Product data management practices in high tech companies

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Abstract

Purpose – The purpose of this study is to provide tangible examples of product data management practices in large high tech companies, and to highlight current challenges.
Design/methodology/approach – This research is a qualitative interview study. First, a product data management (PDM) system frame was defined to aid analyses. Secondly, an interview study was carried out in four companies to clarify the practical realisation of PDM, and the current challenges. The interviewees are experts in the field of PDM, currently holding significant related posts in their companies.
Findings – Overall target of PDM activities are seen similar in all companies, however, there are some diversity in the realisation of these practices. PDM related challenges identified in this study are various, strongly influenced by company background and current organisational state.
Research limitations/implications – This study includes interviews in four companies with different backgrounds, and a workshop, providing a good view on topical issues in the field of PDM. The obtained results could vary to some degree, should the sample size be larger, or especially should the products of the studied companies be less complex.
Practical implications – This article provides managers and PDM system developers' better understanding over the issues that are affecting PDM solution development and on major system requirements, together with relevant insight to current challenges.
Originality/value – The existing literature is relatively scarce in describing the practicalities of PDM. The obtained results highlight the significance of company background influencing the selection of PDM solutions.
Keywords Product data management, product lifecycle management, industrial management, product structure, data systems
Paper type Research paper

1 Introduction

In modern global economy, companies are forced to continuously come up with new innovative products to improve, or even maintain, their market position. Work is typically organised in a multi-site, multi-project and multi-cultural environment leading to a situation where companies must pay especial attention on ensuring that product data is correct and flowing rapidly, ideally in an automated manner, between all the actors in the value chain (e.g. Giménez *et al.*, 2008).

Current business environment is typically dependent on data-systems. In engineering and manufacturing companies, efficient data management practices have become one of the key aspects for business efficiency.

Data management practices are emphasised when companies collaborate with their partners, suppliers and subcontractors relating to R&D or manufacturing. Shortening time-to-market, increasing product complexity with decreasing product lifecycles, growing legal and environmental requirements, together with demands for continuous costs reduction and higher operational efficiency set challenges for today's manufacturing companies. (e.g. Ameri and Dutta, 2005; Stark, 2005; Saaksvuori and Immonen, 2004; CIMdata, 2002). Traditional solutions are not adequate to tackle these challenges. Product data management (PDM) has become one of the most important considerations for companies, especially in engineering and manufacturing industries. Design and manufacturing processes benefit significantly of improved product data sharing, and the usage and visualisation possibilities offered by PDM (Chan and Yu, 2007). In order to be competitive, companies require a common presentation of product data that is electronically transferrable over organisations (Saaksvuori and Immonen, 2004). This is yet to be fully realised (Abramovici, 2007).

The main purpose of introducing PDM is to help companies to manage their operations electronically, making it more efficient and effective. PDM systems typically control all basic data on how to design, maintain, and dispose a product. If a company is not able to control product related data, it will be difficult to for them get the product under control (Stark, 2005). PDM helps to organise and utilise data, enabling accelerating time-to-market due to reduced lead-times. (Huang *et al.*, 2004; Sulaiman, 2000; Philpotts, 1996).

This paper studies the different elements of product data management systems, including practical realisation of PDM in selected case companies. This includes discussing definitions, processes, and data systems related to PDM solutions. These issues are studied to attain practical knowledge on PDM systems and to provide tangible descriptions on how companies are applying PDM practices. In addition, the current challenges are clarified. The above can be condensed into the following research questions:

RQ1. What type of practices companies utilise for product data management purposes?
RQ2. What are the main challenges of PDM in high tech companies?

This study addresses the research questions in a qualitative manner both, through literature and industry interviews. A simplified PDM system frame was also created to support the analysis.

2 Literature review on PDM and related concepts

Managing product data has became a challenging task for manufacturing companies who simultaneously need to design and re-design products in a shorter time, while trying to respond to changing market needs and environmental concerns, improve product reliability and offer add-on services (see e.g. Trappey *et al.*, 2008; Yang *et al.*, 2007). Product development process requires improved solutions for handling product data in order to better support collaborative engineering and management of product development projects, product structures, documents, and quality (Yang *et al.*, 2007; Rouibah and Ould-Ali, 2007). To develop product designs, feedback from the field is required (Jun *et al.*, 2007). Other company functions, aside product development, also require better data management practices. For example, supply chain performance is heavily dependent on product related data handling (e.g. Huang *et al.*, 2003, 2005; Johansson and Medbo, 2004).

