LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY
LUT School of Engineering Science
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Bio-based Process Engineering

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Master's thesis

PRODUCT DATA MANAGEMENT AS A RESOURCE-SAVING FOUNDATION FOR THE PRODUCTION CHAIN

Examiner: Professor Satu-Pia Reinikainen
Supervisor: Teo Kostilainen

TIIVISTELMÄ

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TUOTETIEDONHALLINTA RESURSSIEN SÄÄSTÄMISEN PERUSTEENA TUOTANTOKETJUSSA

Diplomityö

2020

80 sivua, 32 kuvaajaa, 1 taulukko ja 1 liite

Tarkastaja: Professori Satu-Pia Reinikainen
Ohjaaja: Teo Kostilainen

Diplomityön tavoitteena oli tunnistaa, ratkoa ja havainnollistaa tuotetiedonhallintaan ja nimikehallintaan liittyviä riskejä ja tuoda esiin niiden mahdollisia tunnistus– ja ratkaisukeinoja eri suuruisille yrityksille. Erityisesti nimikehallintaan suunnattujen lisäresurssien kannattavuutta on kyseenalaistettu, sillä sen arvontuottoa on ollut vaikea näyttää toteen.

Työssä teoreettista tutkimusta suoritettiin tutustumalla alalle ajankohtaisiin kirjallisuuslähteisiin. Lähteistä valittiin tutkimuskohteiksi erityisesti ne, jotka käsittelevät nimikehallinnan riskejä ja arvontuottoa. Tutkimuksen aikana aiheeseen liittyviä ongelmia kartoitettiin myös kyselyllä, johon vastasi teknisellä alalla työskenteleviä henkilöitä. Työssä esitetyt esimerkit on luotu empiirisesti havaittujen tilanteiden, sekä kirjallisuudesta ja kyselystä kartoitetun tiedon avulla.

Tulokset näyttävät tekniikan alalla yleisesti ajankohtaiset ongelmat koskien PDM-järjestelmiä sekä nimikkeitä, sekä esittävät yleisellä tasolla niihin ratkaisuja. Kartoittamalla riskikohdat huomattiin, että tuotetiedon ongelmat yksittäisen nimikkeen tasolla ovat usein helposti vältettävissä. Ongelmat ovat usein seurausta joko toimintatapahäiriöistä, epätarkasta ohjeistuksesta, datan omistajuuden hallinnan puutteesta tai säännöllisesti havaittujen ongelmien sivuuttamisesta. Jos näihin asioihin ei kiinnitetä yrityksessä tarpeeksi huomiota, ne yhdistettynä järjestelmistä aiheutuneisiin hidasteisiin, laittavat yrityksen automaattisesti huonompaan asemaan verrattuna kilpailijayrityksiin.

Hakusanat: product data management, item management, itemization, risk management

ABSTRACT

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The goal of this master's thesis was to identify, investigate, solve and illustrate potential risks associated with product data and item management, and bring possible ways to resolve them for companies of all sizes. Especially the viability of putting more resources into item management has been questioned, because its additional monetary value has been very difficult to demonstrate.

In the thesis theoretical research was carried out by studying literature sources that are currently relevant to the field. The sources focused particularly on the literature on risk management and value-adding of item management. During the study, a survey for employees working in the field of technology was also conducted to map risks related to product data and item management. The examples presented in the thesis have been created through empirically observed situations in the field as well as by using knowledge received from the literature and the survey.

The results will reveal the technology companies' general current issues regarding PDM systems and item management, as well as their solution methods on a general level. By mapping the risk areas, it was discovered that problems of product data at the item level can often be easily avoided when discussing a single item. It was discovered that risks and delays that occur because of poor data are usually the result of either misuse of systems and procedures, inadequate guidance, deficiency of ownership management or neglecting often observed issues. If the aforementioned issues are not taken care of, they, together with the problems and slowness caused by the system(s), put the company in a worse position compared to its rival companies.

Keywords: product data management, item management, itemization, risk management

PREFACE

This thesis was made possible by my employer Etteplan Oyj, which has been flexible and helped me adjust my studies to working at the same time. Even before this study I was working as a member of an item data management team, which further inspired me to do this thesis about the subject. The purpose of the thesis was to support and utilize the knowledge accumulated in my working experience and in my studies so that other people working on the same issues would also benefit from the work. Thesis aims to expose harmful PDM and item related working methods in companies by providing some practical examples.

My student years at Lappeenranta University of Technology have been enriching and full of work. First, I want to show my gratitude towards my family who have supported me during my studies. Secondly, I would like to say special thanks my Thesis supervisor professor Satu-Pia Reinikainen and Teo Kostilainen for the feedback and insight thoughts that I received during the process. Finally, I want to mention my colleagues in work and study who have travelled with me on this journey, thank you!

Aleksi Matilainen

Aleksi Matilainen
Helsingissä 22.03.2020

CONTENTS

SYMBOLS AND ABBREVIATIONS

PDM = Product Data Management.

ERP = Enterprise Resource Planning. ERP is a system that combines other software and systems used by the company to facilitate and transfer information between them.

MDM = Master Data Management

PDF = Portable Document Format. PDF is a popular file format which can be used, for example, for datasheets, documents and pictures.

LCM = Life Cycle Management

LCC = Life Cycle Costs

MSDS = Material Safety Data Sheet

EDM = Enterprise Data Management

SFS = The web service of the Finnish Standards Association for SFS Ry, which includes a wide range of standards.

BOM = Bill Of Materials, BOM is often referred to as the product's structural list. However, BOM does not necessarily include all of the parts that come with a particular product but is generally made up of a so-called flat list of components which are included in the certain product.

RoHS = Restriction Of the use of certain Hazardous Substances in electrical and electronic equipment directive.

VMI = Vendor Managed Inventory

IoT = Internet of Things, IoT is a system that allows devices and systems with unique identifiers to transfer data and communicate to each other over the internet without human intervention.

LIST OF FIGURES

1 INTRODUCTION

Product lifecycle, data and item management are now standard for many companies, especially at larger ones. However, the often-promised added value of product management is often difficult to prove (Saaksvuori, 2016). The companies have also gained a lot of benefits through product data management systems. Product related data management often involves trade-offs within companies because companies do not want delays in deliveries or manufacturing due to data management related delays. Today's companies, which are often also spread over multiple locations, also face a variety of risks, delays and challenges related to product information management. Working methods that have been around for a long time make it difficult to detect methods that are inefficient or harmful. The purpose of this thesis is to demonstrate common but often unidentified risks associated with product data management (PDM) and items. One of the goals of this work is also to give the reader examples of risk locations and thus help identify risks associated with product and item data management in their own company.

1.1 Reason for study

The objective of this thesis is to point out the benefits and savings that PDM and item management generate inside the organizations. Industrial maintenance of information available about products inside of the company could often be better and more accurate. An increasing amount of data can cause harm and unnecessary work throughout the supply and manufacturing chain which could in many cases be optimized with a reasonable amount of work. The idea of this study was to understand how the hazards and misuses associated with product information and items can be detected and avoided.

1.2 Goals for the study

The aim of the thesis is to study how proper item management can be used in the companies to create a more cost-efficient and safer working environment. Another goal of this thesis is to provide a compressed information package about product data and item management's pros and cons. In the last few decades many companies have decentralized their

manufacturing and design processes around the globe, which further increases the requirements and needs for better data quality. Through this work, I hope to gain a better understanding of the different aspects of product data management of the company and to assist potential future readers of my work with the same questions. This thesis is also meant to be useful to new employees working among item and product data management.

1.3 Research questions

Product data management affects almost all organizational units of the company. The information should be easily accessible globally and locally. Because there isn't currently a lot of literature available that concisely discusses the benefits and problems of item management, the research questions during this thesis are:

1. Where does the value of product data and item management come from?
2. What are the noteworthy things about using or designing an item database?
3. What should be considered when handling item data regarding chemicals or prohibited ingredients?

1.4 Research methodology and structure of the work

The research method of the study is qualitative, which aims to approach the subject as openly as possible. The methodology of the thesis sits between case and survey study, in which the essential benefits and risks of product and item management practices are mapped with the help of literature, survey and case related information. In the theorical section some topical sources were used to benefit from the latest academical knowledge, whereas the observations and interviews create a picture of the scale of the problems inside the companies. As the work progressed, information was collected from the sources listed below:

Literature reviews: Material was searched by using online science databases such as LUT Finna, Proquest central and Springer eBooks. Standards were obtained by using SFS online. Also, some books were purchased for the work from Amazon and Ebay online stores.

Observations: Working for more than two years in product data management related roles has provided me with a good starting point for making observations in this area. The observations seek to address issues that are essential to item and product data management even though they are not necessarily obvious in the literature.

Web-based query: The query was executed through an anonymous web form. Students, as well as the employees of Etteplan and other companies working in technical field, answered its questions using a web browser. The query was used to survey the perceptions and observations of employees in different positions within companies regarding product data and item management.

In the thesis, the aforementioned information was utilized. At the end of the thesis additional research results and conclusions are stated based on the literature review, observations and the query. The stages of the study are presented in Figure 1 below.

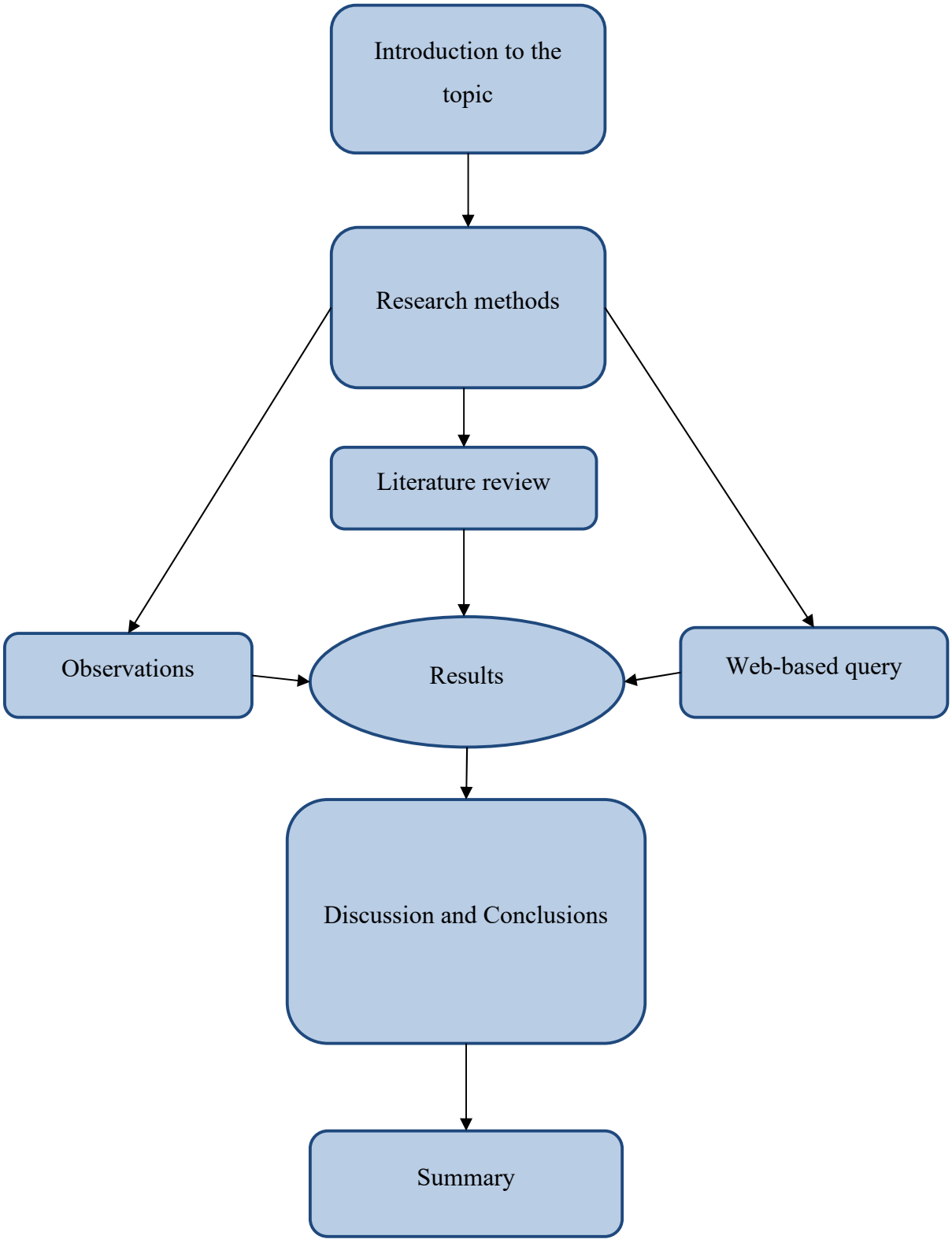


Figure 1. Structure of the thesis

2 ETTEPLAN OYJ COMPANY PRESENTATION

Etteplan Oyj is a Finnish company headquartered at Vantaa, Finland which was founded in 1983. It provides technical solutions for the customers in the following fields: technical documentation, traditional engineering, product development and embedded solutions. In 2018 Etteplan employed around 3400 personnel in many countries on different continents around the world. (Etteplan, 2019)

Etteplan's competitive edge comes from the wide scale of knowledge in many different fields which can be used together to make solutions, creating added value to the customer companies.

In the past few years demand and interest towards product data and item management has increased among many old and potential new customers. It has been noted in almost every business field that the better the data is, the easier it makes everyday work for everyone somehow linked to it. One goal of this work was to provide factual material about item management, which can be utilized for example in the future marketing presentations.

3 INTRODUCTION TO PRODUCT LIFECYCLE, DATA AND ITEM MANAGEMENT

Digitalization over the last few decades has changed the way companies manage data. The changes have had several benefits, but new challenges have also arisen. With an increasing amount of information available, a small single error in product or customer databases produced by an employee can lead to significant losses for the company. Today, almost all companies, depending on their size, have some kind of digital systems which are used to manage customer and product related information. In the Product Lifecycle Management (PLM) related field, there have been often debate about how much should be invested into product data related activities such as item management. In addition, there has been disagreement about the profitability of the investment. Businesses often find it difficult to see the benefits of product management, because they are often related to utilizing legacy information and reducing work repetitions. Other benefits that are often difficult to verify include quality improvements, reduced risks and increased competitiveness, which are directly linked to the aforementioned benefits (Keshab, 2018, p. 8-9).

The company's size and business sector often also have a direct relationship with its requirements for product data management methods. In smaller companies, the amount of product related information and products is often lower compared to the larger ones. However, small companies should not ignore product information management and itemization, as the number of hours lost in a smaller company is often reflected in an even greater loss due to the lower number of employees.

PLM is a plan for the company about how to handle product related information in a practical way. It, as a concept, involves all the necessary product related information which is essential to everyday business at the company. PLM includes procedures, guidelines, instructions and methods to handle all product related data throughout the product's entire lifecycle. Product data management (PDM) is a tool to manage product information as the product moves through its life cycle. PDM is often included as a part of product life cycle management (PLM). PDM is a key component, usually a system or software for PLM, providing helpful data for all other segments in every business (Peltokoski, et al., 2014).

Organizations spend a lot of resources and working time to collect information about products, raw materials and business intelligence (Alrayes, 2015). The last thing that they want is to misplace, misinterpret or lose this kind of information. The cost of poor-quality data is usually difficult to determine, because its drawbacks are not shown immediately. PDM provides tools for handling this information so that it can be beneficially used by the company (Peltokoski, et al., 2014). PDM more specifically allows companies to save, edit and control product information and documents, by providing information which benefits the total lifecycle of a product from designing to decommissioning and recycling.

The quality of the PDM system that handles organizations data must be evaluated in a way that takes into account all the components throughout the supply chain (Alrayes, 2015). All product related data is handled throughout the lifecycle of the product. An item that has been created to describe the product goes through the same life cycle as the product. PDM as a concept includes item management, which is usually directly linked to customer data and location data management. PDM systems allow users to store and edit product information. This kind of product related information usually consists of documents, items and BOM (Bill Of Materials) structures. The data should be provided in such a way that it can easily be updated and accessed by the designated users (Miller, 1994). Without the ability to update and provide information companies could end up spending enormous amounts of money on products which have been already designed or designed but subsequently found to be impossible to manufacture by a partner or subcontractor company (Fulcher, 1998).

Today's technologies enable businesses to store, access, modify and update information in a variety of ways. Many product data management methods used by the large enterprises have lagged behind today's software and global requirements. Product and customer information databases often contain information in a form where it is not possible for the company to take full advantage of it. Most companies are not aware of the deficiencies in their product data and information management. Existing data management methods can work in the current situation, but the opportunity for more efficient productivity is overlooked. The overall data quality inside the company correlates with its efficiency during tough times. In this way, the company gets more of its core operations, such as service and

maintenance, and is able to perform them more cost-effectively also even during economic decline.

Maintaining a correct and good product information database is not free for the company. It requires constant designing, maintenance, updating and product information gathering. Ignoring the requirements of good product data handling will prevent from getting the most out of it.

3.1 Item management

PLM and PDM use “items” to organize and use information in these systems. The main purpose of item is to provide product data in a form that can easily be utilized in other processes inside the company throughout the whole life cycle of a certain product, component, raw material or assembly. Corporate segments, such as designing, service and marketing benefit from items in several ways. Product related information is managed in the PDM system with the items that have specific and unique identification codes used by the company and the product providers. One of the main purposes of items is to ease access to information inside the company and to facilitate maintenance as seen in Figure 2.

