The Requirements and Needs of Global Data Usage in Product Lifecycle Management

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Abstract. This study examines global data movement in large businesses from a product data management (PDM) and enterprise resource planning (ERP) point-of-view. The purpose of this study was to understand and map out how a large global business handles its data in a multiple site structure and how it can be applied in practice. This was done by doing an empirical interview study on five different global businesses with design locations in multiple countries. Their master data management (MDM) solutions were inspected and analyzed to understand which solution would best benefit a large global architecture with many design locations. One working solution is a transactional hub which negates the effects of multisite transfers and reduces lead times.

Keywords: ERP · PLM · MDM · Data management · Global data · Multisite

1 Introduction

In the last twenty years, large businesses have become more international with design, manufacturing, and production located around the globe. This means that each of these sites needs to be connected for smooth data transactions. To achieve this, a reliable software system is needed.

The objective of this study is to understand global design in an enterprise resource planning (ERP) and product data management (PDM) environment. An ERP system provides an all-in-one solution for seamless integration of information flows across an organization [1]; while a PDM system is used for product data management and publication while facilitating the splitting of resources such as designers and product manufacturing between various global sites [2].

The goal of this study is to determine how data flows between different global sites. The main focus of this study is how current PDM and ERP data transfer systems work in practice and how data is transferred between sites. This study is limited to five global machine manufacturing companies with design teams located in Finland. This study is also limited to a PDM and ERP environment. The main target is observing the boundary between PDM and ERP systems in a multinational organization where data is moved between sites on a daily basis.

J. Zdravkovic et al. (Eds.): CAiSE 2015, LNCS 9097, pp. 103–117, 2015.
DOI: 10.1007/978-3-319-19069-3_7

The structure of this paper is split into five main chapters. The second chapter will discuss the background of product lifecycle management (PLM) and how PDM and ERP systems are connected. Chapter 3 will discuss master data management and chapter 4 will consist of a case study in which five companies are interviewed about their global PDM systems. Chapter 5 concludes this study.

2 Understanding PDM and ERP Systems in a Global Environment

Product lifecycle management (PLM) is essentially a business strategy for creating a project-centric environment [3] [4]. The purpose of PLM is to chart the whole lifecycle of a product from concept to retirement and is deeply associated with computer aided design (CAD) and product data management (PDM) systems.

PLM is used to spread the influence of PDM systems beyond design and manufacturing and towards areas such as marketing and sales, in this case through an enterprise resource planning (ERP) system. The main purpose for linking PDM and ERP systems in a CAD design environment is to ensure the efficient movement of designs through the CAD environment into the PDM system which feeds it to the ERP system and subsequently to manufacturing.

To understand product data management it is important to understand PDM systems. According to [5], [2] and [6], PDM is a software framework which enables manufacturers to manage engineering information such as the data needed for new product designs and engineering processes. It allows the control of product information throughout the entire product lifecycle (PLC) and thus takes a more team-oriented approach to product development. The PDM system helps control how manufacturing data is created, reviewed, modified, approved and archived. One of the main functions of a PDM system is to ensure that data modifications happen in an organized manner. It controls data access with a check-in/-out function and controls authorized users [7]. It is also common to use a PDM system to determine the state of an object. A state indicates if an object has been approved to enter the next stage of development [8].

A PDM system needs an authoring tool, such as a CAD program, which supplies data to the PDM system [9]. CAD tools are used to design and modify content such as 3D MCAD and ECAD documents. However, a PDM system is not used to handle physical parts and this is where an enterprise resource planning (ERP) system is needed. An ERP system controls the physical ordering and distribution of parts after the design process. By adding an ERP system with a PDM system, they can be made to work in tandem to control the flow of information from conception to shipping a finished product. It is difficult to get a smoothly working integrated PDM/ERP system because they are fundamentally different ways of looking at data management [2].