Product data is created and utilised in different business functions with disparate ways (Sudarsan *et al.*, 2005). Product data is referred to as *"information broadly related to a product"* (Saaksvuori and Immonen, 2004). Thus, is often used interchangeably with the term product information (Fensel *et al.*, 2001; Liu and Xu, 2001). Also, the term information systems, which covers business related aspects is often used interchangeably with data systems that addresses more operational issues. Product data can be divided into product definition, product lifecycle data, and metadata (Saaksvuori and Immonen, 2004). Product definition and lifecycle data can further be divided into static and dynamic data. It can be said roughly that PDM involves managing the static product data, specifications such as bill of materials (BOM), and operational instructions. Product lifecycle management (PLM), on the other hand, also covers the dynamic product data which occurs during distribution, usage and end-of-life (Yang *et al.*, 2007; Hribernik *et al.*, 2006; Simon *et al.*, 2001). PDM is defined *to integrate and manage processes, applications and all kind of information that define products across multiple systems and media* (e.g. Stark, 2005; Saaksvuori and Immonen, 2004; Philpotts, 1996).

The concept of product lifecycle management (PLM) is closely related to PDM. The common view is that PLM is the predominant concept covering also PDM activities (see e.g. Stark, 2005; Sudarsan *et al.*, 2005; CIMdata, 2002). CIMdata (2002) defines PLM to be *"a strategic business approach that applies a consistent set of business solutions, which support and integrate business processes and functions through product lifecycle"*. PLM provides the capability of collaborative product – process actions, integrating people, processes, and technologies (Ming *et al.*, 2007). This definition is widely used in earlier studies. Good PLM system is seen to require one common PDM process as PDM is the foundation for PLM (CIMdata, 2002), even though PLM is lately seen to be replacing the PDM concept (Giménez *et al.*, 2008).

Regardless of PDM and PLM covering the entire product lifecycle (PLC), in practice data management is still focused towards managing product development and design data, and the methods used to collect product data from middle and end-of-life phases are incomplete (e.g. Yang *et al.*, 2007; Jun *et al.*, 2007; Abramovici, 2007). Unfortunately, in practice the relevant feedback information from the field cannot be adequately obtained and utilised for later product design versions.

PDM system connects product data related product and process management, providing an infrastructure for controlling and sharing data for users together with a related user interface. (Rueckel *et al.*, 2005; Stark, 2005). The content of PDM systems is not unified and varies by a definition. PDM systems contain at least the following basic modules (e.g. Kumar and Midha, 2006; Stark, 2005):

- Information warehouse or data vault
- Information warehouse management: tracing any data related actions
- Document management
- Configuration management
- Product structure management
- Product and workflow structure: definition modules
- Workflow and process management
- System administration management

According to the above listed, compatibility with other IT systems is an essential element of PDM systems (e.g. Wei *et al.*, 2009; Maletz *et al.*, 2007).

PDM systems are used for gathering data from specific software, such as CAD, CAM, FEM, and for storing and administrating data centrally (Stark, 2005). Standard definition of product related data is a key for integrating activities in a value-chain, and for making application integration possible and more functional (e.g. Giménez *et al.*, 2008). Common definition of product data includes creating understanding over data collation needs in later PLC phases, covering the end-to-end (E2E) view of a product, as requested by Yang *et al.* (2007) and Jun *et al.* (2007). According to these two authors, PDM and PLM technologies involve also other challenges. For example, current technologies are not at a satisfactory level to provide reasonable solutions for supporting the increasing need to deliver tailored products (Ming *et al.*, 2007), and to better support the integration of products' mechanic, electronic and software components (Abramovici, 2007). In complex product environment, the diversity of data formats, such as free text, structured and semi-structured data and combinations of these, together with variety of data sources creates a challenge for data management within integrated systems (Feng *et al.*, 2009; Yang *et al.*, 2009).

3 Research process

This research is qualitative in nature. PDM/PLM was first studied by the using existing literature as a key source. The empirical study consists of a workshop and industrial interviews. The research process is described in Figure 1.