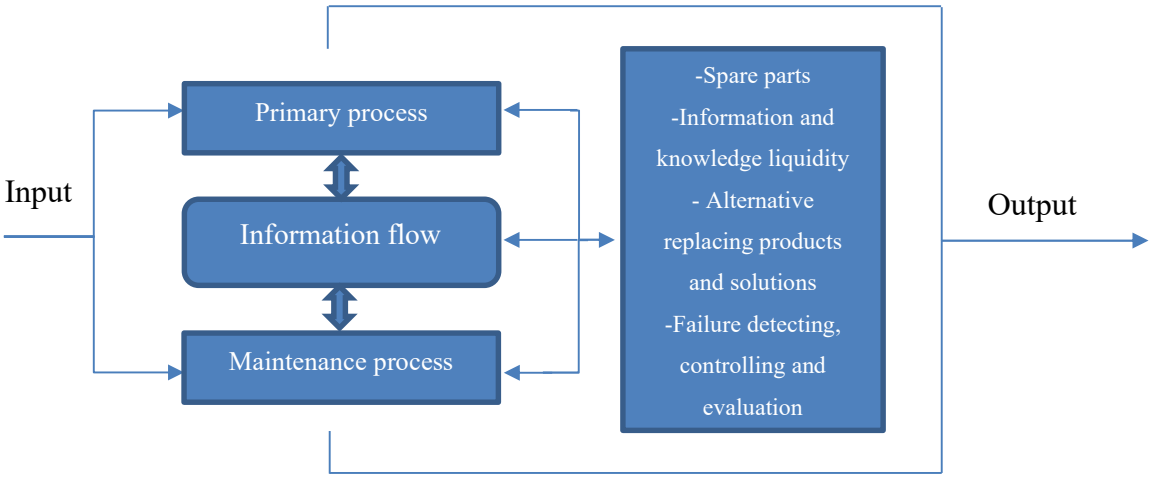


Figure 2. Relationship between the primary process, information flow between the processes and maintenance process. Adapted from Zhu et al (Zhu, et al., 2002).

PDM systems also make it easier to outsource such activities to other companies. An item which has been generated to describe the product in the PDM system goes with the product

throughout its entire life cycle (Hans, et al., 2010). It is essential for the functionality of the item management that the concept is well thought. The creation and management processes of items should be carefully designed within the company. Different software programs, raw materials and products pose a particular challenge to item management. Therefore, item management procedures should always be done based on the specific needs of the company. The item that contains product information will accompany the product through the products entire life cycle as seen in Figure 3. The product is usually in its final stages of its life cycle with the customer company. Outsourcing of maintenance services can be economically viable and often frees up resources for other tasks. Also, the ethical recycling and reuse of products, which is receiving increased attention from customers and authorities, will benefit from proper product data. However, for such opportunities, the company must be able to manage information on the items so that their use does not require prior knowledge of the item itself, and the data can be fully relied upon. (Sinkkonen, 2015)

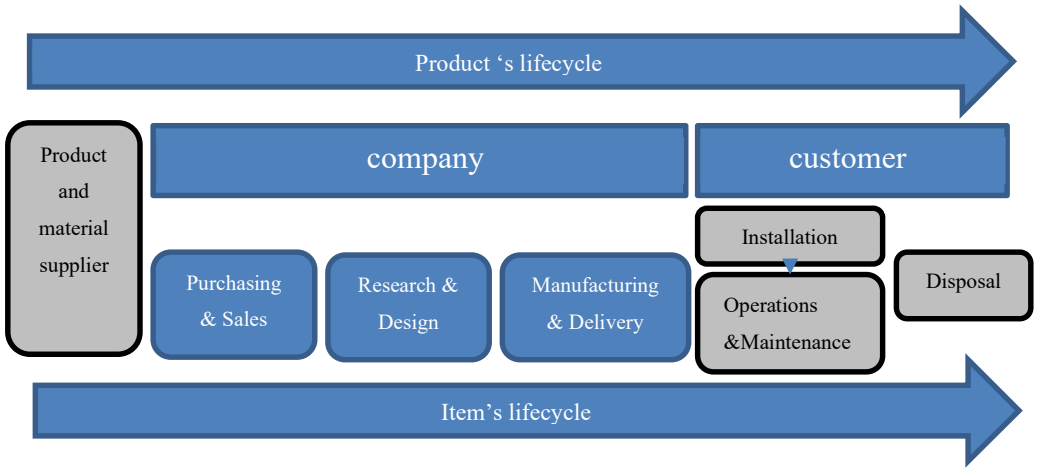


Figure 3. Item - product lifecycle relationship.

The flow of information and items provided by the PDM system is not one-way. In the optimal situation the users that utilize and use the information also provide more information to other users of the system as seen in Figure 4. The information provided by the items is the basis for using product data in the PDM system(s). Users who use the item in their own projects provide future users with more information, for example, in what situations the product or item can be used.

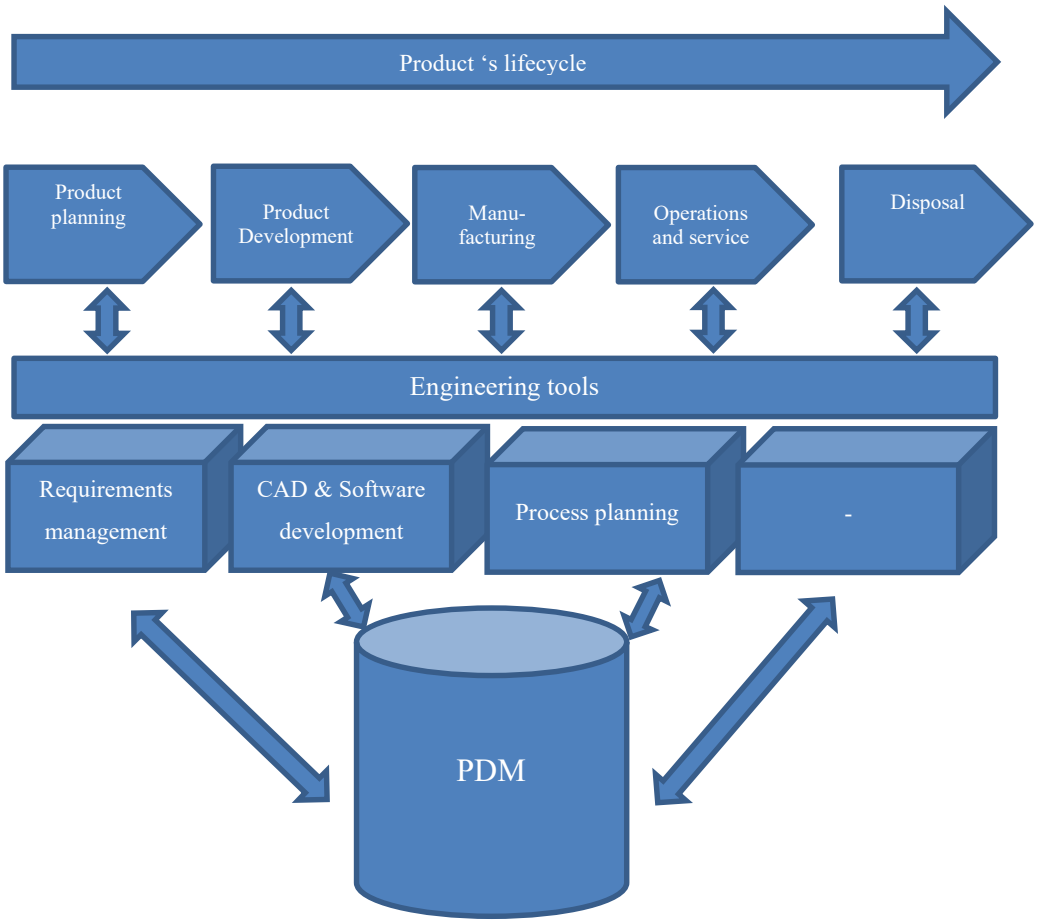


Figure 4. Product life cycle management and its information flow. Adapted from (Bergsjö, 2009, p. 32)

The flow of information in several different directions as in Figure 4 also entails risks. These risks can be minimized with strict guidelines, determination of data ownership and editing permissions. Guidelines that will set almost absolute rules for data and products facilitate the use of information and create harmony in the PDM system. Some PDM systems can handle data in a simpler or multifunctional way but the rules should be set precisely. Every now and then every organization will face products or items that can’t be handled according to the rules and instructions created earlier. For these types of situations data ownership and management must be well defined. Compromises must also be made when improving or updating the current PDM system inside the company. Optimizing too carefully and implementing advanced features that are not necessary can be unnecessarily expensive and thus also hamper the profitability of the entire project (Sinkkonen, 2015).

Usually location and sales data are directly linked to the items, which makes it easier to look for offers from vendors and manufacturers. Items must be created in a way that they will be easily utilizable for non-engineering tasks as well. The information maintained in the PDM system must be easy to use for sales personnel and installers, not just for the engineers.

Today, the problem is not the inadequacy of the system features, but the relatively high level of skills required for employees to use them. Sufficient training regarding systems integration and upgrades is often overlooked. The process of "continuous evolution" also requires constant development from the employees. Businesses are chasing stability year after year, but constantly failing on it because new technologies and needs appear. Even within a company, it is virtually impossible to predict such future needs. Such sudden needs for system upgrades can be brought about by corporate mergers, market changes, or the changing needs of a company's product line. Changes like these can create an atmosphere among the employees that it is unnecessary to spend too much time on learning the new working methods and systems as more changes are coming anyway. This kind of thinking creates an atmosphere of risk. Implementing changes or introducing a new system usually creates "resistance of change" among old employees, because they are accustomed to using the old system(s). In the beginning, the learning curve is steep even though the motivation is not high as seen in Figure 5. As the time goes by the motivation for learning usually goes down because a higher skill level is required for more challenging tasks.

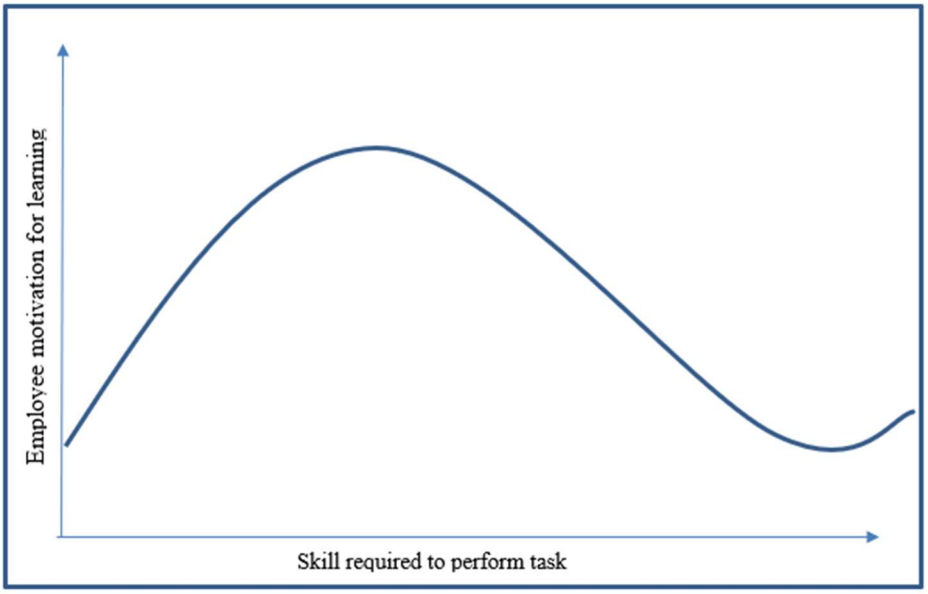


Figure 5. The relationship between motivation and skill required.

Companies too often focus on training only in the early stages of implementing a new system. With the more challenging tasks, there is a clear causality between lack of knowledge and not complying with instructions. Therefore, the benefits of the right practices should be emphasized, instead of just training the procedures to the employees.

4 BENEFITS AND DISADVANTAGES OF ITEMS

Some benefits of proper item management can be easily seen in day-to-day work. When data is well managed and accurate, it is easy to rely on it. Usually the amount of data available for a product will correlate with the quality of the item in the system. The large amount of information provides a good basis for creating a unique item.

Sometimes the benefits of proper item management are not apparent in the short term. Good product data management will help companies to adapt to new challenges and systems. The better the company knows the supply chains, current status, history, alternatives and prices of its products, the more profitable it probably is. (Olson, 2003, p. 3-5)

The profit a company receives is the difference between the product's generated value minus its Life Cycle Costs (LCC). When using a certain product it is also very important to consider its potential additional costs downstream. (European committee for standardization, 2006) All units in organization should work as one big machine that communicates and co-operates with each other in a way that benefits them all. Some demarcations can be made for units that have some kind of individual needs or expertise. That can be used to meet the goals of the organization. (Golwalkar, 2016, p. 2-3) Moreover, the product data management will reduce cost by making engineering and sales work require less effort, by utilizing the work that has been done already earlier.

Considering the whole product life cycle with engineering, manufacturing, product usage, spare parts and recycling maximizes the performance of the product's LCM. The items must be designed so that they support all the stages of the product's lifetime. This also maximizes the profit that company can gain from the product. In other words, the data that the item contains needs to be in order and supported. Additional value to the business can be gained by providing exact performance evaluation, support, recycling and life cycle engineering (LCE) (Sonnemann & Margni, 2015, p. 7-10,39). Product life cycle from manufacturers' point of view will differ from users' point of view as seen in Figure 6. Manufacturers can get several benefits from the correct data, which can further expand the range of services towards customer. User, which usually is also the customer, expects the manufacturer

company to offer some additional services, such as repair and spare parts for the product during its lifespan (Aurich et al., 2004).

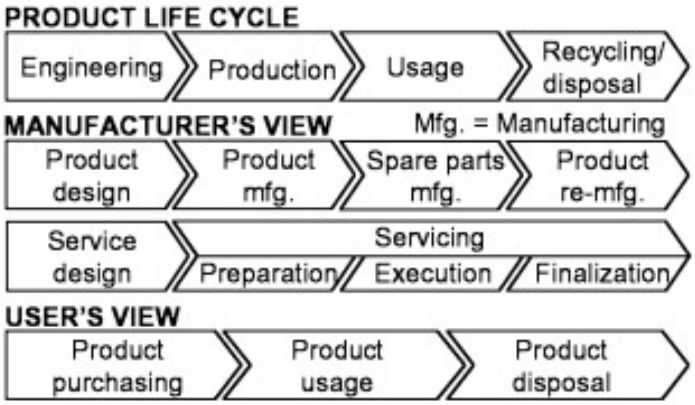


Figure 6. Life cycle of a product from different points of view. (Aurich et al., 2004)

If the data of products is stored in a proper way, it is much easier to see what kind of spare parts should be used. The information available for a product will influence its cost of engineering, maintenance and recycling. For many large projects, additional challenges and costs arise from the large number of suppliers and project related shipments. For example, in the paper industry, the usual amount of deliveries regarding one project ranges from 1500 to 2000 separate deliveries to the site. The number of suppliers also varies from tens to hundreds, and suppliers who do not manufacture the products they sell may also have several suppliers in the supply chain (Kärkkäinen, et al., 1995). Companies have their own policies and ways to store and use product information in their PDM system(s). Identifying and using such items in business-to-business (B2B) and delivery-related schedules correlates directly to the company's potential operating profit from the project. (Hans, et al., 2010)

The essentials for a well managed item:

- Each individual item has a unique code that cannot be repeated in the system.
- The PDM system will be developed and updated as new needs are discovered.
- The product that the item describes is defined in such a way that its attributes and technical data do not create a risk of confusion between two different products.
- The entity that manages item data is defined and trained so that the item changes and updates follow a specific process.

- A distinction is made between product manufacturers and retailers, and when ordering a product, the link between manufacturers and retailers is clear, informative and comparable.
- Utilizing attributes in item management. Attributes make it easier to make large-scale updates to certain item groups.
- The system used for item management provides a versatile and flexible way to manage information with different attributes and units of measurement.

The aforementioned essentials reflect sources (Rivest, et al., 2012) (Rantala, 2016, p. 31-33) (Martio, 2015, p. 95-96) (Olson, 2003) and points which are generally considered important for successful item management.

An item, which itself holds the information within it, is linked in the system to maximize its benefits. Figure 7 illustrates an example of how data can be chained for one item. In addition to product specific linking, the item usually also links to the assembly structures. A well-managed PDM system also greatly benefits from the documents used for sales and purchases. Such documents make it easier to verify the past usage history and potential duplicate status of the items.

