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CHALLENGES WITH PRODUCT DATA EXCHANGE IN PRODUCT DEVELOPMENT NETWORKS

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1. Introduction

1.1 Background

The networked way of doing business has increased, due to the complexity of the business environment, the pace of change in technology and consumption lifecycles, and the globalization and acceleration of business [Möller et al. 2006]. OEMs (Original Equipment Manufacturer) are often no longer the dominant player in a supply chain, as the suppliers possess specialist expertise and knowledge in key parts of the total product [Gupta et al. 2003]. This is the trend also in product development projects, which are more frequently conducted in a collaborative manner within company networks [Gunasekaran 1998]. Original Design Manufacturing (ODM) and design collaboration are becoming more common. Lead-times of development projects are shrinking as companies compete on the time needed to bring new products to the market. In order to shorten product development projects companies utilize product platforms and same modules over many products. Accordingly, multiple companies are working on same product data simultaneously.

The nature of product development contributes a few additional challenges to product data management (PDM) compared to, for example, the production process. The result of a product development project is product specification realized in product data: documents, CAD models and BOM (Bill of Material), for example. The starting point for product data can be something very implicit: a sketch from an industrial designer or a set of requirements for a product. At the end of a product development project the product data should be mature; it should define a product. In order to mature the product data, a large number of engineering changes may be required. Numerous engineering change requests (ECR) are used for requesting impact estimates of a change.

Conducting product development in a company network brings additional PDM issues that need consideration. Engineering change management (ECM) is stretched over single-company walls: other companies have to analyse change proposals to see how a proposed change would affect their work. Furthermore, updated documents have to be delivered to all relevant parties. This involves proprietary information, as well as sensitive trade information. Nevertheless, the originator of an ECR has only limited visibility to the change process progress in other companies. Different companies use different processes and systems for PDM and ECM. This makes networked PDM challenging.

The objective of this research was to identify common PDM-related challenges in current collaborative product development networks. We also aimed at finding ways to address these challenges and to identify future research needs in the area of networked PDM. The research questions were: 1) What kind of challenges are related to product data exchange in these networks? 2) How can

we address these challenges? 3) What kind of future research is needed in the area of networked PDM? In order to answer these questions we conducted four case studies in European product development networks. The results of this research are expected to contribute to the research field of design organization and management by revealing the PDM-related challenges in the state of the art collaborative product development and by outlining future research directions to deal with these challenges.

2. Previous work

The engineers who work in different locations use different systems and computer platforms linked via the Internet. Domazet et al. [2000] identify their needs for sharing design information: the engineers have to be able to view parts designed by other team members, design assigned components or sub-assemblies under constraints specified, analyze, discuss and modify design solutions, propagate design modifications as soon as possible, and review and verify design solution in different phases of a development process. This information is usually stored in documents.

Eloranta et al. [2001] found documents and their consistency, usage, proper storage and linking to be a source for improvement when business processes are developed. They found many of the problems in business processes to be related to information sharing and exploitation, and, therefore, a need for better methods and tools, such as PDM systems and better integrated enterprise systems.

Möller et al. [2006] have also noticed, that efficient information flow is essential to the functioning of a business network. Just like we discovered in our case studies, they also found in another network that the most difficult issue is notifying network members of product variants resulting from product development. Furthermore, the suppliers own product development requires common product adjustments, which would require preliminary exchange of product development data.

Currently, product data is exchanged by e-mail or www-interfaces to PDM systems [Kotinurmi et al. 2003]. In addition, many portal-based solutions have been proposed; for example, for supporting tasks in collaborative engineering project preparation and management [Ren et al. 2003] and for sharing project information and providing collaboration tools like discussion boards, notice boards, links, versioning etc. [Precup et al. 2003].

These practices can make design document exchange slow and error prone due to a substantial amount of related manual work and can thus be a major obstacle to product development outsourcing. Furthermore, these exchange mechanisms can lead to design documents being located simultaneously in different companies without common version control.

3. Research data and methodology

The study was conducted as exploratory and descriptive case studies [Yin, 1994] including data from four case networks. Three of the company networks were developing and producing consumer goods and one was developing and producing investments goods. The case companies were based in Finland, Germany, and Austria.

Semi-structured interviews were used to collect the data. We have analyzed the current state of the processes, methods, tools and systems; their challenges and proposed recommendations. The viewpoints we took were collaborative product development, PDM and ECM, and Information technology (IT) support for ECM and product data exchange.

We interviewed 76 persons from the case networks. The interviewees had various roles to cover the different viewpoints to networked PDM – designers, engineering change managers, material leaders, project managers, business developers in outsourcing, PDM system specialists, and system integration specialists. The interviews were recorded and notes were taken during the interviews. The recordings were transcribed and added to a research database. The data was analysed with Atlas.ti software by coding it with relevant keywords. Moreover, we studied hundreds of pages of company material.