[9], introduce a framework for PDM/ERP interoperability in which the user has one interface where they can use both systems and [10] introduces a method for digital manufacturing that eases the way data flows between PDM and ERP systems.

3 MDM in Large Business

Master data management (MDM) is a general term which refers to the "disciplines, technologies, and solutions that are used to create and maintain consistent and accurate master data from all stakeholders across and beyond the enterprise" [11]. MDM is a tool which provides a way to incrementally reduce the amount of superfluous information in an enterprise.

With an excellent MDM system, a company will have correct and authoritative master data. Master data itself is a central prerequisite for companies to perform acceptably [12]. A company's master data is used throughout the whole organization and thus it is imperative that the data is organized accordingly. According to [13], master data includes data models, attributes and definitions. An important part of master data is information systems (IS), which includes the applications and technology used to integrate and share data.

When considering master data implementation it is important to remember that not only is quality and consistency of the data important, but the usage of the data should be available throughout the enterprise. Another advantage of MDM is cost reduction and avoidance, since it can lead to the reduction of data storage costs and remove redundant data copies in consolidation and transactional hub styles of MDM [11]. This is due to MDM enabling the reuse of key processes.

There are three types of MDM implementation styles: (i) consolidation implementation, (ii) coexistence style implementation, and (iii) transactional hub implementation [11]. The consolidation implementation has an analytical focus, while the other two are more operationally oriented [14].

A consolidation implementation brings master data from multiple existing systems and places them into a single MDM hub where a golden record of the data exists. A golden record serves as a trusted source to downstream systems for reporting and analytics or as a system of reference to other operational applications. In a coexistence style implementation master data can be authored and stored in multiple locations. It has a golden record constructed similarly to the one in the consolidation method, typically through batch imports, and can be both queried and updated within the MDM system. A transactional hub implementation is the goal of every MDM system. It is a centralized, complete set of master data for one or more domains. It is a system of record while the other two are systems of reference. Master data in an ideal MDM implementation can be considered a system of record while a system of reference is a replica of the master data which is known to be synchronized with the system of record [11].

4 Case Study

To better understand how a multisite works in practice, five companies were interviewed. These companies are all machine manufacturing companies with design teams located in Finland. The interviewed persons were PDM experts. For the purpose of this study all company data is kept anonymous.

4.1 Company A

Company A is a medium sized company with 100+ employees with one main site in Finland and sub-sites located internationally. The main PDM database is located at the main site and all data from sub-sites is replicated there daily. This keeps the master copy of the data at the main site up-to-date. This indicates that they are using a consolidation style MDM implementation.

There has been no need to handle data ownership as most sites have their own design projects and products which are site based. This causes little conflict between sites. Technically there is only one database which is at the main-site and when a new part is created the meta-data is created in the main database. The documentation is then synchronized nightly. Most product design and product maintenance is located at the main site. However, sometimes assemblies will have the same subassemblies. This causes some data management issues, because there is no data locking mechanisms. This is not seen as a large problem since most of the design work is order engineering.

Approval processes are relaxed since many drawings are created and used only once so if problems do arise the drawings can be redone easily. However, purchased components have their own approval processes which are mostly related to internal system specific details e.g. naming and grouping. When the approval is complete the data is sent to the main site PDM and ERP systems. There is no process to check for the quality of the data or if the synchronization of data was successful.

All purchases are done through the ERP system. Long-term components are purchased at an early date in the design cycle, then the main quantity of parts and finally any other parts that are needed. It is not enough to approve an item in the PDM system and move it to the ERP system for purchases to be made; they need to be activated separately from the assembly's purchase order located in the ERP system.