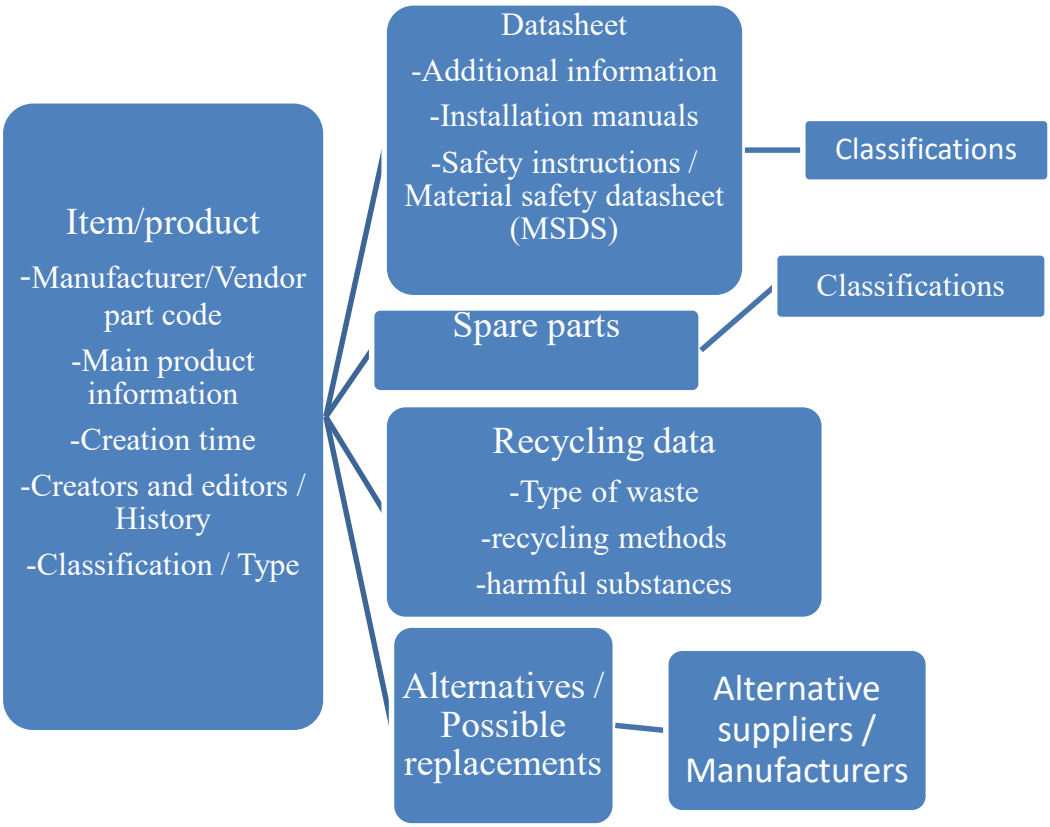


Figure 7. Example of data and information linking on item.

4.1 Facilitating warehouse operations with information provided by items

There are many reasons for companies to keep different kind of inventories. For example, buffer inventories are held to keep uncertainty as low as possible and cycle inventories are held to keep warehouse costs down. Only products with unique item data can be held in the buffer inventories. Also, all the other possible misunderstandings that could occur to the person placing or receiving the order should be minimized (Shenoy & Roberto, 2018, p. 9).

The more complex the end product is, the more parts it needs. Employee amount, the complexity of the end product and time spent all correlate to each other. The more parts the end product has, the more chance there is that some critical part will be ordered wrongly or from an unnecessarily expensive vendor. Reducing maintenance and updating costs with the help of items will eventually cumulate big part of the gross margin of the end product (IFIP Advances in Information and Communication Technology, 2012, p. 25-26).

Companies usually store key components which are used in many end products. The easy availability of these key components can in many cases reduce a company's response time from order to product. Also, with the rightly timed automated purchases, an item can be used to create purchases automatically. For example, the system can independently purchase a particular product as it goes lower in stock (Niiranen, 2008).

4.2 Risk identification and management regarding product data

Nowadays, the products and services offered by companies carry several risks. The risks can be directly related to the design phase of the products, the materials used in the design, incorrect installation methods, the use of the product or risks associated with environment. Identifying potential risks in advance is particularly important, but not always possible. However, risks identified during a product's life cycle, or risks posed by a specific attribute of a product, such as the chemical or welding process used, can be utilized in the future projects.

Finnish Standards Association (SFS) defines risk analysis and risk definitions for technical systems in IEC 60300-3-9 as follows:
"Risk is present in all human activity; it can be health and safety related, economic or affect the environment. The objective of risk management is to control, prevent or reduce loss of life, illness or injury, damage to property and consequential loss and environmental impact" (Finnish Standards Association SFS, 2000).

When updates are made to the current items, the aim is to improve their data quality and reduce possible future risks. There are also downsides to it, because there always is the risk of making a mistake. The ownership of data must be well defined inside the corporation. Without proper administration and ownership management the employees can cause harm in the system even when they are not aware of it. These kinds of scenarios are most likely to happen when something needs to be modified for projects which are close to the deadline. It is often easy to follow rules and procedures when there is plenty of time and no hurry. When time is of the essence, people tend to bend rules and not follow the procedures. In many cases vague data can easily be misunderstood in a harmful way. This is most likely to happen especially with products that have configurations behind them.

Wrong practices and procedures for managing product information can make it difficult to come up with a solution which will work for all parties. As a result, implementation of new methods must be done in a controlled manner. Figure 8 shows the phases of handling the issue in a sustainable way. When a problem occurs, it is often unclear how the solution will work in the longer term. For this reason, the solution(s) that have already been implemented should be retrospectively reviewed. This avoids the creation of new problems.

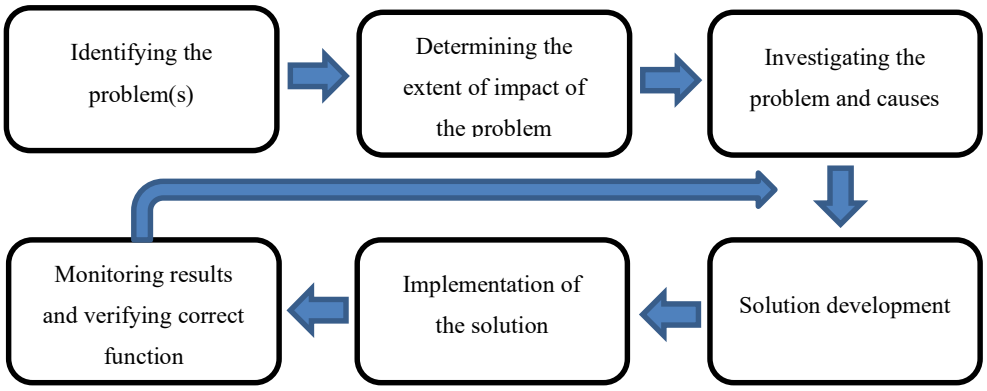


Figure 8. Problem identifying and implementation of the solution.

Companies should have an internal portal for storing data problems. With the help of it, it is easier to map the scale of the problem and its consequences. It also makes it easier for employees to report problems that occur during the normal work.

In large companies, the person who uses items and other product related data should also be able to recognize the importance and scope of using product information. Often, data-management neglect, or "canistering", is done in situations where the relevance of the information is only considered from users' own perspective. Frequently observed harmful thought patterns related to item formation in large companies consist of:

- Item information and the potential uses of the associated product are considered solely from the point of view of the user.
- The magnitude of the problem and future problems related to certain product or item is underestimated by the user.

- The real benefits of correcting and organizing data in a proper way is hard to perceive.

When working with items in large companies, the globality of the products can easily be overlooked by the designer or sales representative. Products may be replaced by products that perform identically in a particular application, but in another application a new replacement product will be useless or even dangerous. Such linking's and substitutions should always be verified from the manufacturer, as relying on the company's own knowledge to ensure substitution can be very costly.

We can look at the importance of right replacement practice with a simple example. Figure 9 shows the components of a computer assembly. As mentioned earlier, the simplest misrepresentation between products is created without considering product's performance in other assemblies and applications. In the Figure 9, the power supply substitution is created from a 600W power supply to a 450W one. A new replacement power supply would have 150W less power than the original product. The reason for such determination could be, for example, the on-site power savings of new replacement product or the acceleration of work. The employee that creates or requests the substitution between these products has determined that the power supply is working properly for its intended use, in this case with computer assembly that he is working with. However, for a 600W power supply, there may be other users in the system that have designed assemblies which require more power, and thus the new 450W power supply will not be a proper replacement for them.

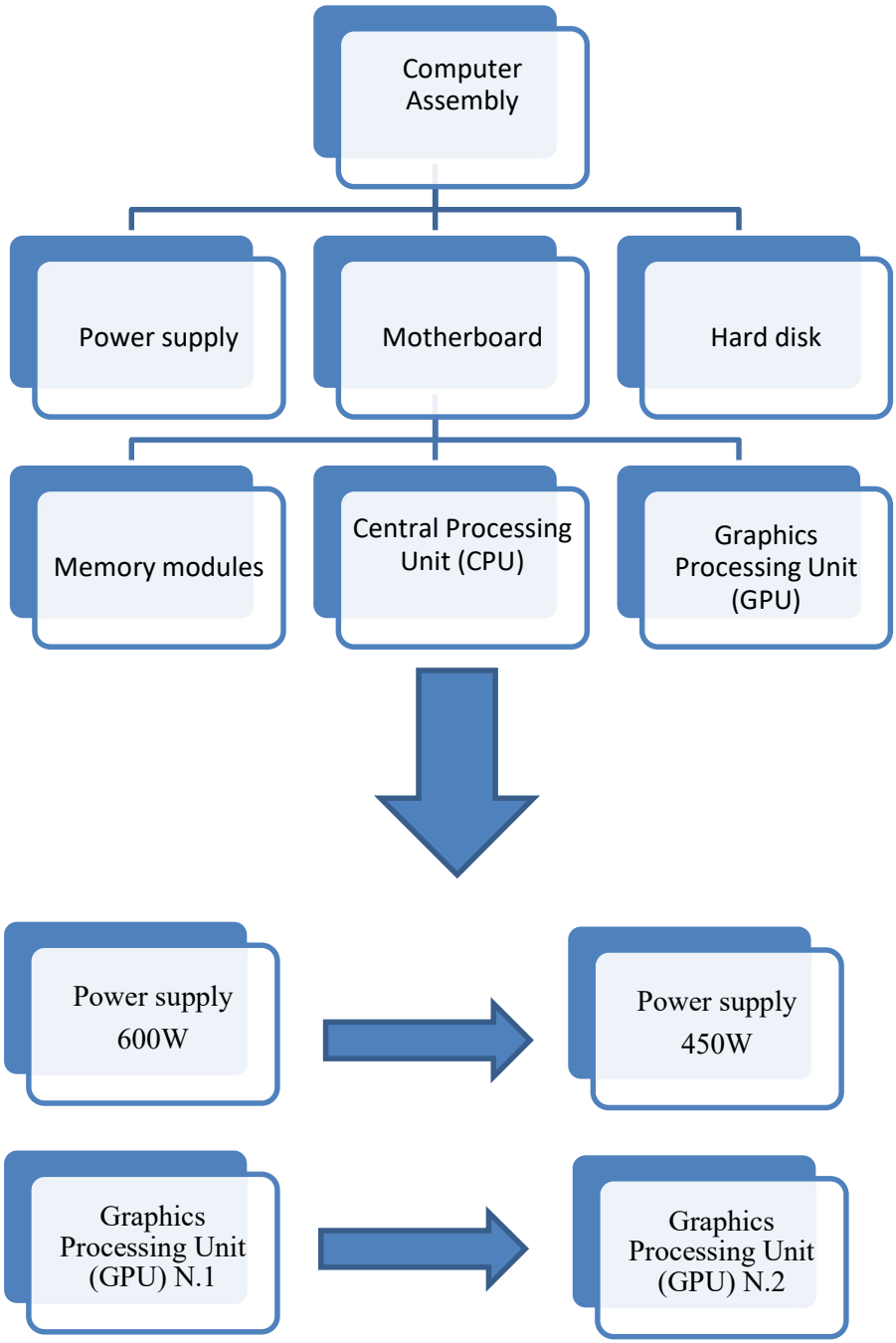


Figure 9. Example of an assembly structure and replacement of products.

In practice, identifying an inappropriate replacing item can be much more complex than the example in Figure 9. It may even be impossible to identify a product which is a suitable replacement without the confirmation from the product manufacturer. Using companies' internal sources for product information can offer them new possibilities, innovations and sometimes even insider information. Often, such practices also entail unnecessary risks, loss

of time, and price increase for the assembly in question (Garcia-Muiña, et al., 2009). External information, on the other hand, cannot bring direct added value to a company because of its wide availability to rival companies. Such information is extremely important in situations where in-house remedies are not enough to obtain the information, such as laboratory tests or product validation, or it is too expensive (Rivest, et al., pp 46-48, 2012).

4.3 Example scenarios

The old methods of managing PDM systems and items may have worked well in the past in the company, but as new services and features have been brought on to the market, they have become obsolete. There are several stumbling blocks in item management which usually are not easy to detect by a person who is not aware of them. Vendor and manufacturing companies have thousands of ways to present their product information, which makes finding the correct information more difficult (Zeeshan & Detlef Gerhard, 2010). Items can entail unpredictable problems to their user. The more orders the company places for a certain product, the more information they usually obtain about it. However, the manufacturer has the most knowledge of the products it manufactures, configures or customizes. Especially products which are customized or configured for a certain project, contain a lot product and item information within the company, but they are sold in low volume, as seen in Figure 10.

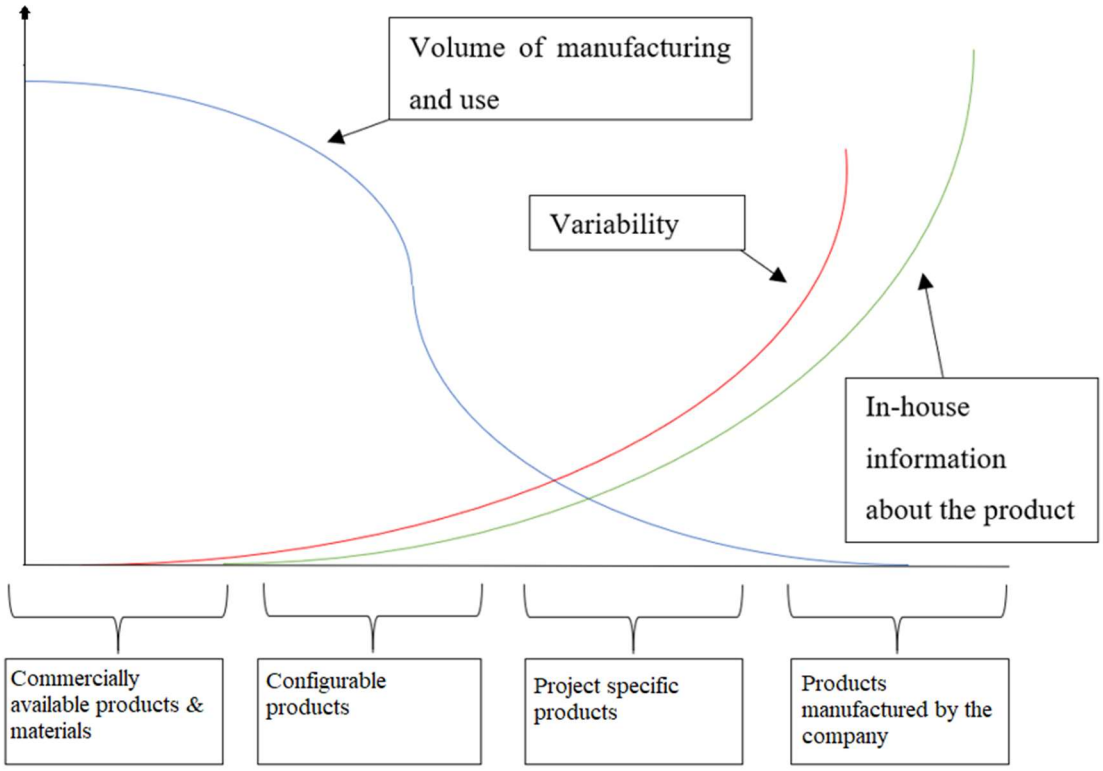


Figure 10. The ratio of product usage and customizability to related information within the company. Adapted from (Martio, 2015)

Usually, products which are customized or manufactured entirely by the company itself create higher profit margins than commercially available products. With high volumes of commercially available products, which usually have lower profit margins, even a small mistake in itemizing can decrease the profitability of the product. This is what makes it especially important to invest in the product data quality and items of the high volume and commercially available products.

4.3.1 Configurable products and items

Configured products are products that can be adapted to meet the requirements of a customer. The product itself will often remain more or less the same, but adjusting values or making small adjustments will make it better suited to the customer's needs (Peltonen H. , 2000, p. 37-39).

Configurable items contain information about a product of this kind, which is usually commercially available at vendor or manufacturer, and which is customized in a such way that the product differs from the basic model of the product the company is offering. The difference between products which are custom made for a specific company and configurable products is usually vague. Usually a product which has been categorized as a "configurable item" is a commercial product with modifications or the information given from the manufacturer or supplier cannot be specified without certain procedures. Usually, such products are used when the compatibility or features of the product are to be further tailored to the application.

When ordering such a product with item, the orderer must be particularly sure that the product's configuration is suitable for this application and whether the original creator of the item has omitted something important from the item.
Especially products that are used in multiple applications are rarely inspected by someone in the marketing and sales department, which increases the risk of ordering the wrong configuration.

Products that are customized, are often much more difficult to return to the manufacturer or vendor companies. That is especially true with electrical devices that are often updated to newer versions on a regular basis and raw materials that may expire even after a short period of time. These types of misorders can create huge financial losses for companies, especially for ones which deal with low order volumes but pricey end products.