4. Challenges with current product data exchange practices

We were able to identify challenges related to PDM and ECM that were common to most or all of the case networks. These challenges caused delays in engineering change analysis loops and they can also

cause problems in the future if important issues, such as design rational, are not documented. The challenges are described in the following subchapters.

4.1 Change descriptions unclear

The biggest problem appeared to be insufficient information related to engineering changes. That is, ECRs and notifications are sent with too little, incomplete or conflicting information. This requires separate inquiries and clarifications by e-mail, phone or in meetings. This needs to be done before the change can be further processed. After the change is clarified in e-mails and telephone conversations the ECR is sometimes updated, but most of the time the information stays in people's mailboxes. The e-mail traffic takes a lot of time and there is no log about the discussions. Sometimes the reason why changes are communicated over the phone and not documented in the systems is that people know each other and are more comfortable with talking over the phone.

The interviewees indicated that the quality of information is very much dependent on the individuals and teams participating in ECM. In best cases, the change is documented using very clear descriptions and additional attachments. In one network, drawing changes are sometimes sent without change identifiers. These changes cannot be used, because there has to be an identifier for each change. Sometimes files are received without any information to which project they belong to, and many people have to be asked to find the correct project.

4.2 Version management

Version management was problematic in the case networks in many ways. On the one hand, the code or version of a component was not always changed after a change to the component. On the other hand, there were multiple identifiers for same components. Component changes were not always communicated to all parties using them. Furthermore, the terminology used differed from company to company: version and revision could have the opposite meanings at supplier and customer.

In one case network, a document describing a component could be changed but the component code remained the same. Creating new codes was considered expensive, and people wanted to avoid it even when this resulted in having two different components with the same code. Insufficient component identification was considered as a big risk. It causes nearly 200 reclamations to suppliers annually.

In another case network the situation was just the opposite. Using different systems and processes included not having a definition of the data needed by different stakeholders, no naming conventions and varying versioning policies. Lack of such a definition resulted in multiple component codes, for example. The different component codes for the same components limit component consolidation for placing larger orders and gaining on the economy of scale.

One customer had over 130 000 component codes in their PDM system. They have 15 plants worldwide, hundreds of customers, thousands of manufacturers and several hundreds of thousands of manufacturers' codes. Monthly increase of codes is 1 500-2 500 and relations to suppliers, customers, manufacturers etc. increase approximately by 10 000. In active use, there are approximately 41 000 codes / year, of which ¾ are customer sourced and ¼ company sourced. Of these company-sourced codes, even half may be duplicates. The codes have no versions or variants. Any changes in attributes related to the code induce the creation of a new one. Component engineers of this company are responsible for storing component data in the PDM system. They follow some processes and they have to go through training. However, there are significant problems in process control. In addition, there are no clear processes for change and removal of codes.

There have been situations when a new version of a document was created but not communicated to a supplier. After manufacturing the product for a year the customer asked which version is used, and only then it was noticed that no-one had communicated the change to the supplier.

4.3 ECM processes not designed for product development

The processes used for ECM have have their roots in mass-production. Therefore, they are too formal, control-based, and in most cases bureaucratic approaches for quick changes. This resulted in changes

being done without process or system support: one company stated that 97-98% of the changes in product development phase are conducted outside the ECM system.
Change control authority was seen problematic from time to time at one customer. There is a list of accounts for ECR approvals. Sometimes the lists themselves are subject to changes, but the product managers are not notified of this and the "old" approvers won't approve or demote ECRs anymore. The ECR cycle time depends on the number of people on the approval list, especially if factories are included. Naturally, when there are many people, the cycle time gets longer. It was also noted that not all persons in the list are directly related to the change processing, which can be accounted to the static nature of the approval lists.

4.4 Systems difficult to use

Currently, the systems do not always contain up-to-date data. It is common that some of the key data is in some personal hard-drive or network folder instead of the PDM system. Furthermore, some of the data is often outdated and cannot be trusted, e.g., the component data may contain components that are not manufactured anymore. In one network, it was stated to be easier to call or visit someone and look at the drawings, than to use the ECM system.
One supplier uses the customer's product structure system. The system uses codes that should be found from code manuals. Although the users usually remember the codes they need, there are difficulties with the codes maybe once a week. Learning to use the systems can take as much as 6 months. During this time a new designer is not very productive.

4.5 Human involvement in data transfer

Product data is transferred between the companies either by e-mail or by web interfaces to a customer's PDM system. Both of these options have a person involved in sending and possibly receiving the data. This person gets the data from one system and e-mails or saves it to another system. This means that there are delays and errors in the data transfer, as people make mistakes or can forget about the data transfer altogether. Furthermore, this approach ties resources: often there is a person who is dedicated for the data transfer.
Tools for product data processing may differ from company to company causing need for data conversion, such as from a native CAD format to STEP or IGES standard formats. In addition to these, product data exchange is more complicated in a company network. Data exchange itself between companies takes time if there is no proper IT support: someone has to remember to do the transfer and notify relevant people of the new data available.

