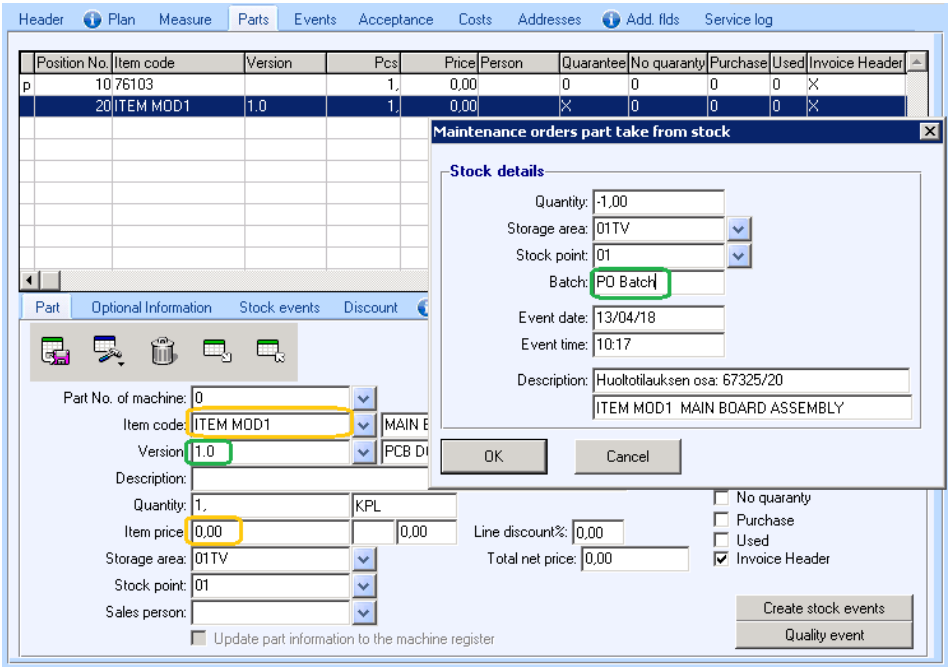

Figure 17. Spare parts on the Maintenance Order.

As seen in Figure 17, spare parts can also be traced by Version and product batch information. There is also tap for the part information change to the machine register. The feature must be activated and need the product structure before working properly. The third needed feature is the item code and its extension. The extension changes the part list item to another, not update the current structure to newer one. The version information can also be kept as an extension to inform the manufactured product version, but that extension is recommended to move under Version as it is in PDM system, shown in Figure 3, to achieve similarities between both product management systems.

The module traceability continues from supplier to customer when it is updated on the part list of the individual product, but it requires that final product has an item structure including the module item. One module-based product structure is defined in Figure 18.

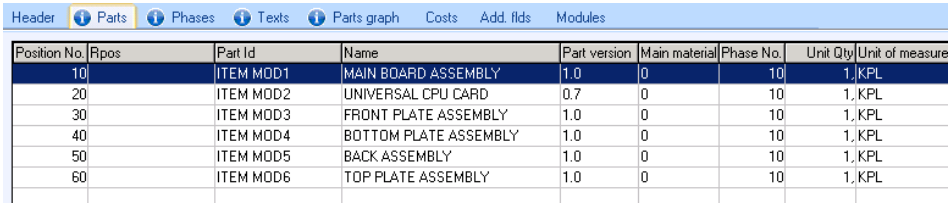

Figure 18. Module items/Spare parts

As seen in Figure 18, the product structures have only few components to checked. All of them have a visible Part Version next to the item code, but it is in a separate column. This component list is copied automatically from the item structure. The module devices of system structures can be updated directly to the machine register in ERP and it is readable without extra data mining process.

Fourth, when the business process management is willing to check the cost accounting of maintenance service where the purchase prices and sales prices are saved on the individual maintenance orders, the case company can analyse and maintain the real cost saving processes. This is based on the earlier traceability parameters and product price lists. The current product version vs. the required product version added with estimates of costs in upgrade processes multiply by number of products.

The case company has created several price lists including the service price list in ERP system shown in Figure 19. The components are added on the price lists in the item information section.