Problems with configurable items can be seen in the following example. The part in question is a temperature sensor which has optional parts and modified ranges. Usually companies are giving selected codes for accessories and customizations which are easily classifiable. Problems usually arise with optional ranges where a specific value can be modified to meet the requirements of the customer company.

On example datasheet 1 (Figure 11.) code Z refers to a range that can be set to certain values between 10-200bars. In the given example, orderer has set this value to 10-150bar. Normally these kinds of ranges have preset values with codes that are already specified. In such cases the manufacturer code would also change with the pressure range. On example number 1 the

manufacturer part code would remain the same even if the pressure range changed from 10-150bar to 20-50bar.

AM Manufacturing SKA44 Pressure sensor Configuration summary		
29 (Output)	-	Profibus PA
NH (Approval)	-	Normal range
Y (Housing)	-	Aluminum IP
Z (Special range, Choose between10-200bar)	-	10-150bar
1 (Connection)	-	DN20 316
EN1092-1 PN15		
WY (Basic markings)	-	Tag
X (Membrane material)	-	Inconel 625
N (Additional accessories)	-	Extra short
cable 1m, acid proof		
IK2 (Custom appearance)	-	Red color, acid
proof		

Figure 11. Example datasheet for product.

Although this kind of identifying method is surprisingly common, it can easily create situations where a custom-made product for a certain company does not match the user's intended use. Products that are custom-made to meet the customers' requirements usually have different return terms compared to their basic versions. Ordering a defective product due to their own actions creates unnecessary financial losses. These kinds of project specific configured products are usually unusable in other projects and they also create confusion among the employees. It is also likely that if the product being ordered is relatively inexpensive in relation to the rest of the business, the original problem may remain in the system unrepaired. From the point of view of the worker dealing with the transaction of an inexpensive product, it may be easier to just order a new fit-for-use part rather than familiarize yourself with the original source of the problem. The most important thing in item creation, besides verifying the accuracy of the information, is to minimize any misuse of the item already at the creation stage. Configurable items obviously require more consideration regarding the possible future misuse.

When creating such a configurable item, control values that are not directly determined by the product code should be mentioned and specified. The most common problem when creating an item which refers to a configurable product is that it is created with the methods of a regular non-configured product. If this kind of incorrect creation process is used, relevant information will be omitted from the item. Sometimes it is difficult to notice whether the product includes configurations or not. Then, it helps if the source material is good and if the person creating the item is already familiar with similar products.

Figures 12 and 13 show the difference between an incorrectly and correctly created item. The main difference between them is that an incorrectly created item can be accidentally used to order products that include different configurations. The configuration of the product must be clearly stated so the user can easily notice its deviation. In the case of Figure 12, the missing values of Z and N can lead to this kind of misuse. In Figure 13 the values of Z and N are clearly defined.

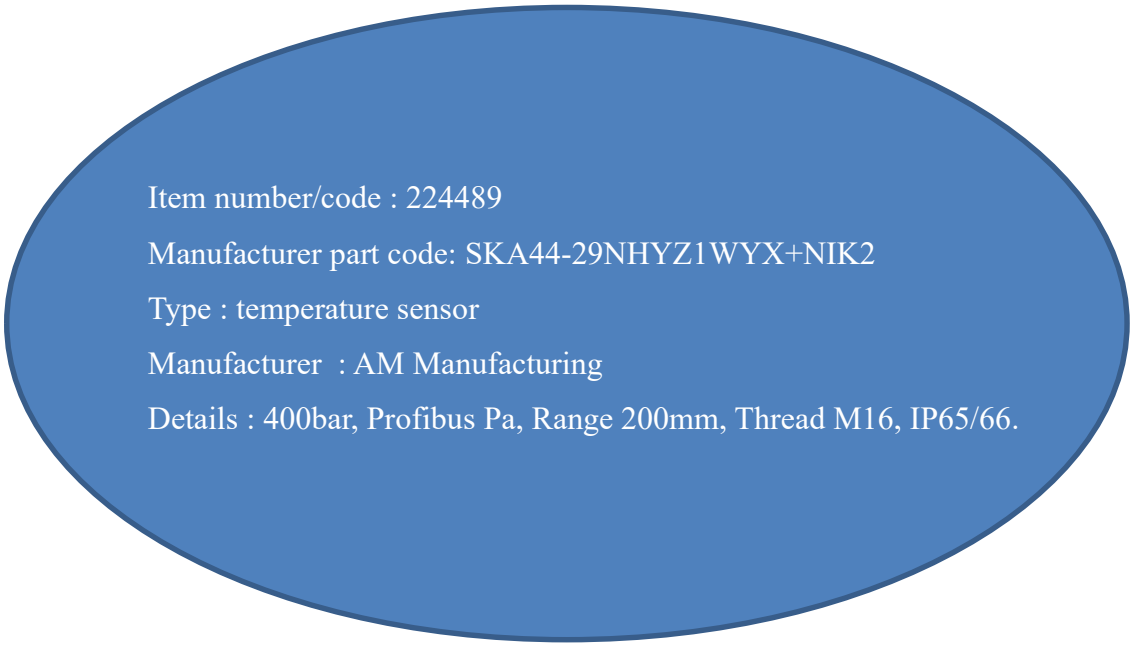


Figure 12. Example of item, which is created in a wrong way 224489, pressure sensor.

Any configurations of the product and possible defects in its manufacturer part code should be easily noticeable on the item. In Figure 13 the included configurations of the product are shown after the manufacturer part code. There are several ways to include configuration data

to the item, but the most important thing is that the created item can be used with just one configuration. When this kind of item is used in other programs, automated notification can be utilized to help its identification.

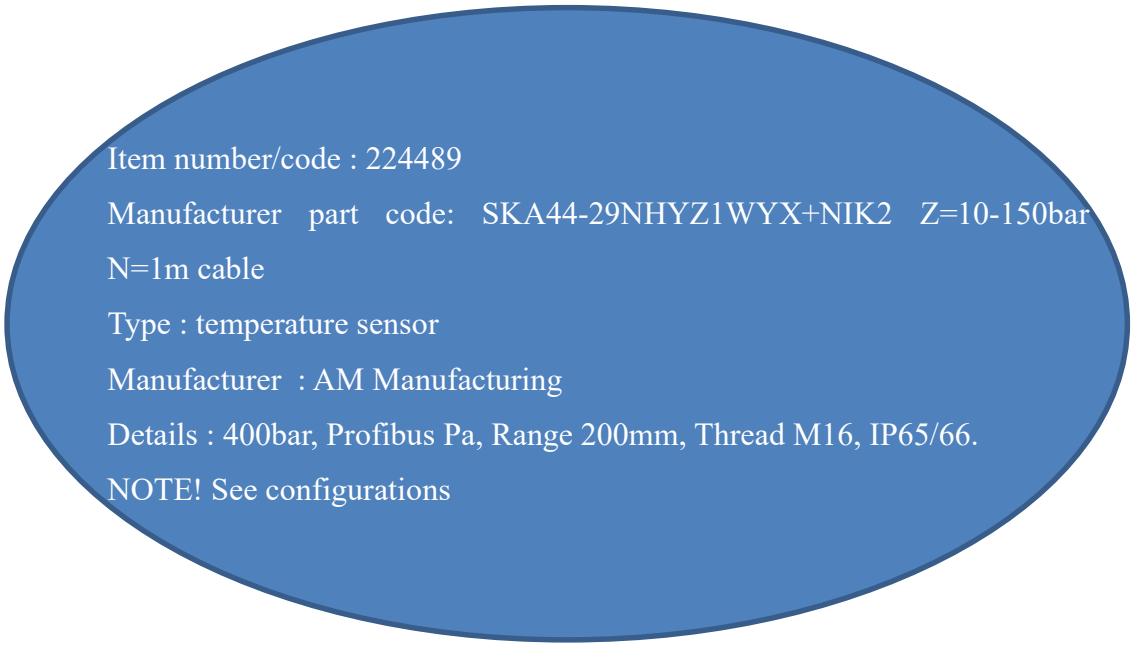


Figure 13. Example of a configured item, which has been created in a correct way.

4.3.2 Benefits of itemizing and identifying the manufacturer product versus relying on vendor's codes

Providing items that can be used to buy products from separate manufacturers and vendors is crucial to creating the company's competitiveness and the biggest possible profit margin. The manufacturer sells the product to dealers in order to achieve the highest possible margin available. The price quoted by the manufacturer correlates with the prices of the raw material, market outlook and the price charged by the retailers. If manufacturer offers similar contracts to all vendors, it will be difficult for them to compete in markets that do not require specialized expertise (Almehdawe & Mantin, 2010). When competing with such contract terms, it is difficult for reseller to offer a better price to the customer than the manufacturer. The manufacturer's products, which are modified or incorporated and resold by the vendor, create competitive asset to them. However, the manufacturer can sell the product at a relatively low price to a vendor who buys the it in big quantities and is reliable. In such cases, the vendor can offer customers more competitive terms of supply, even compared to the

manufacturer. Buying directly from the manufacturer is not always a feasible or economically viable option. For example, in Finland, the quantities of products purchased by the companies are often so small that the large international manufacturers cannot produce them in the desired time, or the cost of delaying other deliveries is not profitable to large manufacturers. In such cases, the companies that purchase products at relatively low volumes often must deal with the products offered by vendors.

Manufacturer companies often sell products that are manufactured by another company. These kinds of products can be sold with customization, as spare parts, or as a part of the assembly. Vendors generally try to provide as little information as possible about the manufacturer and the product they resell. With this method, they will enhance the customer's need to continue to buy the product from them. These products should be identified as accurately as possible to facilitate competitive tendering and avoid potential problems in the future. Vendors usually sell products with manufacturer part codes which have been modified to shorter versions or with codes which they have generated themselves, for example:

Manufacturer part code: SKA44-29NHYZ1WYX+NIK2
Vendor part code for same product: SKA44-12 or 988243

In this way, the customer will have to return to the same supplier in the future if any spare parts or other services regarding this product are needed. When creating and ordering such vendor products as item, possible duplicates with other vendor codes regarding the same product should be identified on the PDM system. It is not always possibly to identify a product like that retrospectively, but the identification process can be facilitated e.g. by asking the vendor for all available information or using only well-established resellers as vendors. The link created between the manufacturer and the vendor item in the company's PDM system makes it easy to track and view potential vendors, and thus also compete on prices and delivery terms. Figure 14 illustrates a link with the manufacturer's product information and vendor information. This type of linking can used for other activities as well, e.g. comparing similar products from other manufacturers. Product linking also allows you to automatically update existing structures already in the PDM system with possible new replacement products, see Figure 14. In addition to what is shown in the picture, the

manufacturer's product may have been marked with an alternative product even though it is not a replacing product. They can be used if there is a need for similar kind of product, but the 100% substitution is not required.

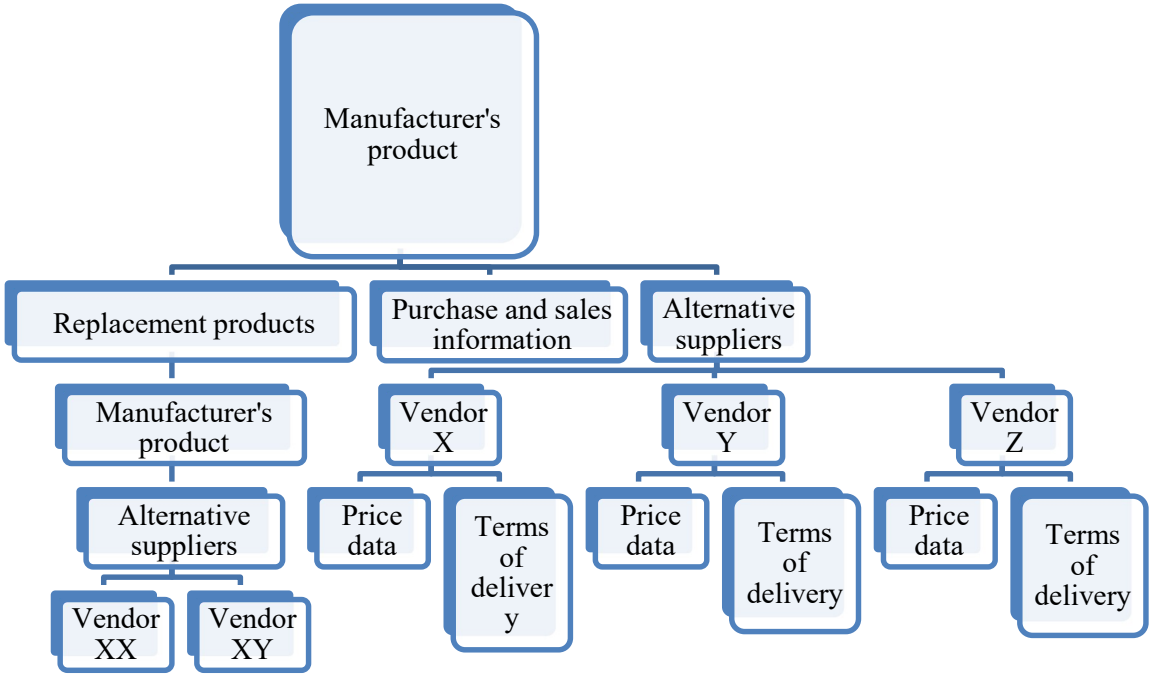


Figure 14. Example structure of a manufacturer product in the PDM system.

An item which is created to the PDM system with the manufacturer's information brings a variety of benefits to the company. For example, VMI (Vendor Managed Inventory) provides added value to the company with the information provided by the manufacturers.

4.3.3 Vendor managed inventories

These days companies use more and more subcontractors and other outsourcing activities in order to achieve flexibility and adaptability to market demands. That's why increasing inventory management costs and sourcing staff require a lot of resources. The total cost of the end product can be lowered by reducing the cost of the ordering process (Viswanathan & Piplani, 2000). Without the buyers of the product, the whole supply chain is useless. With

Vendor Managed Inventories (VMI), the responsibility and cost of product inventory management can be partially delegated to a supplier. This method is also used by the food chain giant Walmart, which has succeeded in sharing part of the costs of managing its products with suppliers, thereby lowering the price of its products (Messinger & Narasimhan, 1995).

4.3.4 Problems and risks with manufacturer identification

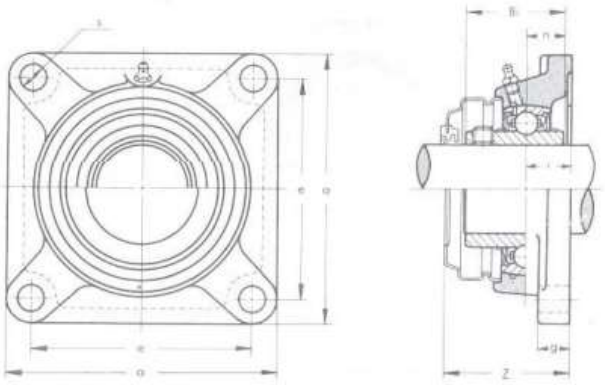
Generally, products are uniquely specified by the manufacturer part code. These codes can also be used to identify vendor products as a particular manufacturer's product. This type of retrospective identification can involve risk for certain types of products and companies. In some cases, individual manufacturer companies may use the same or similar kind of product codes as competitors, even though the products are not identical. Products may also be identified at sites and warehouses by their dimensions and characteristics, which may be very similar in such cases, although there is a slight difference in product codes. As a good example of this, we will look at three bearing housing units from different manufacturers. Figures 15, 16 and 17 present datasheets from the three global manufacturers.

SQUARE FLANGE UNITS
WITH PRESSED STEEL COVERS

ASAHI

UCF 200C(E) type

Normal Duty
Set-screw Locking

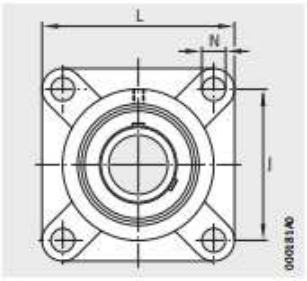


Unit No.		Shaft Diam.	Dimensions mm								Bolt Size	Bearing	Housing	Weight
Open Cover	Closed Cover	mm	a	e	i	g	s	Z	Bi	n	mm	No.	No.	kg
UCF 201C	UCF 201E	12	86	64	15	12	12	43	31	12.7	M10	UC 201	F 204C	0.67
UCF 202C	UCF 202E	15	86	64	15	12	12	43	31	12.7	M10	UC 202	F 204C	0.65
UCF 203C	UCF 203E	17	86	64	15	12	12	43	31	12.7	M10	UC 203	F 204C	0.64
UCF 204C	UCF 204E	20	86	64	15	12	12	43	31	12.7	M10	UC 204	F 204C	0.62
UCF 205C	UCF 205E	25	95	70	16	14	12	48	34.1	14.3	M10	UC 205	F 205C	0.86
UCF 206C	UCF 206E	30	108	83	18	14	12	51	38.1	15.9	M10	UC 206	F 206C	1.2
UCF 207C	UCF 207E	35	117	92	19	16	14	54	42.9	17.5	M12	UC 207	F 207C	1.6
UCF 208C	UCF 208E	40	130	102	21	16	16	62	49.2	19	M14	UC 208	F 208C	2.1
UCF 209C	UCF 209E	45	137	105	22	18	16	63	49.2	19	M14	UC 209	F 209C	2.5
UCF 210C	UCF 210E	50	143	111	22	18	16	66	51.6	19	M14	UC 210	F 210C	2.6
UCF 211C	UCF 211E	55	162	130	25	20	19	69	55.6	22.2	M16	UC 211	F 211C	3.6
UCF 212C	UCF 212E	60	175	143	29	20	19	80	65.1	25.4	M16	UC 212	F 212C	4.8
UCF 213C	UCF 213E	65	187	149	30	20	19	81	65.1	25.4	M16	UC 213	F 213C	5.8

Figure 15. Asahi datasheet (Asahi Seiko Co., Ltd, 2008).