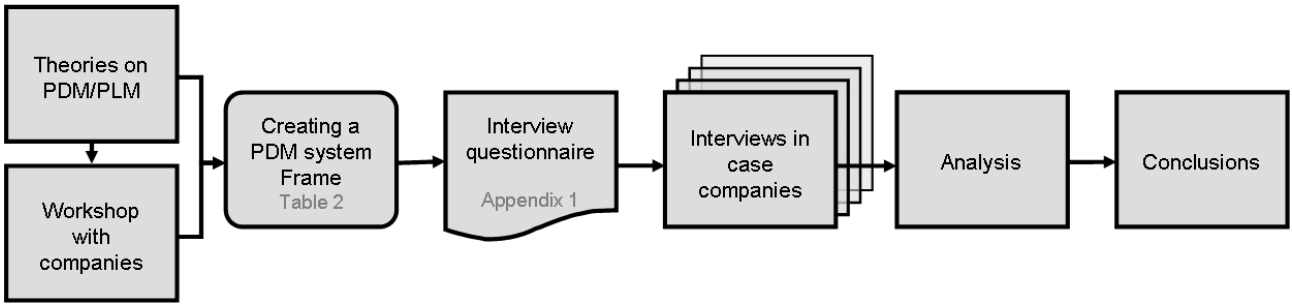

Figure 1. The research process.

At first, a workshop was arranged together with three companies to discuss topical issues on product data management. The attendees are experts in the field, offering a wide perspective on the subject. Based on the workshop and earlier research, a preliminary PDM system frame was created to aid analyses. The frame is aimed to aid further studies in order to focus on the three PDM elements identified important.

The interview questionnaire was formulated based on the created PDM frame and understanding obtained through the literature (see the Appendix 1 for the questionnaire). Interviews were conducted in a qualitative manner, allowing the interviewees to explain and clarify the cases and topics as entities. Interviews were conducted in four heterogeneous companies to obtain a wider view on the studied subject. The study included altogether twelve interviews. The interviewed industry experts were selected carefully on the basis of their professional background and expertise. Selected participants hold responsible positions related to product management, and product data management. The experience and the current interests ensured high motivation among the participants and up-to-date knowledge with respect to the discussed topics.

The interviews were conducted in four companies, all of which manufacture complex, high tech products, combining software and hardware. They all operate globally in multi-site environment, including global challenges and global customer requests. Also, different local laws and regulations are considered in their product design and manufacturing. These companies are all large companies (see company definition by EU Commission, 2005). However, company A is a subsidiary of a consortium, and thus conclusions considering the entire group cannot be drawn. This subsidiary is equivalent to a medium size company when considered separately from the group. Company specific characteristics, relevant to this study are presented in Table 1.

Table 1. Company characteristics.

Company	Business	Special product characteristics	Operational maturity
A	B2B	prototype service and manufacturing, one of a kind product	Mature operations, long business history
B	B2C	customer product with warranty service, short PLC	Mature operations, long business history
C	B2B	system products with services, long PLC	Business merger, unified companies have a long history with well matured operations
D	B2B	new, immature product with long PLC	Rapidly growing company and business, relative new company

4 Results and analysis

4.1 PDM system frame

PDM system frame formulated in this study is presented in Table 2. The issues covered can be divided into three topics: *information systems, processes for PDM, and product structure*. These main topics are seen to be the key elements of a PDM system. The fourth aspect to cover in a PDM system includes product lifecycle in each of the three other sectors mentioned. The product structure is seen to be the key, basic element for creating a PDM system. In fact, product structure is seen as the backbone for a manufacturing company, on which they base their products, sales, and invoicing. However, without a common definition, and understanding of product structure, companies feel that PDM system development is not possible. PDM system creates the basis for interlinking product information by deriving the rules for workflow processes and the supporting information systems.

Table 2. Contents of a PDM system.

Information systems	Existing applications used for product data handling.
	The degree of application integration.
	Information sharing over enterprise and extended enterprise (suppliers, partners, etc.).
	Real value of information. Common understanding on data over organisation.
Processes for PDM	Product data ownership determination.
	Product data maintenance and workflows for product data change execution.
	End-to-end view consideration for processes.
Product Structure	Definition and construction of a product structure based on real business needs.
	Optimal number of product configuration possibilities. Product structure to support providing customer solutions.
	Utilisation of product structure over organisation.

In addition to these three topics, some related major challenges were identified. Even though process management is practiced in the studied companies, it is still clear that processes and information systems are in their own silos, especially in the case of PDM, PLM, and configuration management (CM) activities. This has caused processes and information systems to become dispersed, making their ways of working diverse, not supporting the E2E product – process thinking. Also, different departments create their own applications for specific needs. Utilised applications are mostly tailored in response to company needs, but once a single common solution is required, building on previously tailored complicated applications is challenging.