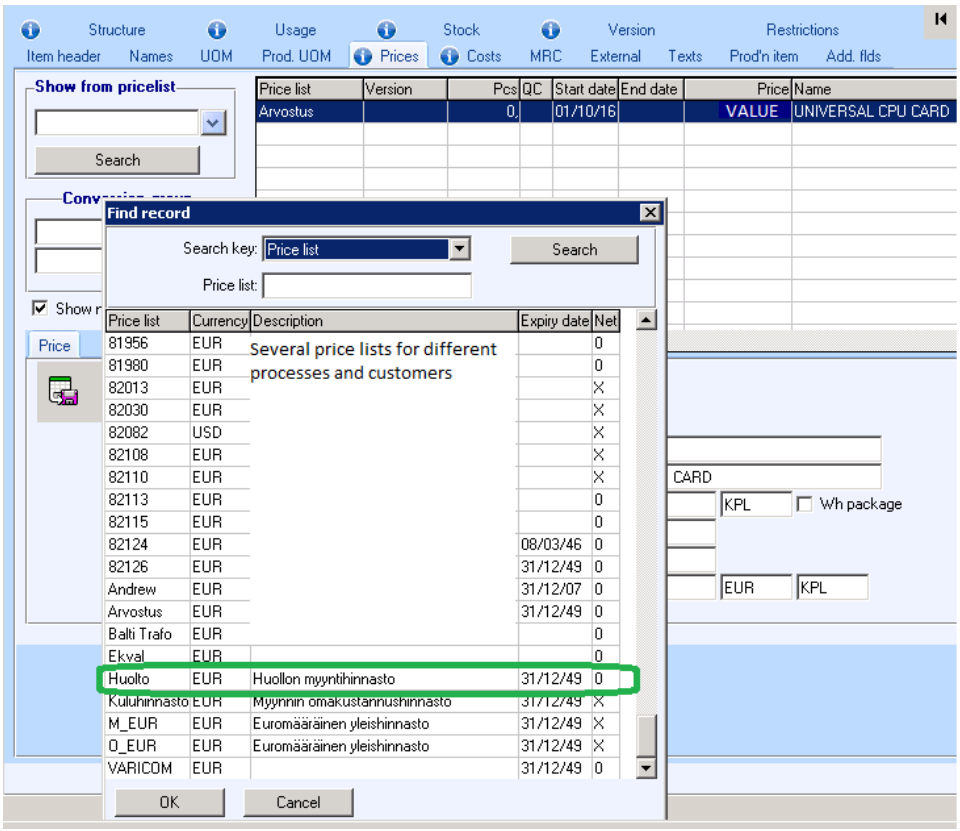

Figure 19. Price List of Maintenance Services.

As seen in Figure 19, Universal CPU card has listed valuation price in ERP system. All other prices are handled case by case in product maintenance service. The service price list named as ‘Huolto’ and general price list named as ‘M_EUR’ offer the cost accountable prices for spare parts and replacement units. They create the statistics of process effectiveness together with cost and valuation price lists created by other business processes.

A benefit of this service price list in ERP system can be seen in Figure 15. The lower orange frame is pointing out the item price (currently 0.00 Eur). This data is collected directly from the service price list, where the price is based on the profit margins and costs of one unit. The basis of cost estimate is calculated from the prices at the time of opening maintenance services and components and work can be re-valuated during the process only if it is necessary in profit losses. The Service Department does not need to wait supplier prices before giving the estimate of costs to the customers. If the selling price is calculated from one unit and the production costs are smaller in batches, such as 10 pcs, 20 pcs, 50 pcs asf., maintenance service can be more cost efficient through production planning of spare parts. The unnecessary cost estimates could be avoided with help of the automated service price list, which offers the sales prices for Service Department without asking around the purchase and sales people, or data-mining of the last sales offerings and purchase prices.

Finally, these proposal stages establish the PDM/PLM process for the case company. It is not limited only for the Service Department or customer services. Features in ERP system are used throughout the company processes from material purchase to waste recycling process. The amount of waste can be identified from the material information and develop different ways to reuse the material. Some material can be used as spare parts or modified to another product structures. The modifications can be done with minor changes instead of replacing the whole unit or module.

The message of possible product upgrade or a substitute item is recommended to add on the old product version, so that the product upgrade info is visible on that item version which must be upgraded in name of the product safety or other reasons. The necessary product upgrades are supported by the PDM system. There is work instructions and component lists for the product upgrade to avoiding time-consuming product structure comparison in the PDM system.

6 Validation of the Proposal

This section continues the proposal on the PDM / PLM process to the earlier products delivered by the case company. The section 5 discusses about the PDM / PLM process in beginning of the product life cycle and business point of view. At the end of the section 6, the final proposal consists of the process description and tools for PDM / PLM process.