Four-bolt flanged housing units

Square version
With grub screws in inner ring



UCF

UCF211-32	F211	UC211-32	3,46	**50,8**	***2***	130	163	43
UCF211-33	F211	UC211-33	3,4	**52,388**	***2 1/16***	130	163	43
UCF211-34	F211	UC211-34	3,35	**53,975**	***2 1/8***	130	163	43
UCF211	F211	UC211	3,31	**55**	–	130	163	43
UCF211-35	F211	UC211-35	3,29	**55,563**	***2 3/16***	130	163	43

Schaeffler Technologies

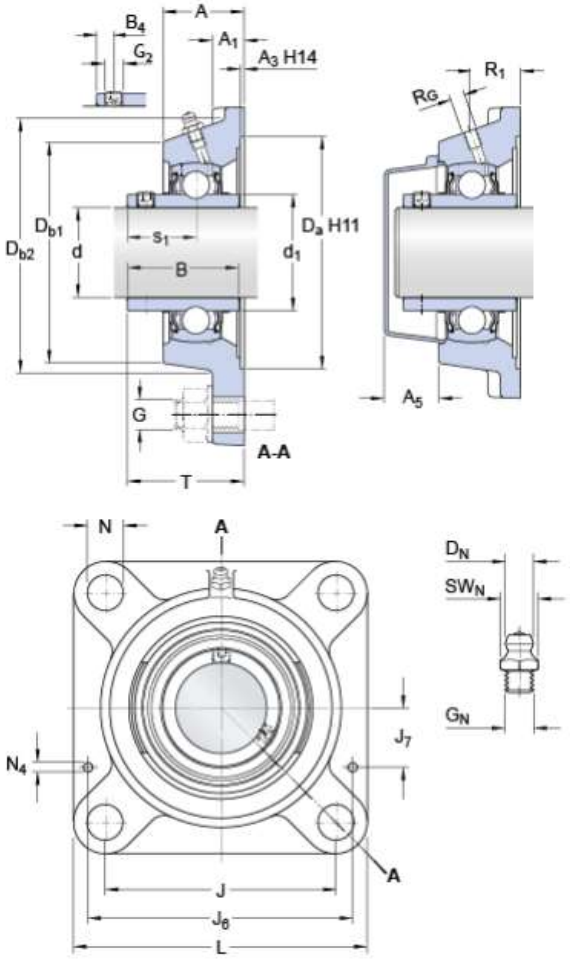
Figure 16. Schaeffler's datasheet (Schaeffler Technologies AG & Co. KG, 2019).

SKF

FY 55 TF

Compliance with standard	ISO
Housing material	Cast iron
Sealing solution	Standard seals with additional flingers

Dimensions



d		55	mm
d_1	≈	69.06	mm
A		47.5	mm
A_1		16	mm
A_3		3.2	mm
A_5		37.5	mm
B		55.6	mm
B_4		9	mm
D_a		150.8	mm
D_{b1}		122	mm
D_{b2}		134	mm
J		130	mm
L		162	mm
N		18	mm
s_1		33.4	mm
T		64.4	mm

Figure 17. SKF's datasheet (SKF inc., 2019).

There are many similarities between these products, such as model, dimensions, description and partly the part code as well. In many applications the products will definitely be replaceable with each other, but the datasheets do not inform about, for example, precise material of the products. Products like these are usually purchased and sold in large

quantities, which can cause major problems if the product is mixed with the wrong manufacturer's product. A failure with one small part of the structure may result in high repair costs or even claims for compensation.

If the company orders adapter sleeves for pillow blocks from a vendor company, an item will be created to the PDM system with the vendor information if it cannot be identified as a certain manufacturer product.

A quote or a purchase order does not necessarily state the manufacturing company for the product H2324. Later, when the company wants to identify the product more precisely, it does not have any other information of the product than its manufacturer part code. After searching for product information, the manufacturer's datasheet will be found with the exact same description and manufacturer part code. Usually the same product code also refers to the same product. Figures 18 and 19 are both information about the products provided by the manufacturers SKF and Schaeffler. All available product information indicates similarity between products.

These kinds of cases are difficult to handle from the item management view of point. Vendors may not want to reveal too much information about the products they sell, which makes it difficult to create items with reliable data. Company employees, especially product data managers, item management teams, sourcing and sales personnel should also recognize the dangers of these kinds of products. Items of products like the examples in Figures 15,16,17,18 and 19 also often involve the risk of using a particular item to purchase a wrong product manufactured by another company.

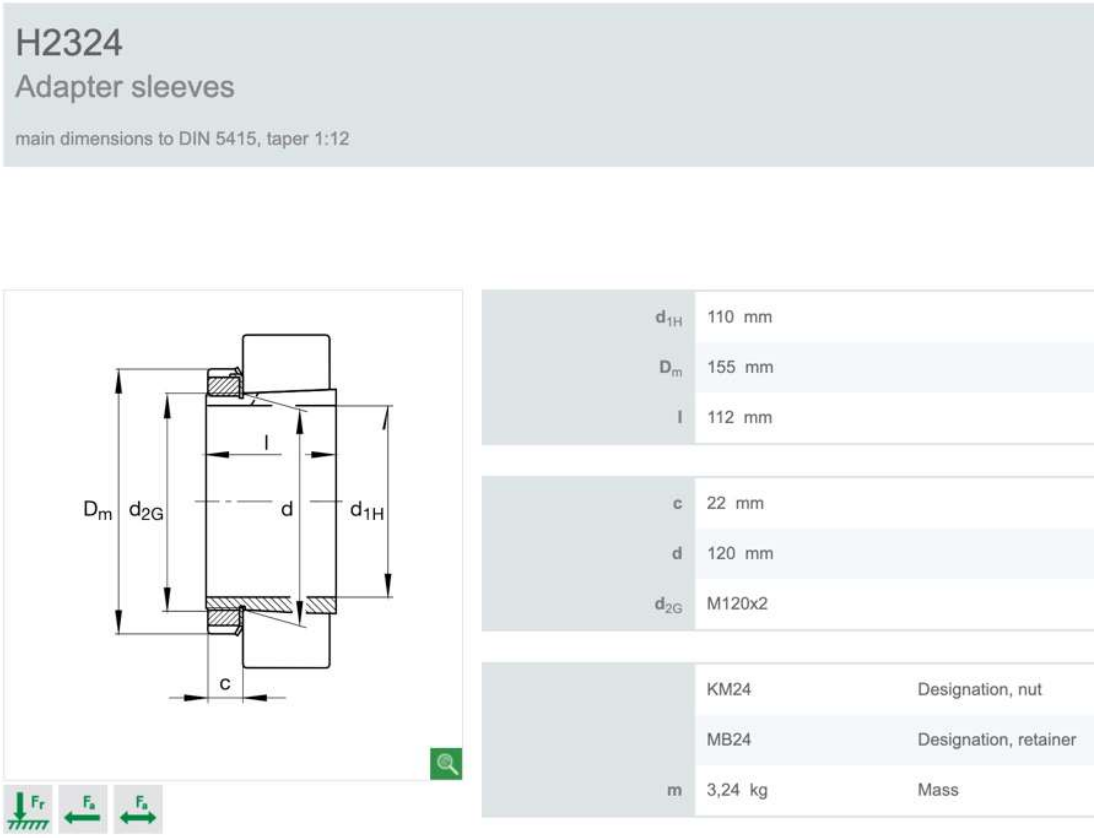


Figure 18. Schaeffler's datasheet for adapter sleeve H2324 (Schaeffler AG, 2019).

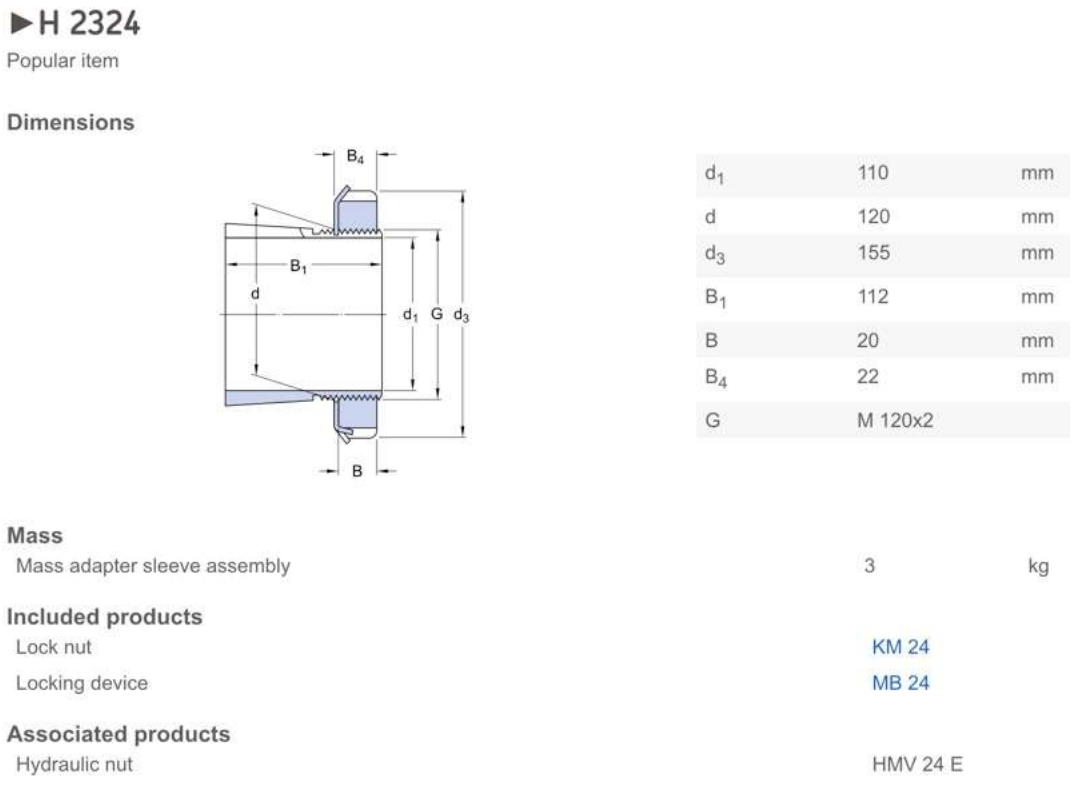


Figure 19. SKF's datasheet for adapter sleeve H2324 (SKF inc., 2019).

Use of such confusing product codes like in the Figure 15, Figure *16*, 17, Figure *18* and Figure *19* is not limited to certain types of products. For this reason, all possible manufacturer information about the product should be collected at the time of the first order and use.

4.3.5 Use of pre-defined restrictive information in design.

At the design state, the material and design choices of a product, structure, or plant greatly influence the price of the design object and, therefore, generally the profits it generates. These choices can be limited with the help of items to the advantage of the company. The wide availability of a product or material compared to a rarer option almost always guarantees a cheaper price. It is often easier for the designer to choose a piece that fits to the structure directly. However, such solutions are often much more expensive than modifying the original design at the design stage and using products that are readily available in standard sizes. Making such decisions during the design phase will have a significant impact on the overall project duration, cost and operating profit.

Considering a situation where a designer needs a hot rolled steel bar according to EN 10060 standard in their structure. The EN 10060 standard is for general purposes and it’s also widely used. Figure 20 shows the way in which the EN 10060 standard defines dimensional requirements. Similar recommendations are also found in most popular dimensional standards.

EN 10060:2003 (E)

Table 1 — Preferred dimensions, mass and dimensional tolerances of hot rolled round steel bars for general and precision purposes

Diameters [a] *d* (mm)	Limit deviation [b] Normal (mm)	Limit deviation [b] Precision (*P*) (mm)	Mass [c, d] (kg/m)	Area of cross section (cm^2)
10	± 0,4	± 0,15	0,617	0,785
12			0,888	1,13
13		± 0,20	1,04	1,33
14			1,21	1,54
15			1,39	1,77
16	± 0,5		1,58	2,01
18			2,00	2,54
19			2,23	2,84
20			2,47	3,14
22			2,98	3,80
24		± 0,25	3,55	4,52
25			3,85	4,91
26	± 0,6		4,17	5,31
27			4,49	5,73
28			4,83	6,16
30			5,55	7,07
32			6,31	8,04
35			7,55	9,62

Table 2 — Dimensions, mass and dimensional tolerances of hot rolled round steel bars for precision applications, for example for screws and rivets

Diameter *d* (mm)	Limit deviation Precision (*P*) (mm)	Mass [a b] (kg/m)	Area of section (cm^2)	Dimension *d* (mm)	Limit deviation Precision (*P*) (mm)	Mass [a b] (kg/m)	Area of section (cm^2)
9,75	± 0,15	0,586	0,75	32,55	± 0,30	6,53	8,32
11,75		0,851	1,08	35,55		7,79	9,93
13,75	± 0,20	1,17	1,48	38,55		9,16	11,67
15,70		1,52	1,94	41,50	± 0,40	10,62	13,53
17,70		1,93	2,46	44,50		12,21	15,55
19,70		2,39	3,05	47,50		13,91	17,72
21,70		2,90	3,70	51,50		16,35	20,83
23,65	± 0,25	3,45	4,39				
26,65		4,38	5,58				
29,60		5,40	6,88				

[a] Calculated using density of 7,85 kg/dm^3

[b] The masses of stainless steel bars shall be multiplied by the factors according to EN 10088-1.

Figure 20. EN 10060:2003 Hot rolled steel bar dimensions (Mechanical Engineering and Metals Industry Standardization in Finland SFS, 2004).

For such products, the selection of a non-standard size often requires rolling, cutting, special ordering or other custom activities, which further raises the purchase price. Thus, for example, a bar compliant with EN 10060 (Figure 20) should not be dimensioned to 12.5mm in diameter at designing. Instead, it would be in the designer's interest to use 12.00mm and 13.00mm or alternatively 11.75mm diameters, which are the options recommended in the

standard. Restricting the available options for the designer also facilitates the design work itself.

In the design phase, the measurement and verification of a given raw material component can be performed as shown in Figure 21. The checks can be automated by utilizing integration between the design and the product data management program.

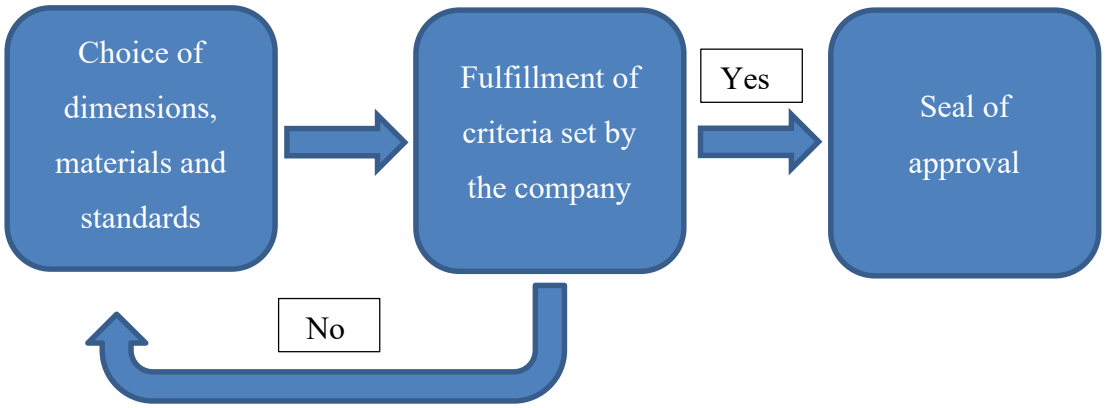


Figure 21. Fulfillment and acceptance of the terms of the raw material.

After the design stage a checking and approval procedure is widely used, but it rarely takes a stand on the price of the design solutions used in the structure. The criteria used for inspections vary greatly from company to company. Especially in companies where the audit focuses mainly on the functionality and durability of the structure, there are often places for savings.

Principles, such as in the aforementioned example, can be used to limit the engineering choices that are harmful to the company. These days there are many programs that can be used to facilitate the integration of design work and item management, for example Dassault systems Solidworks, Solidworks EPDM and Enovia. This way, for example, a standard steel bar designed by an engineer can be automatically moved to the criteria check and approval stage. Also, dimensioning options can be used to exclude free dimensions to further reduce dispersion in design.

5 HANDLING PRODUCT DATA REGARDING CHEMICALS

In the modern world there are various products that contain chemicals of some sort. From the point of view of item management, chemicals, which are often very strictly defined and contain several statutory regulations, must be managed so that they can be used easily and in a versatile manner. For example, in the 2002 European union (EU) introduced the Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive. RoHS handles substances like lead, mercury, chromium and cadmium. The Directive mainly limits the concentrations of substances in the products intended for regular consumers. However, RoHS is just one example of how strictly controlled the use of chemicals and other harmful substances is, and this kind regulation is even expected to increase in the future.