4.2 Current PDM practices and challenges

In order to understand the studied phenomena, and to avoid misunderstandings, the interviewees described their understanding on the discussed concepts. In this study product data was defined by the interviewees to contain all the data related to a product. However, technical product data is emphasised and primary product data contains all the data required to design and manufacture a product (static data).

PDM is defined to be managing all the product related data, the key issue being to ensure that all data is shared among actors who need the information. Effective, efficient and controlled data utilisation is a part of PDM. PDM includes systemising processes for data management, and standardised product change, which enables a visibility log. PDM is seen to contain standardised ways of working, and relevant supporting applications.

Based on the interviewee comments, it is not possible to derive a common definition for PLM. Typically, PLM is seen to widen the PDM perspective to cover all PLC stages. PLM can be seen, as stated by an interviewee, *"PLM is about controlling product processes from design to product termination, and thus also includes other issues including PDM*". PLM adds an event log to PDM systems, enabling obtaining information on both faults and product changes from the field.

4.2.1 PDM system benefits and challenges

Table 3 presents summarised interview results on challenges experienced by the interviewees relating to current PDM systems in their companies. PDM related challenges varied among the studied companies, and some intra company differences could also be identified. Table 3 also summarises the general PDM system benefits experienced by the interviewees. The experienced benefits of PDM systems are seen to be fairly similar among the studied companies. One must note that the benefits listed below can also be assumptions made by the interviewees accompanied with real experiences over PDM system benefits. Noteworthy is that in this research, companies B, C, and D are currently developing their PDM/PLM systems. This has an obvious influence on the experienced challenges.

Table 3. PDM system benefits and challenges.

	PDM system challenges	*Experienced PDM system benefits*
Company A	To keep all product data (PD) available for everyone who needs it without a single PDM application. PD is based on customer information, related data format is not always best in quality.	Data is stored to a system. Besides of used applications, the PDM process ensures quick data searches, and enables having correct information in a system, speeding up order-delivery and design processes (when utilising earlier designs).
Company B	To ensure that data is up-to date, reliable, relevant and good quality when it is brought to the system. To get people, producing PD, to enter it into the PDM system. Combining tools from different user groups in order to carry over data to PDM systems. Incorrect data, or a broken PDM system, could mean significant financial losses.	PDM system speeds up business processes when information is global, correct PDM makes global business activities easier. PDM system takes care of all data related organising, handling, and back-ups, it includes all product related intelligence. Data is stored in an agreed format, and is available to all related personnel. The risk of doing something wrong is reduced when data is stored in one place.
Company C	Combining different applications and getting PD into one PDM system. Later extension of PDM into a PLM system. To have a uniform definition on PDM at the company level. Unifying corporate language. Standardising operations. For example, governing product coding – the logic for version control is not always clear. Personnel changes cause loosing competence on developing the PDM system.	Enables all employees to understand product portfolio in the same way. Enables a single product structure and processes for managing product changes. Increased visibility and reduced multi-layering of information leads to cost reduction, and quicker delivery times.
Company D	Processes for modelling products, changing products, and sharing of information to others are not adequately defined. Currently requiring a lot of manual work. Product structure is continuously chancing due to design errors, modifications, and modernisations. Long term experience on managing complex high tech product structure does not exist.	Systematic way of doing things. All PD is available to all personnel. Provides a controlled product change/ version management process. Do not allow overlapping work (for example, simultaneous product changes).

The interviewees were also asked to provide their views on any overall improvement areas benefiting PDM practices. The results were somewhat fragmented and each company had their own individual challenges. There was some variation in intra company challenges, as different departments view PDM differently. Some of the main development ideas, brought up by the interviewees, are listed below:

- Standardised form product data (requirements/specifications).
- Enormous change is needed in people's attitudes towards the PDM utilisation. Also, increasing the interests towards PDM and related understanding.
- Better and easier integration of PDM and other business tools are required to fully utilise the benefits of PDM systems. Quicker data transfer between tools.
- Further development of bespoke systems, as adding new functionalities as an afterthought is currently difficult.
- Integrating all product data into one system.
- Better system support for configurable products.

4.2.2 Results related to product structure

Product structure is seen as the backbone of a PDM system. Interesting is that interviewees see product structure to have two dimensions, information hierarchy and physical structure. Two companies, C and D, use "top level" product structure which presents *"the hierarchy of product information"* and is used in the companies for information sharing purposes. It is seen as a basic structure on which applications are based. "*This structure cannot be changed without very strong reasoning"*. In practice, different operations use different views to product structure.