6.1 Overview of Validation Stage

A validation stage refers to piloting the proposal with one product data in current product development project. The product is chosen from the products which are almost ready to transfer into production. This limits the product management process only under the project deliveries but provides an immediate and transparent product information in machine register in ERP system, which can be used later in product maintenance service.

First, the ERP recordings may be presented on the basis of software designers recommendations, enabling the enhancement of PDM / PLM process in all business processes of the case company. This information is made use of process description, so that ERP can support the business processes at the case company.

Second, The Executive Board of the case company discusses the company expectations for the final proposal. Their discussion directs the final proposal for the PDM / PLM process, even though the required process parameters and database features are investigated and introduced in the initial proposal.

Third, the proposal stages from section 5.5 are defined as individual improvements or improvement packages linked to each other. The established PLM process is being explored if product information can be updated even though the product structures during their production period did not fully correspond to the current product structure in the ERP system.

Finally, tools developed in this Thesis project are piloted with process data in Service Department. The piloting includes the new service reports and stock inventory of the spare parts.

6.2 Findings of Data Collection 3

Third round in data collection of this thesis consists of the database features. They are investigated how the product traceability in after-sales market have been designed in the perspective of system developers. The recommended system features are compared with company profile – accessibility in these features – and then defined the product management parameters for the case company.

Further discussions with inner stakeholders lead to the corrections in first assumptions of abilities for using the PDM and ERP systems. The prototype structure is created manually only at the top level of parts as the sample data in Figure 18. The production orders and modified by editing the item list, when needed in prototype manufacture. This link creates the product version information behind the Item code and the information follows the manufactured product from the process to another in PLC.

The challenge in the traceability of spare parts has been recognized. Production batches of the electrical subassemblies are mixed to each other in the case company processes after the spare parts has been removed from their package. The markings on the surface of the spare parts has improved. The CPU card in the new projects has got a label sticker which informs the item version without the Item code. All product structures are not followed similar way because the product data management has been designed to avoid heavy product upgrade process, which is caused by the minor changes in product structures. The embedded software and system products are upgradeable by customers. Therefore, these products are maintained in different traceability methods in test database.

Products' LCC and PVA can be done after accepted product structures are determined in the ERP system. Product information such as Product Version, Sales Price and Repair cost are followed on the monthly report of maintenance services. These parameters are presented under year 2018 in Appendix 4. The unified data saving process has been developed during the initial proposal where process parameters are defined and informed to stakeholders in the case company. The data is processed on the Excel spreadsheet, which offers the statistics for business process and product development processes.

The product data created in initial proposal stage is developed towards the tools inside ERP system where order processes creates the real-time product data. The improved product management process can be used in purchase and production order processes as well as logistics where supplier and customer information are linked to the PDM / PLM process. The ability to read the product data directly from the machine register inside the ERP system decline the process item which is used in data-mining process of product structures, price estimates and delivery information.

The final proposal focuses on data creation steps of the product data, which are defined for a business management process. The established PDM / PLM process focuses on the production, distribution and maintenance processes, but a main interest of the case company is to provide an easy product management process during the project deliveries. It is recommended to create the product traceability and identification according to the best practices in product development stages. Both perspective of the product maintenance and product development are noted in suggestions for final proposal of PLM process in Table 6.

Table 6. Service Department's suggestion for final proposal.

	Key focus area	Suggestions from MSU	Description of the suggestion
1	Process Description	Design processes as a demo production line.	When the product data in project deliveries is handled similar way than in PLM process, the product design steps answer the expectations of later processes.
2	Product Structures in ERP system	a) Link the product structures directly from PDM System b) Use the module structures to define the spare part assemblies.	a) The final product structure available for product upgrade process. b) Using the product upgrade process to change earlier module structures in maintenance services. Identifying the spare part modules for the current product structure.
3	Product revision visible in sales items	Use the product version feature in ERP system.	The descriptions of version update procedures to the old delivered products after data-mining process in product maintenance service. Required process impulses shared with earlier stages in process life cycle process.
4	Documented product change info	a) Document the product upgrades. b) Determine the necessary and available product upgrades.	a) Procedure instructions of product upgrades are published with a new product structure. b) Necessary product upgrades are informed directly on the product version which are not allowed to deliver to customers anymore. There are also several accepted product structures, which have available product upgrades, but the products LCA is recommended to define actions.
5	Determine the products EOL in a product structure level.	a) Use History Status for product items in PDM System b) Use the restrictions for use function in ERP System.	a) Before better understanding, all customer returns are individual cases and checked when requested by customers. b) If the all product structures are under maintenance services, none of the product structures are restricted. This can be achieved after the delivered products have Item Version in ERP System.
6	Creation of price list for spare parts	a) Save the product price in ERP. b) Determine the product prices and use a percentage reduction for sales quote.	a) Component costs can be determined for a longer time period in sales item, which are handled through price lists. b) A product or a spare part has a list price, which is determined based on the business objectives. The percentage reduction for sales quote can be used in individual cases for customer satisfaction without changing the traceability of business objectives.