From the point of view of item management, product data on the concentrations should be managed in the systems so that they are easy to monitor, and potential harmful, illegal or dangerous products do not enter the market or waste unnecessary design resources (Valvira, Sosiaali- ja terveysalan lupa- ja valvontavirasto, 2016) (EURLEX, EU Publications, Official Journal of the European Union, 2011). Bilitewski et al. emphasizes in his book the importance of global harmony in the labeling of chemicals and also mentions that many of the chemical products produced today are dangerous to humans. (Bilitewski, et al., 2012)

Different legislation in different countries also creates the need for companies to produce products for similar purposes with different raw materials and chemicals. Thus, in an item management system, any chemical compound created with different ratios or additives should also be linked so that the attributes also provide relevant information regarding production and potential application. Other useful item specific information about chemicals and other harmful substances that create additional opportunities for utilizing the system are:

- Mentions and modalities for substances expressed in different units of measurements
- Tolerance limits
- Moisture percentages

- Chemical stability data
- Minimum requirements for the purity of the product
- NMR (Nuclear magnetic resonance) spectra
- Chemical composition
- Analysis results such as trace and HPLC-UV chromatograms
- Source information

Companies in different business sectors require different kind of product data management about the chemicals they use. For example, a local cleaning company and a global pharmaceutical company have totally different requirements for item data.

The use of documents is also emphasized in the case of chemicals. Chemicals usually include product and Material Safety Data Sheet(s) (MSDS) as well as the information regarding the environmental impact of the product. Such information can usually only be obtained from the manufacturer of the product. This kind of information is often required by the law and therefore all the necessary information should be collected before product goes through the manufacturing process. Subsequent identification of a chemical is often expensive or impossible and the chemicals can be very expensive, even to a small extent.

Depending on the industry, companies should also look for potential chemical accidents within their own company. Companies already pay a lot of attention to safety and security, but trainings and reporting systems are often separate from everyday work. The security-related information linked to an item can, at its simplest, be a warning or error message in a system when ordering or stockpiling two common but hazardous chemicals from a cleaning company.

For example, bleach and ammonia are very common in cleaning companies but if they are combined, they form a harmful hydrazine. Aforementioned situations can be avoided in advance if the system can generate warnings automatically with the help of product data. Then, the suitability of combining such chemicals is easier to determine.

5.1 Product and item data related challenges in chemical industry

Testing of different kind of compounds is very common in the chemical industry and nowadays in many other fields as well. Properly managed dereplication results can be used to facilitate future compound testing and thus often also reduce the total cost of the development process. Mapping and utilizing the information available is an important part of the process of developing new chemical products, for example, new medicines. Companies that actively develop and manufacture chemical compounds require increasing amounts of information from the PDM system(s). These kinds of companies often need several programs and databases to support the main PDM system (Chlipala, et al., 2011). The items of the chemical compounds benefit from and also utilize external sources of information.

5.1.1 Waste management and recycling of chemicals

The use of chemicals in products is nowadays almost the norm. Daily products sold by the companies, such as adhesives, electronic devices and cosmetics, contain a lot of substances that are harmful to nature and humans, but also many chemicals whose recycling has benefits for the company and humanity. For example, the rarity of indium, which is used in the modern-day LCD panels, increases the amount of recycling pressure for the companies. However, due to the rapid development of the recycling industry, the recycling information of items containing chemical information should be updated on a regular basis.

Within a company, the primary product information source after item creation is the item itself and other sources linked to it. In Figure 22 the item will be created after the production process or during it, depending on the company and its field of operation. In many larger acquisitions, recycling remains the responsibility of the manufacturer or supplier.

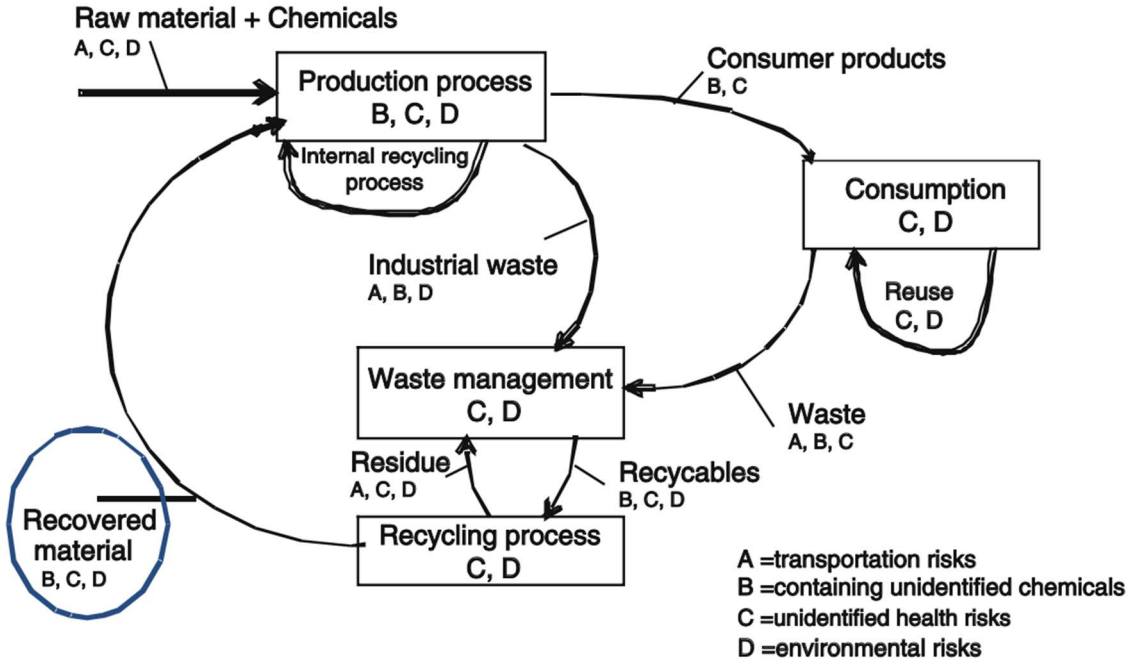


Figure 22. Possible environmental and health risks of a circular economy (Bilitewski, et al., 2012, p. 6)

6 RESOURCE-CONSUMING ITEM DUPLICATES

Having several systems and formats of data flow without proper management will not just be inconvenient for the companies, but it will also lower their product margins and capability to compete against other companies. Almost every corporation has the necessary systems to manage current data without unnecessary item duplicates. However, the PDM systems that corporations use contain duplicates to such an extent that they have a major impact on the company's profitability. In order to achieve harmony and efficiency across all the systems used, item creation methods must be able to eliminate duplication, whether they are item duplicates or company duplicates in the system (Twentyman, 2007). The problems caused by duplicates are usually simple but also common and resource consuming.

The consequences of duplicates may not even be clear to someone who encounters them regularly in his job. Because of this, the problems caused by the duplicates are also often unfamiliar. The realization of such problems can be seen in a simple example where the different organizational units of a large company are using identical item codes to order the exact same product, but they have the same supplier marked to the system with different name. There can be several names for one company in the system, but if the same company name exists several times, it is possible that some deals that certain organizational unit has created between the supplier company do not benefit the other units. In the same way, a special price settled for a certain product and item number cannot be utilized if the duplicate is being used during the purchasing process.

The time spent collecting the required data about the product can be used directly for other tasks, such as development or sales. The charge of a one-hour job that a typical engineer bills from a customer company according to Skoll varies between 100 and 200 euros (Peltonen K. , 2014) (SKOL ry, 2019). Going through the potential duplicates in the PDM system(s) can be time consuming. It is also noteworthy that every item remake that is done by a team or person specialized in item management delays the process of creating or editing other more business critical items.

When looking at the profitability of product and item data management, one important thing is that the daily tasks that are quick to fix momentarily do not create big losses all at once, but these tasks, which are often corrections or searches for information, often accumulate. That is why their impact can be huge in the long run. Thus, small defects in items should be fixed immediately.

Clear and strict guidelines and a schematic approach to item creation create security and harmony within the company. Poor guidelines and rules, on the other hand, can create virtual duplicates into the system, even when the items in reality are not duplicates. Often such cases are identified only after the purchase, when the financial losses have already occurred. Agreeing on these kinds of things is especially important with programs that have abnormal or poor kind of search capabilities. For example, Aton's (a PDM program) search tool cannot detect different letter cases as duplicates. Thus, for example, the manufacturer code "AcG123" cannot be found with search "ACG123" or "acg123". These kinds of differences in programs and systems should be taken into account when deciding about the creation process guidelines and instructions.

Great care should be taken when recognizing and cleaning up existing possible duplicates from the PDM system. Item similarities do not always mean that they are about the same product, even if the product codes and other information on items match. This is especially true when a company updates its item database or shifts to a completely new PDM program. If items have been previously incorrectly updated or they contain unmarked configurations, future orders may result in significant losses.

7 WHERE DOES THE SAVINGS COME FROM?

For each product and material, the items' impact on savings must be identified. The link between the quality of product data and the decreasing lead-time ratio can easily be seen. Jukka Kääriäinen discusses the importance of PDM and specifically mentions the simultaneous work that items allow. Figure 23 deals with the importance of early error detection in the product development lifecycle (Kääriäinen, et al., 2000). At the design stage, repairing a defect is usually still relatively cheap, but at the manufacturing stage, the repair requires starting the entire production chain from scratch and will almost always delay the project in question.

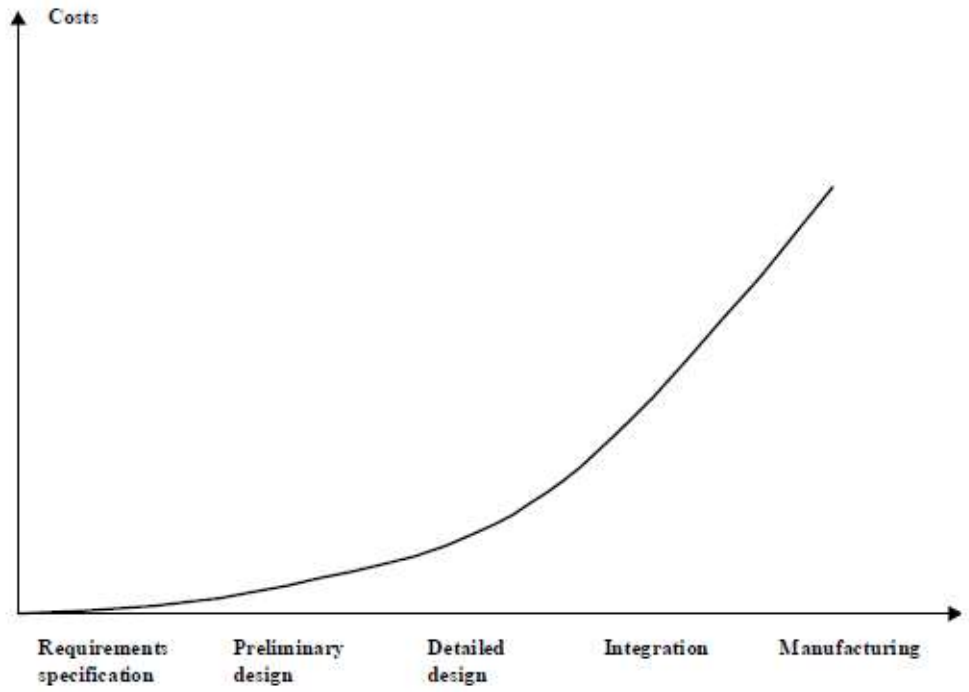


Figure 23. Cost of failure during different stages in the engineering process (Kääriäinen, et al., 2000).

The impact of items on the profitability of a company's products can be examined through a benefit-cost ratio (BCR). BCR can be calculated in several ways but the usual way to do it when analyzing the profitability of an investment is:

$$BC = \frac{B}{CR + (O + M)}$$

Where,

BC = Benefit-cost ratio
B = Benefits from the investment to the company
CR = Expenses for the investment
O = overall operating costs
M = Maintenance costs

In the formula, item service costs should be placed under overall operating costs. The added value of an item service to the company usually comes in the long term. If item service is only calculated as an expense for the first year or for the first time that product is used in the projects without considering the benefits of workload savings or risk reduction in subsequent orders, it is difficult to see the total value and benefits of the investment. The information provided by a good item database reduces the total operating costs as well as the maintenance costs in the above formula. Thus, the benefit to the company accumulates over the years. The easiest way to point out the benefits is with an hypothetical example:

The customer company pays for the electric motor assembly offered by a manufacturing company. This is the first time that the manufacturing company is selling this motor, and due to this reason, an item is also created in to the PDM system. An agreement has also been made with the company, whereby the manufacturer is responsible for the maintenance of this engine for five years. First year cost-benefit ratio is negatively affected due to the cost of itemization. However, after the first year, new sales of this motor and its spare part orders will be facilitated by the item which was created to the system earlier. Due to the positive effects of the item created for the motor, maintenance costs will decrease after the first year which in turn will increase the profitability and the benefit-cost ratio (BCR). In the following years, operating costs will be reduced because a good item database provides information regarding maintenance, datasheets and motor features. Time spent by employees on motor related tasks is decreasing.

A considerable part of the benefits of itemization is obtained when the product is used in larger quantities. Reviewing previous stores, resellers and technical information will

increase benefit-cost ratio of every sale made by reducing the operating and maintenance costs. Managing old items, which are not anymore available, or the company has decided to replace them with better alternatives, has a surprisingly positive impact on the profitability of the company. Professor Boris Otto has studied the benefits of PDM to the Festo company and noticed that significant savings were obtained inside the company by obsoleting useless items and replacing them with alternative items. In total, Festo was able to reduce sales, general and administrative expenses in 2008 by 12 million euros. (Boris, 2011, p. 286). For example, the time spent on quotes and sending them back and forth can be tens of hours per employee. In the system, obsolete or unavailable products which have not been replaced will cause reduced sales. Also, possible product specific prices will not be used for all organizational units of the company.

Similar kind of observations have also been made in other engineering related companies. Venning lists small business product data related problems in a seminar presentation and mentions legacy data, pace of change and platform changes as key points. (Venning, 2000)

8 SURVEY REGARDING PRODUCT DATA HANDLING PRACTISES IN COMPANIES

In this thesis, information on employee practices and risks regarding the management of product data was mapped using an online survey. More specifically, the survey mapped the risks and harms associated with product data management programs, practices and employees. The main goal of a survey is to collect information from multiple respondents through it (UKEssays, 2020). The survey for this master's thesis was done anonymously, because it was found to be the best way to get answers on a sensitive topic. The main purpose of the survey was to find employees from a variety of companies and positions and thus map out the most common issues related with the topic. The survey remained the same for all respondents. The questions of the survey can be seen in appendix 1. Below, Figure 24 shows an example of a question, answer and reflection workflow. In this study, answers that dealt with similar kind of topics and responses were combined into a generalized problem.

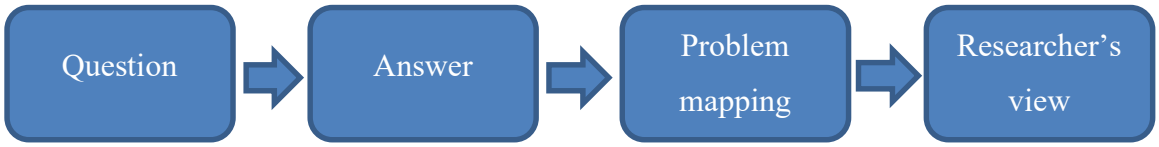


Figure 24. Processing method of the survey results.

8.1 Results from the survey

In order to make it easier to review the responses, they were divided into three different sections according to the size of the company, job description and item usage. With the help of the answers, biggest problems of the current working methods in the field of product data management were mapped. The total number of survey respondents was 35. After each question the respondents also were given a free text field, which gave them the opportunity to elaborate their answer(s). This was found to be an effective method to get more out of the responses.

8.1.1 Distribution of the respondents by job description

The 35 respondents worked in several different jobs and roles in many companies that operate in the field of technology. Figure 25 shows the distribution of respondents by job description. The answers were processed and divided on the basis of respondents' job description in order to get an overall picture of the problems. 37% of the respondents work as a designer, 26% directly with PDM, 24% in sales & delivery or technical documentation, 5% as managers and the rest 8% in the "other" category worked as project engineers, test engineers and R&D personnel.