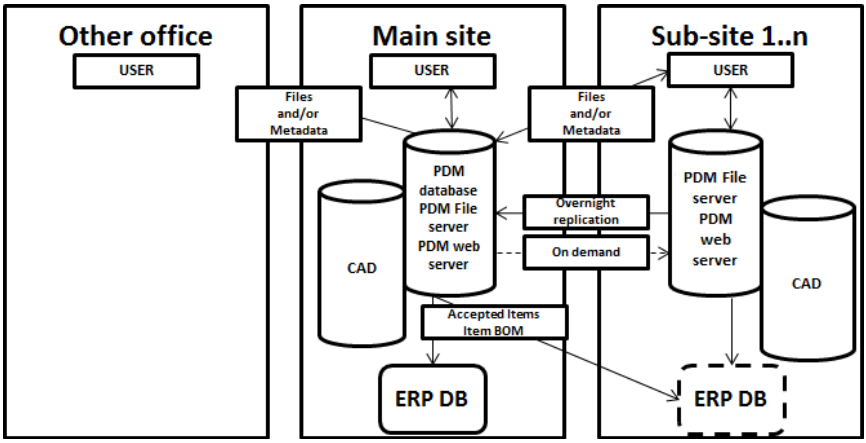

Fig. 1. Company A: PDM Architecture

Design tasks are monitored poorly. Designers inform project managers on how a task is progressing, but no clear system exists for monitoring tasks. Design hours are

calculated and fixed accordingly. These hours are used as a loose baseline on how complete a design project is. This is a very difficult process since the design progress also constitutes the timeline for part purchases.

Figure 1 shows the PDM architecture for company A. Each site has its own PDM file server and PDM web server which are used as a physical client for the PDM software. The main site has the main PDM database which sends information to the global ERP database. Sub-sites send data to the main site in an overnight replication process. There are also other offices which need to use the PDM information so the needed files and metadata is sent accordingly.

All sites, including daughter companies, are connected through the ERP and PDM systems so no other data movement is necessary. Designers use a local file database to access information and non-designer users are connected to their own systems where they can locate the necessary information. Company A has one data storage location which collects all information into a central location. The design data moves only in one direction and sub-sites are not able to access data from other sub-sites without additional synchronization. Synchronization to the central site works well. Moving data toward sub-sites, however, is more complicated and designers have to wait for the data to arrive. Sometimes after a manual data sync, parts of the assembly data will be missing which causes further problems. Usually, sites handle their own projects, but some capacity sharing is done when needed. Designers will then get additional CAD data while assembly data is available through the ERP system.

Design approval transparency is very poor. The only way to see if something goes wrong with design approval is when it cannot be found in the ERP system. Technically the ERP has a monitoring element, but it is so sensitive it suffers from major inflation of messages. Another problem with PDM-ERP transfers is the way certain parameters are handled e.g. groups, types, and units. They need to be manually transferred across to the ERP if any changes are done after the initial transfer. Another large issue with transfers is how parts are moved straight to project structures. Even though the structure should not change after creation, most errors occur when two BOM lines are placed under the same number or something changes on the PDM side which has not transferred correctly.

PDM-ERP transfers for individual items work really well. Product structures are created automatically for each item and when product specifications e.g. group, unit, are kept in check in the ERP system there are little problems with it. The night replication also works well.

4.2 Company B

Company B is a large multinational company with 16,000+ employees. Their headquarters are located in Helsinki, Finland with sub-sites abroad. There are two PDM systems, an internal EDM (Teamcenter) and a global PDM (Aton) which makes things more complex. The higher level PDM system sends data to the global ERP.

Currently, CAD systems are loosely integrated into the PDM system. Items are approved as prototypes or final products. Final products are sent to the ERP system. When objects are approved in Teamcenter they are sent to Aton. Aton is used for final

approvals and items are then sent to the global ERP system. The reason Teamcenter is not used for final approvals is because electrical and hydraulics designs are not available in the design process. Thus, the full assembly is not available until Aton. Only marginal changes are possible in Aton as almost everything is done in Teamcenter e.g. Aton cannot create new revisions, instead certain assembly attributes are filled in and final approval processes happen here The ERP system is used for some designer monitoring, but the main methods are email and meetings.