4.6 No visibility across company boundaries

PDM processes differ from company to company. Some standardization attempts are raising attention in automotive and electronics industries as. Still, the progress of a network process, like ECR from a company to its 2nd tier supplier can only be tracked at company interfaces. Typically the customer has no visibility to the supplier's process.
In one company the product managers have to send a lot of e-mails to keep up with the status of their ECRs. One product manager can have 30-40 open ECRs and lots of related e-mails in the mailbox. The status of an individual ECR or all the open ECRs is practically impossible to track from the mailbox. It has happened that the supplier waits for some input from the product manager and the product manager waits for the supplier to respond to the ECR. After the customer has ordered the change, visibility to the change disappears; the customer cannot see the estimated delivery time or which documents are influenced.

4.7 Data ownership not clear

The master documentation is typically stored in the customer's systems. The supplier has copies of the drawings in their own database. After the drawings have been copied to the supplier's system there is no way of seeing if they are being modified by the customer. If the supplier modifies these drawings,

there is no information about this in the customer's system before the modified drawings are uploaded back to the customer's system.
One supplier uploads the modified drawings to the customer's system with a script that is run only once a week. It can happen that someone from the customer's R&D department works on the same drawing that is being modified by the supplier. This happens rarely, however. It was estimated that there are such cases once a year and it takes about 2-3 days work to fix the problem.
In one company network it was not clear who owns the data at each phase of the product data lifecycle, what data is transferred from one system to another, who is responsible for the updates, and where the master is located. Not having such definition resulted in data being dispersed over the company, with many masters.

5. Discussion

The challenges identified are typically caused by the networked way of doing business. However, challenges 4.1-4.4 can also be company-internal challenges. This means that they will be especially problematic if the issues have not been addressed even within the participating companies. Challenges 4.5-4.7 are, however, only due to the cross-company collaboration.
Some of the challenges are due to the nature of product development, and can thus not be resolved thoroughly. For example, change descriptions are often unclear, because the information is not available by the time the engineering change request is created:

> *"It is like product creation process, one has to start and think, and then come some ideas and then you have to speak together. That's the only way, there is no automatic way."*

5.1 Applicability of the results

Many of the challenges identified were due to the networked way of working. However, multinational companies with geographically distributed divisions bear the same symptoms as company networks. This is especially apparent in companies that have acquired other companies in different countries.
In collaboration cases, strong negotiation power of the customer results in customer-based solutions – be them processes or IT tools. The processes and tools have typically been developed from the viewpoint of optimizing the activities within this company. The networked way of doing business might not have been considered during the development, thus resulting in the possible transfer of inadequate processes and IT tools, along with time slot to learn to use the processes and tools. If there are some procedures defined between the companies, they differ from project to project and from company to company and thus their usability for implementation possibilities to IT systems are low.

5.2 Limitations of the study

We have focused mainly on the two main partners – the customer, usually in the role of a client or a brand owner and the supplier in the role of an engineering design supplier or an ODM. Those two partners usually represent the majority of the interaction within the network. As engineering change analysis is extended further down the supplier chain, delays will typically be multiplied accordingly.

6. Conclusions

Challenges related to network-level PDM include version management (different identifiers of the same documents and different version notations in use at collaborating stakeholders) and slow and difficult-to-manage ECM processes. As a result, product prototypes can be made using an old version of a drawing and engineering change reviews often take unacceptably long to accomplish. Furthermore, the status of engineering change processes (progress in different companies) is difficult to obtain in a company network. Based on our observations, the challenges result from missing processes and inadequate IT support for networked PDM. Moreover, processes for ECM in product development were copied from those of mass-production thus resulting in adopting control-based and in most cases bureaucratic approaches for change management.

Our interviews indicated that the biggest problem is the long duration of change reviews. There are constantly many open changes under review. Impact of the changes must be evaluated in all the companies of a company network before implementation. This review can take weeks, even months. In addition, there may be several changes, which are dependent on each other. Before they can be implemented, all of them need to be evaluated. Slow reviews affect project schedule or product quality. Consequently, in many cases, in order to save the longish waiting time, changes are implemented without a proper review, which can lead to scrap in production.

6.1 Managerial implications

The challenges in networked PDM have an impact on project schedule, product quality, product cost and eventually the whole product profitability. In the competitive quest, where fast time-to-market is most important, the costly improvements in networked PDM should be out-weighted by the increase in competitivity and market share.