However, there is also another view to product structure which can be identified in all the case companies. This way of seeing product structure is seen to describe products at structural item level. It is seen to contain details of materials, components, subsystems, and such, of a product, but also including technical, software and mechanical structures. Product changes are dealt with at this information level. The changes that a product faces during its lifecycle are mostly caused by the needs for product and business efficiency. This means that some components can be changed to cheaper ones, cost reductions. Product improvements are made to attain better quality, or to improve reliability, or to offer new product features.

All the other studied companies except company A, provide different solutions for their customers based on product variants. However, currently PDM system support for product configuration is seen to be quite poor. Also, the solutions for product variant related practices are strongly company specific, see Table 4.

Table 4. Practices related to product variants.

Company B	Different product variants are provided for different markets. Variants may include: different colours, country specific materials, such as manuals and country specific language settings.
	In the future, also software may be one of the variants.
	Variant management is currently carried out manually and is thus laborious. A new PDM system provides a solution for handling product variants in an automated manner.
Company C	The number of product variants is seen excessive: *"variants enable hundreds of thousands different configurations."*
	Software variants are preferred over hardware ones.
	Reducing the number of variants is attempted by offering few standardised solutions.
Company D	Limited number (5-6) product variants. However, the final product solution is a combination of a standard system and a limited number of offered variations. The standard system is a "one of a kind" -product by nature.
	Regulations set by authorities are also seen to be causing needs for product variants.

4.2.3 Product data management processes

This chapter summarises product data management practices in the case companies. Results are condensed into Tables 5 and 6, highlighting some important aspects of PDM, including data ownership, data maintenance and availability.

Companies view that their PDM system solutions can be centralised, decentralised or be combination of these. The centralised solution is seen to mean data ownership being defined to one main organisation. Companies B and C have centralised solutions, while companies A and D utilise decentralised solutions for their PDM solutions.

Table 5. Data ownership practices.

Company A	Ownership is based on operational responsibilities.
	Data ownership is defined in work instructions. Checklists are utilised to ensure process follow ups.
	Customer creates and delivers the utilised product data.
Company B	A specific PD-team owns the global product data, while manufacturing plants own the local data.
	Operational ownership is based on business responsibilities.
	PLC status based ownerships are also defined in detail.

Company C	Business unit owns product master data and related configuration data. Business unit also maintains some local data. Operational PDM organisation owns delivery data related to products and creates product set-ups in ERP. Virtual data owner network organisation: ensures data accuracy. In operations environment the one who creates data, also owns the same piece of data.
Company D	Data ownership is defined at function level. A dedicated person deals with changes concerning product data and related communication.

Data ownership in the studied companies, especially at practical level is seen to be mainly formed naturally. Data ownership in all the interviewed companies is based on the principle of someone creating data also has the ownership. Data ownerships are also created based on business responsibilities, so that for example a purchasing manager is responsible of maintaining product pricing data. Data ownership over a product, or a certain product attribute changes based on the phase of product lifecycle, as described for example for companies B and C. One of the larger companies has a special organisations established for assuming the overall responsibility over product data, and related management. Even though product data ownership is defined clearly on paper, the companies experience certain "black holes" in the sense of some data attributes not having owners, making any corrective actions difficult, as revealed by companies B and C.

Table 6. Data maintenance and availability practices.

Company A	Data maintenance is not experienced to be an issue of major significance. Automation is not utilised for data maintenance purposes. Data availability is based on user groups and given rights. Every operational unit requires some product data. Data is trusted to be correct in the systems.
Company B	Data maintenance is experienced laborious. The role of PD-team is emphasised for manual data checking before data is transferred to PDM application and to ERP. This includes maintaining data in PDM-systems and transacting all product data change requests. The most crucial part is seen to be product development and design phases, and having valid data on all components, and such, in the system. After product development, product data is transferred into a product data maintenance phase, and the organisation is considered to be managing product change process. There is always need for a person to check the correctness of data in the systems, as the systems cannot be programmed to conduct self-checking.
Company C	Data maintenance is experienced laborious as there are no uniform product structures in use. The amount of product data and related attributes is also seen enormous. Data maintenance over PLC and over product changes is carried out under unclear product configuration rules. Data accuracy and quality are measured continuously. Besides of tools, certain data searches can be laborious when operations personnel do not understand the information presented by specialists.
Company D	The used systems are seen fragmented and the practices unclear. Product data is relatively unorganised. Searching and managing this data is seen especially time consuming and often conducted manually. Overall product data is combined only in ERP, but not in product design tools, or purposes other than production. Separate CAD is used for mechanical and electrical structural designs.