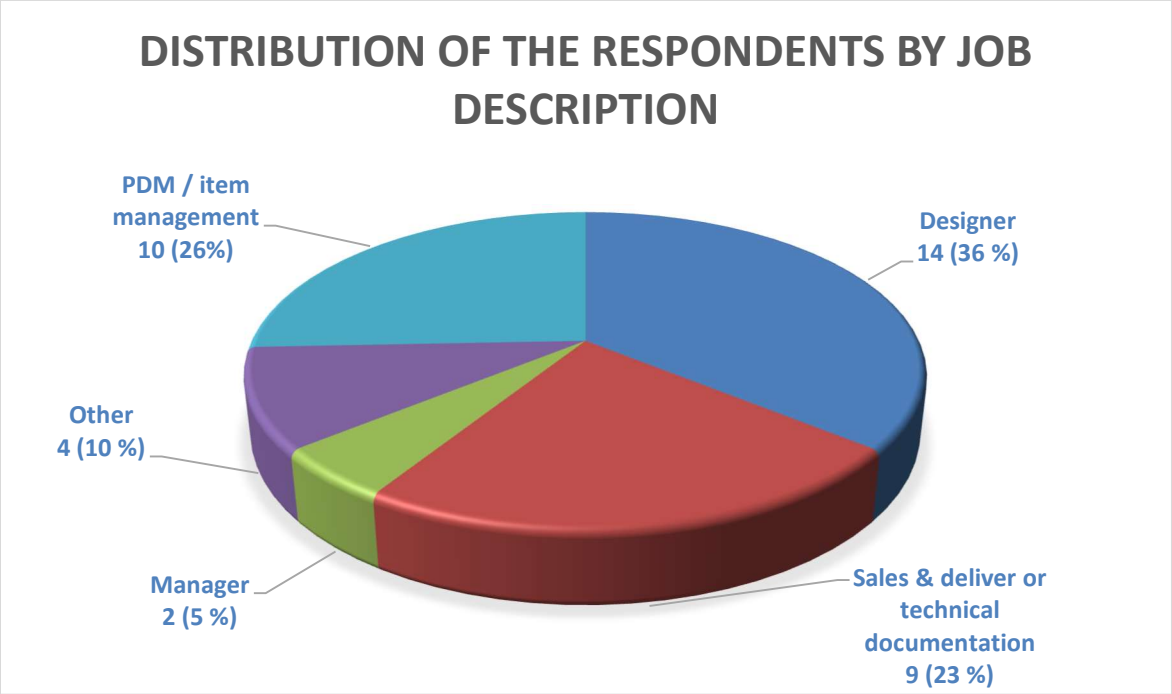


Figure 25. Distribution of the respondents by job description

8.1.2 The decentralization of the respondent's companies into different locations

The question about the decentralization explored the locations of departments and business units in corporate organizations. Many of the problems in product data management and processing are often directly related to the fact that organizational units are located in different countries or localities. Most of the respondents worked for large companies, which is also reflected in the answers shown in Figure 26. 30 of the 35 respondents said that their

companies had decentralized design, maintenance and manufacturing to different locations and countries. Sometimes the IT-support was also located in a different country which created problems that are not directly related to product data management or item management but have an impact on it. Organizational units operating in different countries often have procedures that differ from the global instructions set for the whole company. This is especially true with the units that are used to operating without global control.

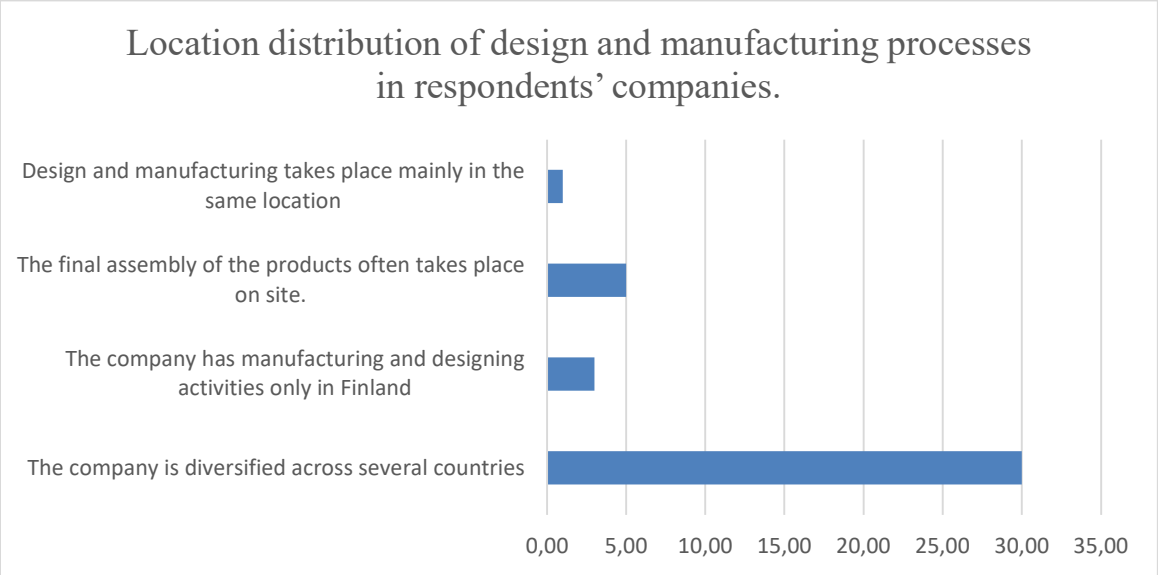


Figure 26. Location distribution of Design and manufacturing processes in respondents' companies.

8.1.3 Distribution of PDM systems used by the respondents' companies

With the help of this question, the total amount of different PDM systems used in companies was mapped. The answers to this question illustrate well how many different system companies have for product data and item management. In many cases, the program(s) the respondents used were not directly related to the quality of the problems detected. The problems were mostly caused by the users and processes, rather than the program itself. The usage rates of the different programs that utilize PDM data among the respondents can be seen in Figure 27. As expected, the most used program was SAP with a 71,43% share, because it is the most popular software in sales & acquisition. Solidworks EPDM was used in 45,71%, Vertex in 17,14%, Enovia in 25,71%, Aton in 40%, Teamcenter engineering & enterprise in 37,14%, Autodesk vault in 25,71%, PTC windchill

25,71% and Oracle in 2,86% of the companies. Each company used more than just one software program to utilize PDM data.

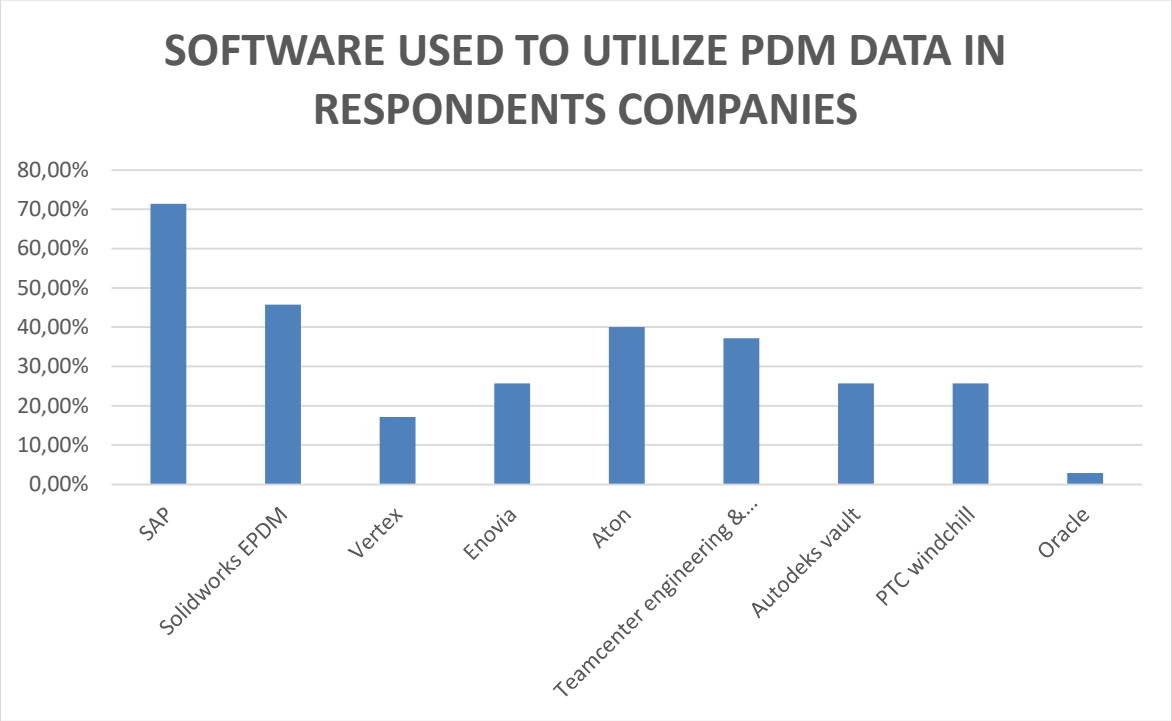


Figure 27. PDM software used in companies among respondents.

8.1.4 Item usage rates among respondents

The number of respondents using items on a daily basis was high as can be seen in Figure 28. Without the PDM personnel included, of the respondents who use items daily, most worked as designers, whose work was also most affected by problems which are related to products and item management. 43,48% of the respondents had a portal and/or a team which is responsible for item creation process or/and management. However, in a large number of respondents' companies, item creation process was, partially or entirely, the responsibility of the designer. Especially products that are not commercial, required the work of a designer. 66% of the respondents used items daily or several times a week in their work, 17% used them weekly, 9% monthly and 8% less than once a year.

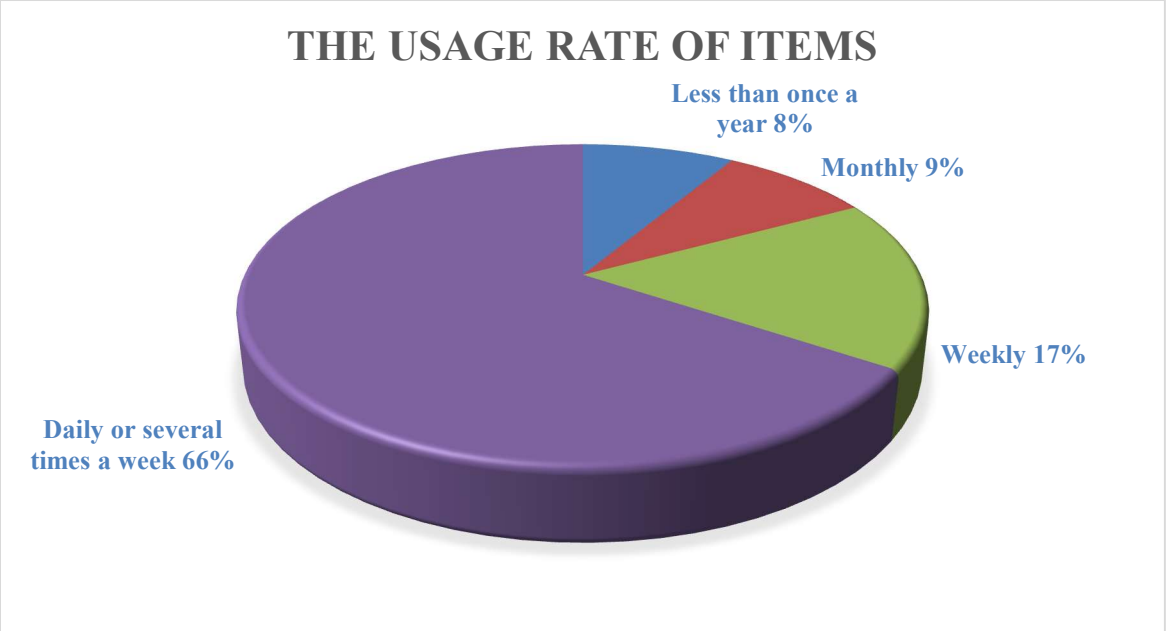


Figure 28. The usage rate of items among respondents.

The importance of items throughout the production process is also well illustrated by the fact that 58.33% of designers said that they them daily or several times a week.

8.1.5 Supplier and manufacturer product identification issues

The survey also contained questions about product identification issues. The differences between manufacturer and vendor products and items were a problem particularly for PDM and sales personnel. Nine out of the thirty-five (25,71%) respondents mentioned problem(s) related to products bought from vendors. Product related information which is provided by the retailers and suppliers often creates problems in companies that are diversified across several countries. In a multinational company, replacements between products cannot be based solely on the recommendations of the supplier/vendor. Product identification afterwards was seen as a big problem especially if the retailer/vendor company was a small one or located in a 3rd world country.

8.1.6 PDM and item management methods and ownerships in respondent companies

The questions regarding data ownership was included in the survey in order to achieve a better overview of the different data ownership and editing rights practices in the companies. Many of the respondents uncovered problems caused by either inadequate control or over-control. Figure 29 below shows the methods for managing data ownership among the companies of the respondents. The majority (62%) of the respondents, answered that their company had defined editing and viewing rights and the data ownership was determined. 32% of respondents had product management rights sorted into different groups. In this response group, often, the upholding of rights was either confusing or non-existent. There were also two responses (6%) to the query that mentioned that everyone can edit and read product data, and also there is no ownership for it. There is certainly room for improvement in managing the ownership of the data in 38% of the respondents' companies.

Two respondents, who stated that company product information management is not being monitored and all have edit access, also reported that they worked in medium and large sized companies. In a small company, due to the small number of employees, there is some degree of tolerance in the process of defining data editing rights, as the job descriptions tend to be more unclear than in larger companies.

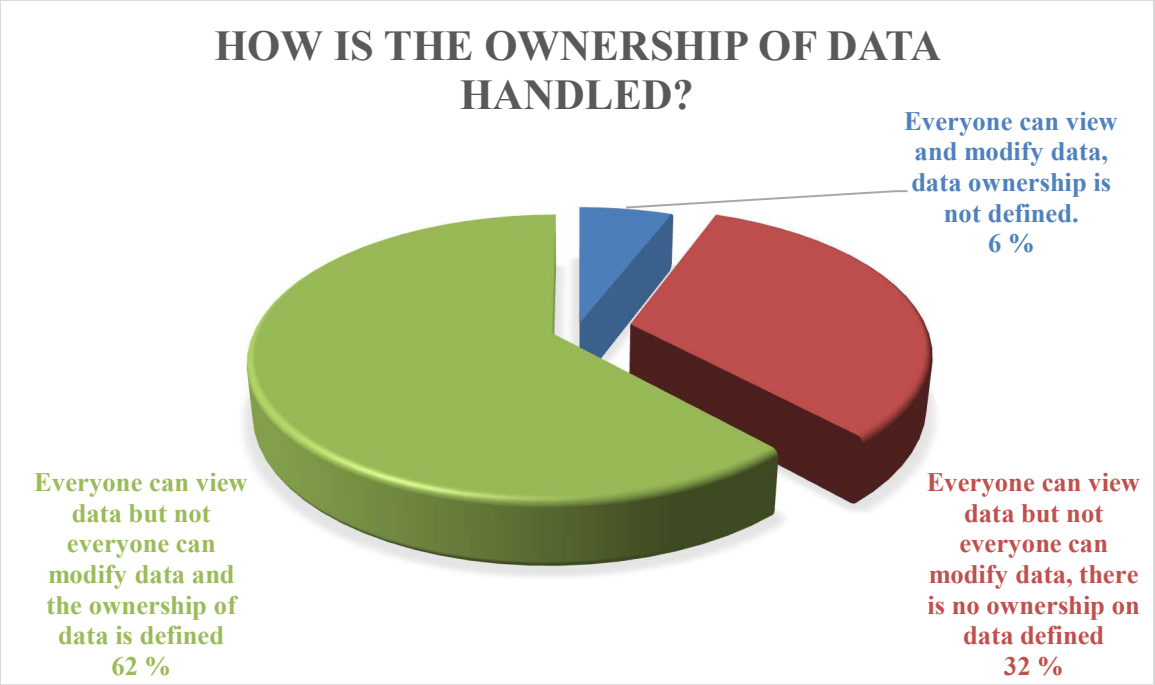


Figure 29. Data ownership distribution of the companies among respondents.

8.1.7 Issues caused by insufficient data quality and possible future risks

All free text answers were categorized into table 1 in order to identify the problems encountered. Thus, the problems that respondents have can be divided into three main categories: data ownership related problems (1), system related problems (2) and problems that occur because of carelessness (3). Specifically, for categories 1 and 3, respondents said that they expected better corporate governance. Smaller organization units were perceived as lacking in training when they were located in a different country or locality compared to larger units.

Many of the respondents complained about the slowness of the PDM system(s), even though system sluggishness problems are often the responsibility of some other team than the product management team.

Table 1. Problem identification from the query.

Problem mentioned	**Possible consequences**
Deficient or incorrect documents are attached or linked to the items. (1, 3)	Delays and quality problems.
Items are missing important information. (1,2,3)	Unnecessary revisions, delays, unnecessary work, Possibility of interference
Products exported do not match the item data. (1,2,3)	Products can get stuck in the customs, ordering the wrong products
Legacy data integrations with wrong data. (2)	Possible loss of old correct information, Moving the problems of the old system to the new one.
Customer(s) cannot identify the product ordered. (1,2,3)	order delay or delivery of the wrong product
Lack of limitation of rights. (1)	Content varies, duplicates, causes confusion on spare part deliveries
System errors, other system related problems. (2)	Integrations between two different programs does not work, causes delays and extra work
Sufficient information about the product. (1,3)	With sufficient information it is hard to create item which can be used in a correct manner.

8.1.8 Impact of product data quality on job tasks

There is no doubt about the fact that the quality of product information has a direct link to the quality and efficiency of work. This can easily be seen from the survey results. Only 3 out of 35 (9,09%) respondents answered that the quality of the product data has no impact on their daily work as seen in Figure 30. Instead, 48,48% of the respondents answered that

the accuracy of the information is critically important to the daily work. The rest 42,42% of the respondents answered that they do not actively pay attention to the quality of the information, but when the data quality is vague it affects their work.