As seen in Table 6, the product traceability and identification follow almost the same suggestions than in Table 5, but improvement in the final proposal is tools which share the information to each process after product maintenance service.

The suggestion is to identify the item versions in separate text field in databases, which eventually provides an ability to transfer product data from the PDM system to the ERP system. It is recommended to run for holistic product portfolio and product structures. The module items, spare parts, include traceable components from the manufacturing service provider to the customer in product maintenance services, therefore the item properties are recommended to change to traceable by batch identification.

6.3 Final Proposal Based on Findings of Data Collection 3

The final proposal of improved product management process includes definition of data creation steps and tools to achieve product identification in business processes. It answers the issues of the products life cycle assessment, which is needed in prototype manufacturing processes and project deliveries as well as product maintenance service at the product manufacture company.

6.3.1 Product Structures in ERP system

The product structures are transferred or created only at the top level of parts to ERP system, which uses revision handling for the product and module codes. This product information is a basis for the product development process in project deliveries. The final product structures are created/edited onto transferred product data and saved with own special version identification in project deliveries.

The manufacture and purchase order processes create ability to check individual product version directly from the ERP system and the product information is created according to the designed product structures in PDM system. This simplify the product traceability process and offers the evaluation of process efficiencies in every business process. The product structures can be followed in real-time statistics, which is based on the individual process recordings.

The PDM / PLM process can be built on the updateable product version information. The individual product is handled case-by-case according to the service instructions of the product version. A transparent product structure identification does not need data-mining process throughout earlier product life cycle, and the product upgrades are visible next to the item codes after maintenance process.

6.3.2 Product Change Info in PDM / PLM system

The product maintenance service requires the information of products EOL. This information is determined for product version, not only for product types. The product maintenance follows the product version information case-by-case and upgrade the product versions, which has meet their EOL. Eventually the all product structures have met their EOL and product supports can be closed and decision can be published to the customers.

It is recommended that maintenance procedures are completed in product upgrades. The procedure instructions are informed on the product version information, which is not allowed to dispatch to customers. This procedure instruction identifies the final product version and component changes between product structures. It may be possible that earlier product is worth to scrap rather than upgrade. When the all product versions have met their EOL, and the company does not offer any product support for the customers, this documentation shares a product information of the substitute item(s), which can be used in after-sales marketing.

A holistic product data management requires that product information is shared between all product management systems. The ERP system has ability to create automatic notifications as a pop-up windows when process recording meets the restricted product versions. This automatic feature does not allow to use the product versions in maintenance services, so products maintenance process can be run and identified for every product version.

6.3.3 Creation of price list for maintenance service

The product manufacturer offers product maintenance services or has partnership with another company. The product maintenance services have always cost prices: work,

spare part, handling, technical support and product development or any other costs related to product maintenance.

The maintenance orders handle the individual products traced by serial numbers. The traceable module items can be followed from purchase orders through service order to sales orders traced by the serial numbers and module batch information. The service price is defined for spare parts and maintenance work which is saved into the price list for the process recordings. An invoice details define a total cost of repairs determined by the order type of individual item. The total repair cost includes all the costs under the maintenance order, but can be reduced with invoiced items, when company manages to sell product upgrades.

The costs of maintenance services are linked to the individual products providing the real costs of PLM. The challenges in cost estimates is maintained by Business Management Unit, where decisions are made based on the products' LCA and financial figures in service business. Currently the service price list is maintained by Service Engineer, which keeps the sales prices up-to-date with help of the Sales Team. Spare parts follow their profit margins, costs and stock inventory. The ERP system reduce needs of discussed price estimates in preliminary service offers. It informs the last fixed price for individual spare part, which can be used in calculation of total price of the individual service order.

6.4 Final Proposal

The final proposal for established product life cycle management process uses the database features designed by the software companies. The system features are linked to each other and product information is shared with other processes from the data creation step to further product life cycle processes.