Manual work is required at least to some degree in all the studied companies for maintaining product data. In the larger companies, when manufacturing complex products and maintaining different data attributes and related documents over PLC, data maintenance is laborious and requires a lot of resources. Practices among companies, however, vary and are dependent on the company background (Table 1).

4.2.4 Information systems

Table 7 presents information system solutions in the studied companies, summarising the type of applications used in PDM/PLM activities together with relevant integration to other operational applications. Also, data transfer to and from customers and suppliers is described.

Table 7. Information systems for PDM/PLM.

Company A	There are no dedicated PDM/PLM applications in use. The main information systems are ERP and other relevant databases. A separate production control system (PCS) is linked to ERP, and CAD/CAM applications are linked to PCS. Information sharing with customers vary based on the customer, and the system the customer is using. The information from customer is uploaded for example by using FTP, or an Excel file, or obtained directly from customer's system. Data transfer to customer is not automated, and occurs mainly via e-mail. Product data is not shared with suppliers in a wide context. Information from suppliers is mostly obtained by e-mail on issues, such as, technical specifications, drawings, and material declarations. Further integration to improve the collaboration is not seen to be needed. Data is stored in a database for indefinitely.
Company B	Different applications are used for PDM/PLM purposes. There is a dedicated PLM application Teamcenter in use. Teamcenter is an off-the-shelf solution. Current PDM applications are integrated into several other systems (mCAD, ERP). At different PLC stages, additional supporting applications are utilised. Most commonly used ones are different MS office tools. During the design phase, CAD systems are used to create data. In order to ensure E2E coverage in PDM, PDM and ERP integration tools are needed. After-sales utilises a program for spare parts. Integration between applications is mostly one way, such as from PDM to ERP, and from CAD to PDM. In new PDM system, information sharing is seen to be two-way, further integrating different applications. Information sharing to customers and suppliers is mostly dealt with via e-mail. New PDM system is seen to help information sharing with suppliers when adequate supplier logins can be used, enabling remote access on relevant aspects. The need for better information sharing with supplier has been recognised.
Company C	Dedicated systems for PDM/PLM are used: there are 5 component systems and 7 PDM systems in use. There are plans for these 12 systems to be integrated to a single PDM system (Enovia). There are also 10 separate applications in use for PLM. Systems are typically tailored for company's needs. Product development personnel may also use their own Excel sheets to maintain data before it is launched to ERP. Integration between PDM/PLM applications to ERP/CAD systems is seen to have penetrating impact. Different tools are required especially in service business, a service catalogue is required for finding all product related information. More than 10 sales and offer configuration tools are in use, all of which will be integrated to ERP/CRM. Product related information is shared to customers and suppliers by using client PDM. This solution provides certain user groups with the information they require, but does not include any added value.
Company D	PLM system (Windchill) implementation is ongoing. Coming application is seen to cover PDM application, process descriptions, and CAD integration. This is an off-the-self solution. Information transfer from PLM to ERP is seen to be an automated one-way solution in future. Currently there is no integration between used applications.

	The main tools currently used, include ERP and CAD software. Excel is also widely used. No systems exist for transferring data to and from the customers. No system exists for exchanging data with suppliers (design and manufacturing suppliers). Information sharing is based on e-mail which is not ideal. Only EDI is used to handle invoices and order confirmations. One of the main focus of new solutions will be suppliers so that they will be able to exploit company's PLM system.

4.3 Analysis on PDM system practices and the identified challenges

PDM processes, applications and related work practices are very diverse in the case companies. The studied companies, except company A, all have ongoing efforts towards centralised PDM systems. There is an obvious need for PDM/PLM system development, motivation emerging from the current business environment and processes not being in balance. The root causes for development needs are somewhat different, but all companies aim to improve their practices in order to ensure better product data quality and availability. One of the studied companies already has virtually good PDM practices, while another one is still developing the related basic working practices. Two of the other companies are struggling with creating a common understanding on their products and harmonising the related product structure within their companies, highlighting how the starting point of PDM/PLM system construction is obtaining common understanding on the product and related data hierarchy. There is also a need to freeze the product data hierarchy as all the other PDM/PLM system elements are built based on this foundation.