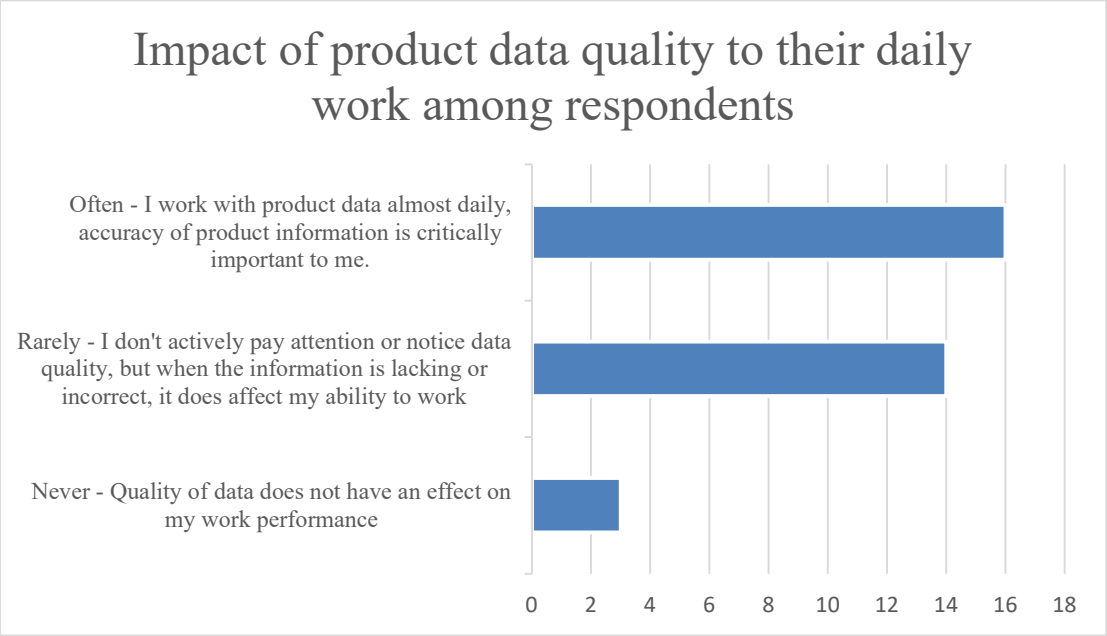


Figure 30. Impact of product data quality to their daily work among respondents

8.1.9 Improvements

The survey question regarding future improvements to the current PDM system(s) seeks to find their most important development targets. Figure 31 shows the distribution of answers to the question “When you think of the PDM system(s) that you use, what could be improved?”. A total of 85 improvement targets were chosen in this multiple-choice question by the 35 respondents.

The functionality of the search tools was criticized in several responses. Finding the right information easily was seen as the most important area for improvement with a share of 65,71% (23/35). However, the problems related to finding information are rarely only the system’s fault. Problems encountered during the creation process of the data, such as misplaced information, spelling errors, and special characters, clearly impair the locatability of the data. Integration between PDM systems and other systems used by the employees should be tested in a test environment before implementing them. Many respondents also

informed about issues in the current integration processes. They cause a lot of unnecessary work and other problems that are hard to fix afterwards.

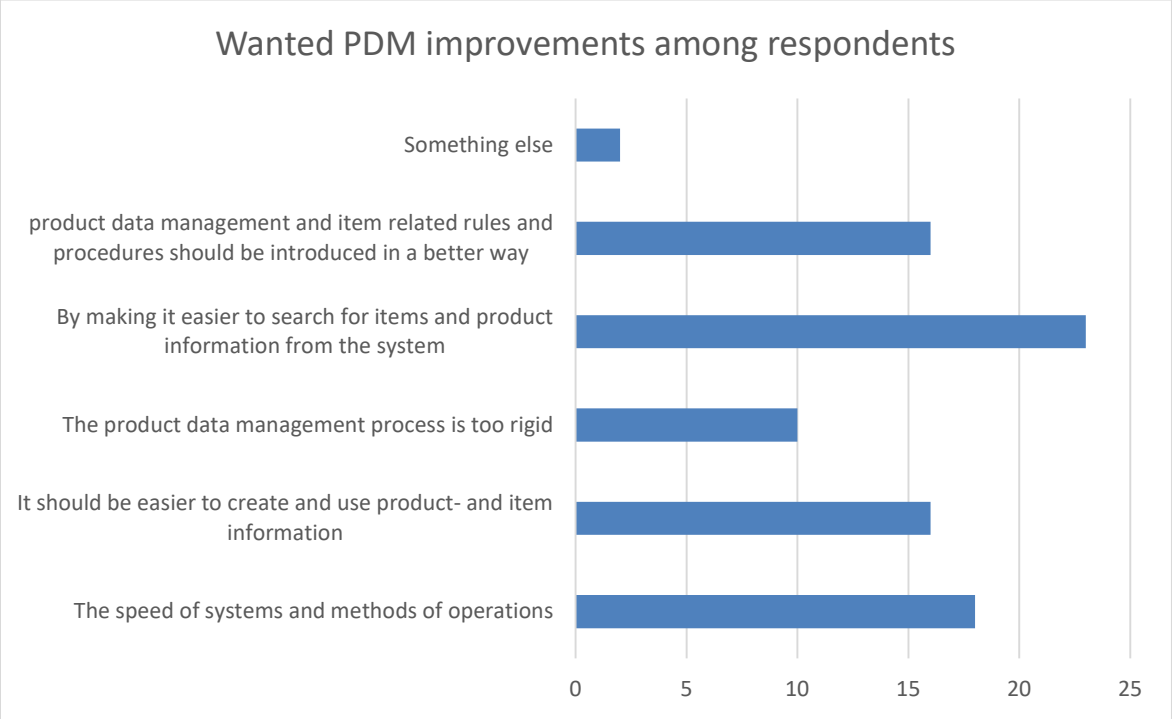


Figure 31. Wanted PDM system improvements among respondents.

8.2 Analysis

It is clear that inaccurate data causes a lot of problems which occur on a regular basis. Often such problems are ignored as the larger vision guides the work forward and the costs involved are relatively small. These problems are relatively easy to recover from, as the costs have already been budgeted in advance. However, if these kinds of problems take place often, the cumulative effect can be rather big and their costs significant. Once the vague data like this gets fixed, the profit margin of the products will also increase. A greater damage to the company is caused by problems that are difficult to predict or take place after a long period time or seldom.

Of the problems shown in Table 1, at least those in categories 1 and 3 can be solved in most cases with the tools that companies already have. The complex problems caused by poor integration between two or more systems are and will continue to be a headache for

companies. Companies are, for obvious reasons, in a hurry to implement a new system/platform as quickly as possible, which often comes with the price that the people involved in the implementation process are not familiar with the tasks for which the system/platform is designed. System related problems (category 2 in Table 1) could be potentially avoided or at least reduced by dividing items into different price categories. Companies tend to already have several categories for their products, but often lack the price categories. They would ease the harmonization's of the items, because it could be done in the order of priority. In price categories, it might be best to take into consideration both the product volume and the price, rather than just the price of the product. Low-priced products in high volumes can cause big losses to the company's competitiveness and thus those products that generate highest turnover should be the first ones to fix on the systems.

Many of those who responded to the survey felt that product information management practices made their work more difficult or slower, rather than supported it. For example, designers reported a lot of "unnecessary" work regarding items or other product related data that do not actually contribute to the project but take a long time to fix. In reality item updates in the PDM system(s) are often necessary for future projects and sales, but the operating units cannot see the issue from the point of view of others. That is why the principles of the whole production chain should be introduced to all employees so that they would understand how the process works. The risks that were identified during this thesis are summarized in the Figure 32 below. It shows the points that have to be taken into account when managing product data risks.

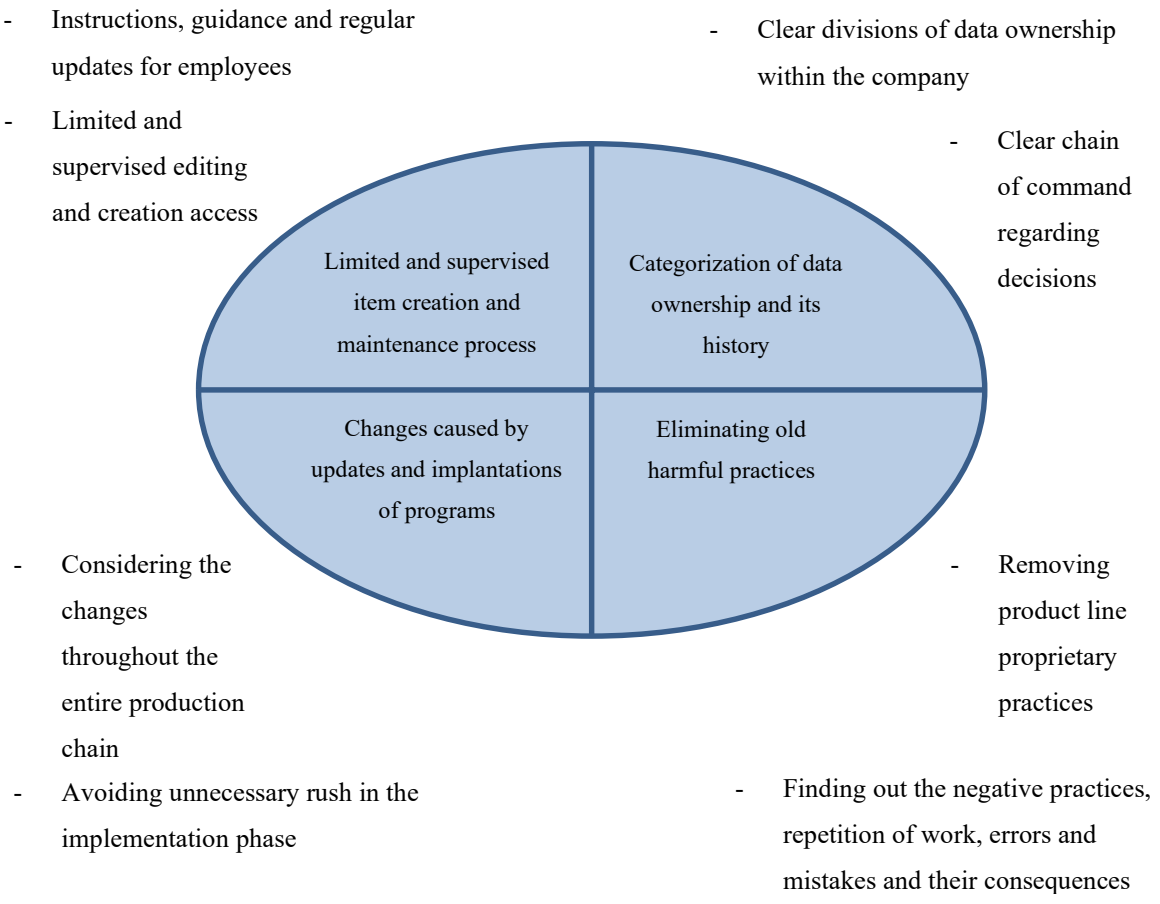


Figure 32. The main tools for managing item related risks in the PDM systems of companies.

A few simple steps, such as guidance, avoiding misconduct, and a supported process, are sure to produce good results for many companies. On the other hand, achieving a perfect environment is almost impossible due to the diversity of systems and human error. The objective for companies should be that there would be no losses caused by easily foreseen problems, at least the same problem should not occur more than once without taking action on it.

9 CONCLUSION AND DISCUSSION

The goal of this master's thesis was to identify the risks and problems associated with the PDM practices of potential clients of the target company Etteplan Oyj. The work also sought to develop solutions to these problems with the help of examples.

Problems related to product data management and in particular to item management were assessed by researching and comparing literature sources, and by conducting a survey on product data management practices of employees in different companies. In addition, the work of the author has been product and item data management related for two and a half years, which has created a good basis for observing the most common problems.

From the perspective of the reliability of the study, the number of the respondents of the survey must be taken into account. However, the survey together with the literature revealed the most common problems in the industry. Because the work handled the examples on a generic level, their application to different systems must be considered case by case.

The undersigned had access to these systems during this research: Enovia, Aton, PTC windchill and SAP. At the beginning of the work, the problems were approached from the theoretical point of view and from the point of view of the problems encountered in the working life. All the identified problems at this stage were mapped and categorized, after which the responses to the survey could be compared with the problems identified earlier. In this way, item and product data management related problems were studied and the reasons for them were mapped. Problems that were associated with a particular system were not addressed in this work.

As a result of the study, work observed the companies' most common stumbling blocks in terms of product data and item data management. The biggest problems for businesses usually arise from the lack of data management or proper guidelines. The work also explored the problems that occur because the correct data is too hard to find and use and how the systems should be designed to facilitate it. Also, other system related problems, such as legacy data quality issues, bad search tools and integrations errors should not be overlooked when planning the systems and their instructions, updates and maintenance.

Generally, case-specific issues in PDM also create an atmosphere where one solution does not suit for all companies. When designing product data solutions, companies should always think through the entire production chain. Many of the problems encountered were clearly caused by the fact that the item was created just for a one particular task, not for whole the company. With orthodox process guidance, proper data creation and ownership management, the company gets good building blocks for accurate product data, which will further help it to grow and become more competitive against the rival companies that suffer from bad data and unnecessary work phases.

On the other hand, in the future, the amount of product information available on products is likely to be increasing. There are already clear signs of such development in the food, cosmetics and clothing industry. In the future, legislation may also demand companies to provide more data about their products. Companies want to give their customers a reliable image by providing as much information as possible about their products. As the companies observe the problems caused by poor product information, their requirements for it increase. Companies, as customers, should demand better information also from resellers and suppliers. This way the competitive edge of vendors and suppliers cannot be based on hiding product information, but on providing better product data and services than its competitors.

9.1 Future research topics

One of the biggest problems with product data management comes straight from the companies manufacturing the products. Companies have many ways of presenting the product related information on their quotes, sale orders, websites and datasheets. They also categorize their products according to different criteria and each PDM system has its own way of presenting product information. Indeed, Peltonen mentions in his doctoral thesis that without standards for systems, there is no such basic model that would facilitate the transfer of product information between systems (Peltonen H. , 2000). An in-house standard that all product lines and departments are committed to would reduce the unnecessary work a lot. A study looking at this kind of implementation would probably yield interesting data by comparing, for example, long-term change request amounts before and after it.

Also, future studies could look into the new data requirements caused by the spread of IoT ("Internet of Things"). In the near future as the IoT gets more common, the current data management procedures and integrations will be deficient. A case study looking into the implementation of IoT in a company could bring a lot of beneficial information. As the systems and products, such as industrial sensors and home appliances, evolve so that they can communicate with each other, the data amount is expected to increase exponentially. This data brings a lot of value to the companies and they can utilize it in several different ways, for example, in predictive maintenance, remote software updates, providing performance monitoring and information about the possible misuse of the products. As discovered in this study, companies are already having integration issues with the current operations, and IoT is bound to bring a lot of new challenges to them. The traditional product data management and software will merge more and more in the future.

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APPENDIX I

Questions used to map companies' current ITEM practices:

1. What is the size of the company that you are working for?

    - Small 0-50 employees
    - Medium 50-250 employees
    - Large 250+ employees

2. What kind of position do you work in?

    - I work directly with product data/item management
    - I work as designer
    - I work among sales and purchases or technical documentation
    - I work in manager position
    - Something else, what kind?

      Additional comments:

3. Is the company that you are working for a so-called "decentralized company" or does the design and manufacturing work take place in the same premises?

    - The company is diversified across several countries
    - The company has manufacturing and designing activities only in Finland
    - The final assembly of the products often takes place on site.
    - Something else, what?

4. What systems are used by the company that utilize or create product information/data?

    - SAP
    - Solidworks EPDM
    - Vertex
    - Enovia
    - Zentail
    - Aton
    - Teamcenter engineering & enterprise
    - Autodesk vault
    - Oracle
    - PTC Windchill
    - Apriori
    - Axalant
    - Something else, what?

5. How often do you interact with items or product information they contain in your work?
    - Less than once a year
    - Monthly
    - Weekly
    - Daily or several times a week

6. Have you noticed difficulties identifying and/or linking supplier products to the corresponding manufacturer's product?
    - Yes
    - No

      Additional comments:

7. When the need arises for a new "item" to be made, do you make an “item” by yourself, or does your company have a dedicated team or some sort of portal for creation process?
    - I make the items myself
    - Our company has a team or portal through which items can be requested.
    - Something else, please open slightly:

8. How is the ownership of data handled? Please select the most descriptive option.
    - Everyone can view and modify data; data ownership is not defined.
    - Everyone can view data but not everyone can modify data, there is no ownership on data defined
    - Everyone can view data but not everyone can modify data and the ownership of data is defined

    Additional comment:

9. Has insufficient data quality caused issues, e.g.time delays on production, delivery or service? What kind of?

10. Are you worried about risks associated with insufficient data quality, that might realize later in a products lifecycle, or have you heard or experienced such risks coming to fruition? What kind? Please open little bit.

11. How much does your company's product data quality affect your work?

    - Never - Quality of data does not have an effect on my work performance
    - Rarely - I don't actively pay attention or notice data quality, but when the information is lacking or incorrect, it does affect my ability to work
    - Often - I work with product data almost daily, accuracy of product information is critically important to me.

    Additional comments:

12. When you think of the PDM system(s) that you use, what could be improved?

- The speed of systems and methods of operations
- It should be easier to create and use product- and item information
- The product data management process is too rigid
- By making it easier to search for items and product information from the system
- product data management and item related rules and procedures should be introduced in a better way
- Something else, what?

Additional comments:

13. Free text field regarding this survey