Many of the challenges were related to company-internal processes and systems. Therefore, it is important to start developing networked PDM by defining the internal processes and tools first. Only after that should network-level issues be taken into consideration. The following steps should be taken when implementing PDM on a company network:

1. Define and implement internal PDM processes and desired performance level
2. Establish internal IT support for PDM processes
3. Define intra-company PDM processes and desired performance level
4. Implement desired IT support for intra-company PDM processes

The ECM processes should cover documenting change descriptions in an adequate way. Key concepts, such as version/revision/edition, should be defined in the network. Version management should also cover what is the realization of a change, as well as product structure version control.

Where-used relations tell who should be informed of a change, so updating these relations so that they are visible in the systems is important. There should be an automatic check based on the where-used relationship to reveal if a component or module is used by more than one product development project. It should be noted, that the power of the where-used relationship is mainly for standard components and for so called “carry-over” parts or modules, which are used in many products. Having the where-used relationship working, one can move to consolidating standard components and carry-over parts by checking comparing technical specifications of similar modules and components.

Change analysis and approval loops should not be static to make sure relevant stakeholders are included and irrelevant stakeholders not disturbed by the change processing. A concept for different change management approach at different phase of product life-cycle is needed. It was noted that product development has different needs for change management than mass production. The focus in design and development is on the speed of the execution of changes, thus allowing the product to be corrected and improved by fast design iterations. Furthermore, a concept for dynamically building the list of change processing authorities is needed.

IT support for networked PDM should guarantee fast and error-free transfer of product data between the companies. This includes designing the systems from user perspective so that the systems support users’ work tasks instead of hindering them. Furthermore, data transfer should be automated in order to avoid human errors.

The processes and systems should make it easy to follow the status of an ECR even across company boundaries. The processes should also include the concept of data ownership and how to manage changes to ownership during the product life cycle.

6.2 Future work

We discovered many challenges in networked PDM and ECM. These challenges were addressed in the previous section, but a more thorough concept for efficient product data exchange in product development networks is needed. The concept can be seen as made of four distinct but interrelated building blocks: concepts, processes, policies, and IT support, as depicted in Figure 1.

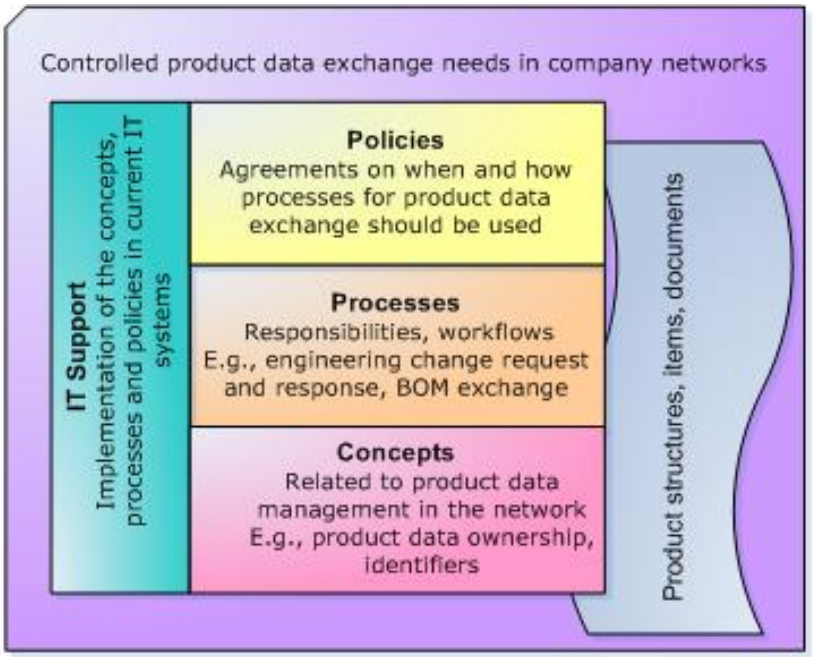

Figure 1. Building blocks for future research

The company network has to agree on the **processes** used for product data exchange between the companies, as well as on the **policies** of using these processes. For example, what changes have to be notified to other members of the network? Who can make changes to a drawing? Who is responsible for initiating a process? How are the network-level processes and policies managed? This also includes setting performance metrics so that the processes can be monitored and corrective actions can be taken if needed. In addition to the policies and processes, the **concepts** they are based on have to be defined. The company network should have a common vocabulary to ensure everyone is speaking about the same thing when discussing an issue. For example, for some companies, product data ownership describes the parties allowed to access certain product data, whereas for others, the ownership includes the right to make changes and decide about the implementation of changes. After the policies, processes and concepts have been defined, they should be implemented in the **IT tools** supporting collaboration. In addition, the collaboration systems should be designed so that the tools support work tasks and people will actually use them. Another issue is to find ways to motivate people to use the tools instead of e-mail. This way important information would not be buried in personal e-mail accounts, but be available in the IT systems for all relevant stakeholders.

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