Centralised PDM/PLM solutions are seen to support business operations in a multi-site, global environment when the speed of data transfer and on-time data availability is essential. Workflows for handling product data are well understood in the studied companies, having strong and long lasting impact on business (companies A and B).

The bigger the organisation is the more laborious data maintenance is experienced, even with an increased number of automated actions. Manual work includes data entry into systems, and content checking, constantly risking human errors. Vast amount of data increases data maintenance work remarkably.

Product data related errors are attempted to prevent by defining data ownerships. Each of the studied companies has a baseline system for data ownership. Data responsibilities are allocated according to organisational units and related business responsibilities. A person creating a piece of data is typically also a data owner. In companies B and C there are specific organisations in place for carrying the responsibility over data ownership.

Practicalities of data ownership are seen more complex than any related definitions on paper. Typically, responsibilities over correcting incorrect data in the systems are not clear, making it difficult to find the persons responsible of any piece of data that needs correcting. This may be one of the reasons for some of the interviewed companies to have specific organisations in place to ensure product data quality. In company C, there is a specific organisation even for measuring data quality and accuracy.

The case companies have different dissimilar information systems in use for PDM purposes. One of the companies does not have any specific PDM application, while all the others do. The used applications are more often off-the-self solutions, and tailoring is attempted to minimise, or even totally avoid. The later application development is seen to be problematic after extensive tailoring.

Aside a major PDM application, also other tools are used. The basic MS office tools are seen relatively functional for these purposes. CAD is also a part of every company's tool set. Tool integration varies among the interviewed companies. In company C, the integration is said to be penetrating, when the others are see information sharing as the only one way onwards as the communicative part of PDM is seen somewhat lacking. Also, sharing information and data with customers and suppliers is at a primitive level, except in company C. The main tool for information transfer with suppliers is still e-mail. However, these issues are developed towards better solutions with ongoing PDM application implementation projects. Also, in the case of the interviewed companies the communicative data transfer (internal) and collaborative roles (external) are increasing.

An interesting challenge relating to product data practices was found in the personnel's attitudes towards product data handling practices. It is seen vital for the people creating product related data to understand why it is so important to enter the data in the system so that it will be available to other personnel from the very

beginning to avoid unnecessary challenges with version control. The correct format of data is also vital to avoid unnecessary work. In addition, there are some intra-organisational challenges relating to common understanding over data elements, their importance and related responsibilities. It is not clear in all the companies, during which process phase data is to be maintained, or even which piece of information.

PDM/PLM systems are considered to ensure a controlled way to handle product data, including related processes, work instructions, and applications. The case companies emphasise that PDM/PLM systems are a key for companies to speed up their business processes. The data needs to be timely, and correct from the very beginning. In addition, data is seen important to be available in all company locations globally to speed up order-delivery processes. This study emphasises the importance of providing reliable up-to-date data, increasing needs for traceability, and better solutions integration. As an example, in some cases, *"the business is not interfered by the lack of materials or components, but the insufficiency of data at critical moments"*.

The ideal situation involves getting all product data into one single system. Other development areas include smoother data transfer between applications, and the better compatibility of applications. PDM systems are seen important to be flexible enough in order to better respond to any changes in business practices. There is also a need for PDM/PLM system solutions that would better support product configuration management, as most of today's systems are more concentrated on managing products at item level.

5 Conclusions

Product data management is a relatively new academic research area, and as a consequence the literature is somewhat scarce on practical solutions, including descriptions on how data ownerships are defined, how product data is maintained, what are the relevant process solutions. PDM/PLM is seen to be one of the important solutions for developing operational efficiency, especially for companies with complex manufactured products, potentially including add-on services offered to customers. Many companies are currently developing their tools and processes to better manage and process product related data. Product data and its efficient handling is becoming an important asset for business development.

The purpose of this article is to study the current product data management practices and related challenges in four case companies. The overall target of PDM activities in the studied companies are similar – to ensure the correctness of data and its availability to all personnel. Data quality is seen to be number one in priority and is attempted to assure when defining data ownership. Companies typically define data ownership based on business responsibilities, often making the person creating a piece of data also a data owner in that case. Companies with a long business history also have special product data teams assuring data quality and accuracy, having the final responsibility over product data. PDM practices are typically planned to fit for organisational culture and the nature of business, practices thus varying between companies. Companies typically have information systems to aid data handling. It can be noted that large companies trust special PDM applications to organise their PDM practices in a centralised manner. In addition, several other applications are used, while the practices are still fairly primitive, for example, e-mail contacts to suppliers, and utilising Excel sheets for data management during design. Data maintenance is seen as an integral element of PDM processes, however, mostly experienced as extremely laborious. All data cannot be processed automatically, and especially in large companies this manual work requires a lot of resources just because the quantity of data to be maintained. Seamless application integration is difficult, a deficiency that is causing lot of manual work and administration.