The product designers create the product data on the PDM system, where the data is transferred or created accordingly the original product structure to the ERP system and used as it has been designed. When the project deliveries in product development projects requires further development of product structures during the prototype manufacturing process, the product changes can be stored on the production orders and copied as a special version of the product item. This procedure creates the transparent product version on the machine register (see the Figure 13), which is shown always when the

individual product is handled in processes. The version number is once created, but the process efficiency is done for the coming processes such as stock inventory or product traceability in product crisis.

The PLM helps the case company maintain products' installed base, when the product versions are maintained in sales items. The basis of business development process is built on the product life cycle data, product and customer information. The product data management is built on the same item identification and product structures in all product management systems and data is transferred from system to another when it is possible.

The order processes use only the stored data in ERP system. Missing product management data is created into the system, if it cannot be transferred from elsewhere. The data savings can be shared with other order processes without extra work after the data is created or updated. When the extra information is needed, that is added on the system data, which can be used in statistics provided by the system tools and available directly to other stakeholders.

6.5 Recommendations /Action Plan

The stages of initial proposal are taken into use in data creation steps to share the product information right after the products represents some product structure delivered to customers.

The first step is to determine the company ability to fulfil the manufacturers obligations in the business area, in which the company delivers products. The required process data and creation steps of product data are defined for continuous process development to fulfil the stakeholder expectations of other business processes.

A suggestion for product management process is to build new check point in product development projects. Product life cycle assessment and the product change info is stored under product version when it is defined as unreliable product structure.

The project deliveries include only final products, which does not need the module traceability in prototype production. This is fact, when purchase orders include only the product items without modules. The challenge in module traceability is recognized only in the

product maintenance service which uses the modules as a spare parts and assembly them into the old units. The solution of this challenge is not in high priority in product management process point of view at the case company. It is vital to product manufacturers and repair service providers to trace spare parts, because a production batch may need recall process. Therefore, it is recommended to trace product modules from the production to customer.

7 Conclusions

This section discusses the final proposal as defined in the previous section compared to the Thesis objective. It contains a summary of the study and managerial implications before it revises the reliability and validity of the study based on the evaluation criteria.

7.1 Executive Summary

The objective of this thesis is to establish product life cycle management process to enable access to immediate and transparent product version traceability information. Transparent product version becomes even more important in case company's business area where sustainability and customer services affect to the company performance.

The study is conducted as an action research. It analyses the current PDM / PLM process by interviewing the inner stakeholders of the case company and analysing product data quality in order processes. These results are compared to the existing knowledge of product traceability and products' life cycle management. An initial proposal consists of process improvements in early stages in product life cycle where the company core competence is strongly present. The final proposal is developed for customer services to maintain products' installed base and technical support with other partner companies such as suppliers and service providers.

CSA's interviews reveal that the product management process is just about managing product information, which is the responsibility of the R & D department. Processes are planned under the terms of the R & D department, where a challenge is to maintain product information in aspect of the product maintenance operations provided by MSU or by another service provider. The current state of product management process is not 100 % sure, which can lead to situation that necessary product upgrades is not completed or the module structures are mismatched to each other under product maintenance service.

The proposal of improved product management system utilizes two databases in case company. The PDM system is fully independent for product development projects and outsourced manufacture services. The order processes use the similar product structures at the level of final assembly inside the ERP system, where purchase order process

use the item version identification of the module structures. The module structure works as spare part list for product maintenance service and is traceable in stock inventory. The product structures are directly separated from each other and material traceability follows its value-chain from the supplier to the customer allowing the claim and product recall processes be directly followed by the process traceability info such as product batches in purchase orders.

The proposal of improved PLM process piloting is run in ERP test database. The maintenance service unit use database tools to collect the defined data from the stored product data, where process costs and product structures are informed in minor efforts with help of the price lists and item lists. The units are handled individually throughout the life cycle processes, and process recordings allows the use of statistical tools to generate improved product management process without tangible products itself.

The business process management gets benefits in both product maintenance services and product development services. The transparent product version identifies defective products in a product version level, when the earlier service statistics revealed only the product type. The products life cycle costing can be evaluated based on the real-time product data.

7.2 Managerial Implications

The final proposal refers to the process improvement throughout the company processes, although this study focuses on the perspective of the product maintenance service. The product version information provides proactive approach to maintain company products in outsourced order processes and customer services.

The proposal of improved product management process expects more attention to a product information in product development and production stages. The product development stage is affecting in product life cycle costing. The most of the product maintenance costs can be reduced in good design processes of product structures and documentation. When the product structure is determined under restricted product version, the system informs the nearest available product version or a substitute item defined by the product designers. This is a check point in project development projects, where the products have several versions available in the system and some of them requires more

work and spare parts than others. The product information supports directly the Maintenance Service Unit to achieve cost efficiency in the customer services.

The same product item gets a version information which separates the items in product lists. That means more rows in order documentation but less work in product traceability and identification. The knowledge of the obligations is recognized in company operations for PDM / PLM, in which the obligatory and optional process parameters are notified in every process from the company perspective, not separately operating business units. The products are recommended to mark visually with item and item version information to achieve the possibility to recognized the product visually without any other data source such as product package or parental product item. The spare parts are treated as finished products.

Proposal stages are defined as an individual or package improvements based on the ability of current product management process. Some parameters of the product information database are more important than others, but closely related to the business processes. The product price is not obligatory product information, but the product management process gains efficiency with price lists inside the ERP system. Although the product and process costs and sales prices are not constant, the default price directs the service offerings to sustainable level where the company covers own costs in value-chain of customer service. There is not income in every maintenance orders, and the sales price is 0.00 Euros, but the default price reduce the time-consuming price evaluations with sales department on the individual cases.

The proposal of the PLM process includes process parameters of several subprocesses. In addition, the PLM process refers to the business processes. Therefore, the PLM process can be utilized in calculations of process efficiency in the self-assessment using the quality management principles. The PDM / PLM process improves continuously with its subprocesses. The service price list gets new items every time, when individual case is closed.

Piloting phase is at high priority. The project is running at this moment but needs human resources to run that through every production process. The service request of ERP system features must get replies from the technical support from ERP system supplier before the demo phase can be continue to product repair services. Monthly report of

product maintenance service utilizes the new price calculations on the maintenance orders but does not include replacement units or warranty repair. The report is ready to handle product version in repair processes.

7.3 Thesis Evaluation

This thesis follows commonly used steps to establish the quality of any empirical social research. Yin defines four case study tactics for design tests. Concepts that have been offered for these tests include reliability, confirmability, and data dependability (Yin, 2009, p. 40). An action research leaves the theory to the readers responsibility. Blichfeldt and Andersen summarize differences between action research and case study:

> "the transparency of research processes in action research can be improved by articulating and discussing (a) the framework of ideas brought into the study and (b) analytical generalisation of findings." (Blichfeldt & Andersen, 2006, p. 5)

Discussions and the number of participants in action research provides several ideas brought into the study. The more members in the research team, the more aspects they build on the research results. The usefulness of interviews has long been recognized in social sciences, but there are also criticisms. Interviewees are selected to support expected research results or people are dishonest in research topics (Alshenqeeti 2014, p. 44). Ethical issues should be considered at all stages of the interview process. A validation of action research requires two conditions. The first condition is that the new system provides valid signals for management actions. The second condition is the skill and knowledge after the piloting stage in process development (Kaplan 1998, p. 110).

Näslund et al. (2010, p. 335) highlight that researcher traits have a potential to introduce their own bias in a research. The author of this article has a role in customer services and company safety, so one way to reduce bias is to clearly describe the role of the author (Turner 2010, p. 756). To avoid leading questions, open questions might be too broad to map the current state, which leads eventually to the situation that further questions must be represented in future.

In this thesis, questions were formed to achieve a holistic picture of how the interviewees see the research topic. Firstly, the result of the interviews helped forming the starting point for the literature review regarding what to search and study for the next interview

round. Second interview round guided the process development in the company processes at early stage of PLM before product maintenance service. The suggested parameters of PLM process were commented by workshop participants. Third interview round had challenges in final proposal of PLM process. It took too much time to get results from the workshop and from the technical support of the ERP system provider that product data recordings of product maintenances services could not be improved with all discovered process parameters.

A research is reliable when its result is repeatable and other researchers arrive at the same findings and conclusions (Yin 2009, p. 45). The reliability is well documented research procedures and findings. Participation of several researchers enhances the reliability and diminish the biases of the individual person. since the risk of bias is reduced with several researchers collecting evidence. (Näslund et al. 2010, p. 336)

In this thesis, research reliability consists of interviews and operational measures through data-mining process. The reliability of the interviews was guaranteed by recordings and questionnaires, which can also be used in later studies. Author’s and managers’ own biases are strongly present in this study, where their own interests conflict to each other, but workshop approach for the initial proposal of product life cycle management process was managed to arrange before dead-line of this study was ended. All the topics mentioned topics of this thesis are in the author's own project where other people's opinions are being asked alongside their daily work on a case-by-case basis, but some essential guidance is needed to pilot the final proposal of PLM process.