PDM related challenges faced by high tech companies are numerous. Every company has its own difficulties reflecting their business and organisational status. Regardless of company background, the development of current PDM/PLM systems is a key activity for developing business efficiency, excluding the one of a kind prototype provider (Company A). Root causes behind the PDM development activities are various – reorganisation, new business without defined processes, or a desire for better operational efficiency. The main challenge typically, however, is to get the personnel to understand product data coherently and to use standardised processes to prevent incomplete data in system. Personnel using the systems are one of the vital aspects for any effective PDM system. Should personnel not understand the process adequately, they do not work accordingly, potentially ruining the entire PDM system. Also, obtaining a harmonised product structure is a challenge in non-mature organisations. Rules for product

variation, or chancing unstable structure, will cause additional work in data processing and maintenance. PDM/PLM technologies utilised in companies are seen immature, not adequately supporting all the required functionalities, such as product configurations.

PDM/PLM related issues are not simple to study in practice. The field is broad, and has different layers, such as product item, platform or product family levels, to consider. However, in literature these layers are usually discussed all together, even when the management practices are different. Managers need to pay attention on how PDM, and even PLM, practices still emphasise data management during product design and development, ignoring the fact that PLC data is not optimally utilised.

The purpose of this study was to obtain understanding over current product data management practices in high tech companies, together with related challenges. Product data management is a topical, increasingly important research area. This study was not intended to be all-inclusive, but rather to obtain potential development ideas. A wider set of interviews might have provided a somewhat different view to the obtained one.

Potential topics for further research include clarifying the implementation of PDM/PLM solutions in different business situations. This type of information might help PDM/PLM applications, or consultation providers to notice the different needs arising from company specific characteristics. It is also important to notice how the current business trends, such as globalisation, or company mergers, affect PDM. The impact of numerous different tools on PDM, and information integration are also worth further study.

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Attachment 1: Questionnaire

Part A COMPANY INFORMATION

1 Company name
2 Main products; main customers
3 Year of establishment, number of employees, turnover
4 Interviewee names; job titles; years of experience in industry

Part B GENERAL QUESTIONS ON PRODUCT DATA MANAGEMENT

1 Please describe how you understand the term product data.
2 What is product data management (PDM)?
3 What are the main challenges in area of PDM in your organisation?
Product structure and/or data related weaknesses, process related problems, and/or information system weaknesses.
4 What are the benefits of PDM system?
5 What would be a real innovation on PDM to make a big impact on your company's success?

Part C PRODUCT STRUCTURE AND PRODUCT LIFECYCLE MANAGEMENT

1 How do you define a product structure?
2 What is product lifecycle management (PLM)?
3 What are the reasons for product structure changes during product lifecycle (PLC)?
4 Do you offer different product variants/versions to your customers?
If yes, how do use product variants? Is the amount of variants limited or infinite etc.?
5 What product traceability means to your company?

Part D PRODUCT DATA MANAGEMENT PROCESSES AND DATA OWNERSHIP

1 Is the managing and maintaining product data laborious?
2 How is the product data maintenance organised in practical level? (Description of the operational model of the data maintenance)
3 How the data ownership is defined in different organisations in a company (for example in product development, manufacturing, and sales operations)?

3.1 Who/which organisation owns the product data that you(/your organisation) utilise? (Who is responsible person to sustain the data)?
3.2 Can you identify, who is delivering/creating the product data that you utilise?
3.3 How do you use product data and/or product structure (in which operations/tasks)?
3.4 What kind of changes is causing to the product data on your operation point of view?

Part E INFORMATION SYSTEMS

1 Which kind of tools do you have for PDM and/or PLM activities?
Can you describe the solution you have? Is this solution tailored for your needs or are you using off-the-self application? Do you have some other administrative tools for that purpose like Excel etc.?
2 What is the level of integration between PDM and/or PLM system and systems like CAD, MRP/ERP etc.?
3 Do you have systems to share/transfer product data information with suppliers and/or customers?
4 Any other comments /suggestions related to the topic?