Operational measures have the same database available. Determining the same time interval for data-mining process beyond the improved product data management and comparing the results to the product data created by proposal of improved product management process. There is number of cases which can be researched, and they include data differences although the same research topic. The reliability depends on the age of the cases that are under research, so the time range is essential to determine before the research of data-mining methods. The improvements of transparent and immediate product management process are confirmed with improved data recordings and statistical tools in MSU.

The result of this research is a final proposal for the implementation of an improved product life cycle management process. The interviews reveal the status of the product management process in the case company at the interviewing time and from the interviewees personal point of views. The data-mining process tells the situation from a longer period of time, when product data quality is measured in both current analysis and the initial and final plan stages. The literature review answers the questions for best practices, but company resources affect these conclusions and discussions. The literature sources contained laws and standards. The laws provide a reliable source of minimum requirements. Standards defined reliable quality requirements. The procedure instructions work as a reference for the earlier practices at the case company. The proposal of improved PDM / PLM process description is created for the further process development projects lead by the top-management team at the case company.

The relevance of this action research is the improved product management process for the case company. The research provides product traceability and data-saving procedures for maintaining the improved product management system. Firstly, the transparent product traceability system is ensured by the data mining process, where all process steps from the purchase orders to the products' EOL have been taken into account. Still the individual actions are planned by employees themselves in the processes, where product traceability has been recognized as shared information, faster processes and the quality of stored data. Secondly, the research audits the case company's product management process towards the national legislation and ISO standard requirements. The research report can be used as a process quality documentation at the case company.

7.4 Closing Words

The study offers lots of thinking in SME companies, which have challenges to operate in global or continental markets. The literature review provides the perspective in after-sales business which can be used customer services and manufacturers service design.

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Research Interview Template

vs Jan 2018

TOPIC: Product Management System

Information about the informant (Interview 1)

Table 1

Details	
Name (code) of the informant	
Position in the case company	
Date of the interview	
Duration of the interview	
Document	Field notes

Field notes (Interview 1)

Table 2

	Topic(s) of the interview	QUESTIONS	FIELD NOTES
0	**Product traceability in a Product Management System**	A focus on this interview is a case company product management process and a product traceability at interviewee's own work.	The purpose of this interview is to determine the product management systems are recognized and used in the company operations.
1	**Starting point 1:** **Product management in the company**	What kind of product management systems are in use at the company? Name the systems and define the purposes.	
2	**Interviewee's** **Experience**	Which systems are related to your work? How the product structures are related to our work? Explain functionalities and contents in these systems.	
3	**How the product management is implemented in the company?**	What are the product management objectives?	

		How is product version implemented in your product management system? Which product-related information do you think will need to find out about the systems you use?	
4	**Find out the requested and entered information for product management**	What product management information is used for your job? who maintains information on systems?	
5	**Strengths**	What are strengths of the product management process? How these strengths have been utilized? Which meters are used to measure the product information?	
6	**Concerns**	If you find any disadvantages, what are the reasons for their existence? What is your concern about developing a product management process?	
7	**Analysis**	How different product versions can be specified in the results of your work?	
8	**Best practices**	Does the company have guidelines for implementing product management processes? What product management issues should the company follow conscientiously?	
9	**Development**	In what area do you see development needs?	

		What would you develop? How? What and how do you develop product management in your job? How can a company avoid product management problems?	
10	**Addiotional information**	What would you add to the development of a product model that did not yet speak?	

Process Development Discussions

vs May 2018

TOPIC: Product Management System

Information about the members of discussions

Table 1

Details	
Name (code) of the informant	TD, PM, TE, CO
Position in the case company	Tester Designer, Project Manager, Technician, Controller
Date of the interview	May 10th 2018
Document	Field notes

Field notes (Interview 2)

Table 2

	Topic(s)	Problem	FIELD NOTES
0	Use informative product version with product items in ERP system	Product version does not exist, when the product must be dispatched to project customer.	TD: The special version in ERP system is usable database feature. PM: The product structures can be transferred to ERP system. TE: I agree with the visible product version, but who manages the process. It is not my responsibility. CO: Yes, it could help us in several order processes.
1	Establishing PDM / PLM process	It is not necessary in product design phase, because the products are prototypes.	TD: It would be good to recognize the product structures from maintainable products. PD: I do not have opinions about the processes. TE: Let see later, if we have time. CO: It must be important for you (service technician). I see that you have done lots of research work.
2	Transfer the product data information from PDM system to ERP system	The product structures are not real, because product designers may change the components in the process. No new items have been opened in the system.	TD: If it can be done, why not PM: I do what you want in PDM system. Product designers are responsible to update the product structures, but the product deliveries cannot wait that. TE: Who manages the process? It is not my responsibility. CO: If the product information already exists, why do that twice.

Meeting Minutes of the project of PDM / PLM

Call to order

A meeting of PDM / PLM project team was held at Neukkari 3 on May 21st 2018.

Attendees

Attendees included **Service Engineer, Quality Manager, Project Manager, Technician, Logistics Coordinator, Buyer, Vice President,**

Members not in attendance

Members not in attendance included **Director of Operations**.

Approval of minutes

Not needed. Task list shared to attendees.

Reports

Results of the CSA of PDM / PLM process and best practices of Product identification and traceability was introduced to attendees. The team agreed to investigate the product version handling in prototype manufacture process to enable immediate and transparent product identification in ERP database.

There is need for further investigation in outsourced processes, because all processes have to be redesigned when the product version is in use. For instance, purchase order process uses own product identification codes for assembled but not tested products. Change this procedure could cause extra work to suppliers.

Executive Board of the case company instructed that a system product of current R & D project would be the target in the piloting stage of the improved product version handling. There is no product structure for the system product. In other hand, its converter module is almost ready. Therefore, the converter module is the first sales item for this piloting stage.

Unfinished business

An improved product version identification is in the highest priority; therefore, the process development focuses only on that. There is no need to interfere with the sales prices and the traceability of the production batches

New business

Establishing PLM process continues under product development project in material purchasing process, where purchase items are corresponding the product structures in PDM system.

Announcements

Project Manager creates the module structure for the chosen converter product. Buyer and Service Engineer checks how the product structures can be utilized in purchasing process before next purchase order is in process.

	23 May 2018
Secretary	**Date of approval**

Monthly Report of Product Maintenance Service

Parameters of product management process in Maintenance Orders. PDM / PLM process improvement highlighted in **bold text.**

2017		2018
Reception Date		Reception Date
Maintenance Order		Maintenance Order
Customer No.		Customer No.
Customer Name		Customer Name
Item (Product)		Item (Product)
Serial Number		**Version (Product)**
Outside Serial Number		Serial Number
Fault Description		Outside Serial Number
Maintenance Order Type		Fault Description
Reason Code		Reason Code
Effect Code		Effect Code
Work Description		Work Description
Item (Spare Part)		Item (Spare Part)
Quantity (Spare Part)		**Version (Spare Part)**
Storage		Quantity (Spare Part)
Purchase (True/False)		Storage
Delivery Date		Purchase (True/False)
		Maintenance Order Type
		Address
		Delivery Date
		Cost Price
		Price (Service Price List)
		Sales Order No.

Manufacturers Obligations in Product Traceability in EU / Finland

European Commission's The 'Blue Guide' on the implementation of EU products rules 2016:

> "The central role that the concept of making available plays in Union harmonisation legislation is related to the fact that all economic operators in the supply-chain have traceability obligations and need to have an active role in ensuring that only compliant products circulate on the Union market. (European Commission 2014, p. C 272/18),
>
> Union harmonisation legislation applies to finished products. Yet, the concept of product varies between different pieces of Union harmonisation legislation. The objects covered by legislation are referred to, for instance, as products, equipment, apparatus, devices, appliances, instruments, materials, assemblies, components or safety components, units, fittings, accessories, systems or partly completed machinery. Thus, within the terms of a specific Union harmonisation act, components, spare parts or sub-assemblies may be regarded as finished products and their end-use may be the assembly or incorporation into a finished product. It is the responsibility of the manufacturer to verify whether or not the product is within the scope of a given piece of Union harmonisation legislation (European Commission 2014, p. C 272/16)
>
> From a manufacturer's perspective traceability matters because it enables effective control of the production process and suppliers before the marketing of the products, and control of their distribution chain after the placing of the product on the market. In case of non-compliance, manufacturers are able to reduce the impact of recalls or withdrawals depending on the detail of their traceability system.
>
> The manufacturer has to comply with this obligation regardless of his location (within or outside the EU). This provision implies that products sold without packaging or any accompanying documents, must bear the name and address of the manufacturer on the product itself. "(European Commission 2014, p. C 272/52-53)

The Finnish Electrical Safety Act complies with EU harmonization guidelines from 2017 onwards. Obligations for the economic operators have been listed by TUKES, Finnish Safety and Chemicals Agency. The lists state the key obligations associated with making electrical equipment available on the market. (TUKES 2014, p. 20)