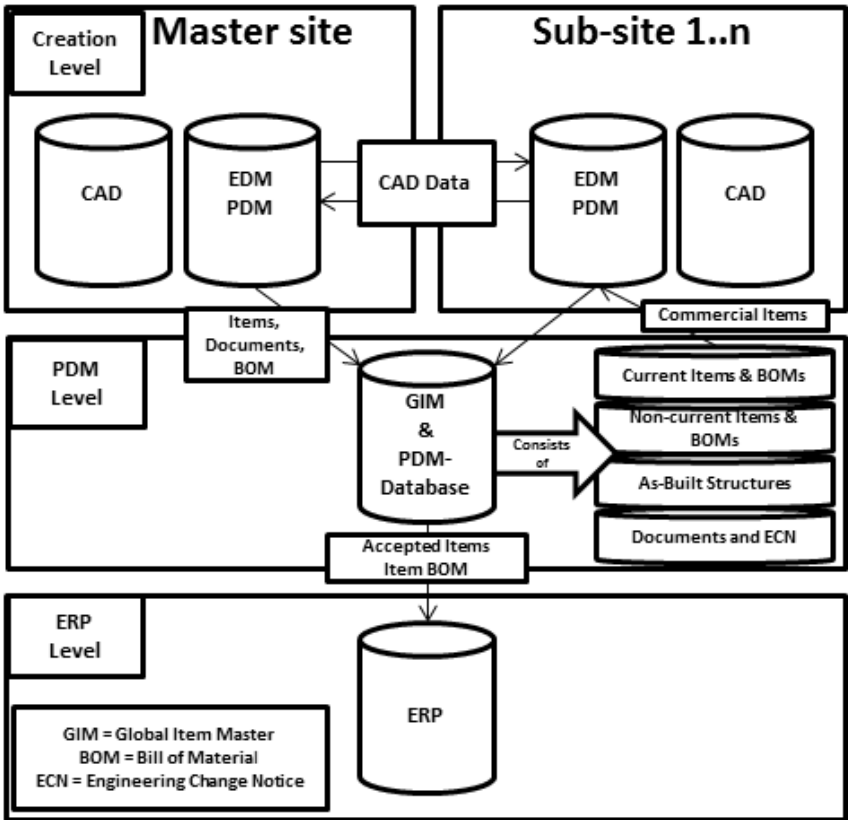

Fig. 2. Company B: PDM Architecture

All data is moved from the PDM system to the ERP system. ERP has no backward compatibility, except with commercial items which need to be modified in the PDM system before they can be readmitted to the ERP system. Basic data movement between PDM and ERP systems is satisfactory. The multisite only works on-demand. There is little need for moving data between sites as most assemblies are completed at one site. Sometimes, different product modules are designed at other sites. This does add the need for multisite data transfers. Replication is only done on-demand. Users can access it from the PDM client interface and administration can access it through the server scripts. Items that have been replicated before can be transferred by users, but other items must be handled by the administration. The PDM client interface will

inform the user that the data has been sent, but it will not report if the transfer was successful. Ownership can only be transferred by an admin.

Figure 2 shows the PDM architecture for company B. There is one master site and multiple sub-sites, but they are technically on the same creation level as both can submit information to the main PDM database, Aton. CAD data is moved between the creation level PDM sites, but other PDM information is approved on the PDM level. Aton can then be used to send the PDM information into the global ERP system. This indicates that Company B currently has a consolidation method system, but they are moving toward a transactional hub with a single PDM and ERP system.

There is no need for improvements, even though all processes could be moved to Teamcenter. There is also no backward data movement from ERP to PDM where some information such as order information, average prices, warehouse inventory could be very useful.

This was an affordable PDM solution; stable and relatively high quality. The fact that there are two PDM systems interlinked is unnecessary from a user's perspective. The simplest solution would be to move to use just the Teamcenter PDM, but many other business units only use Aton.

4.3 Company C

Company C is a large multinational company with 18,000+ employees and headquarters in Helsinki, Finland. They have 2 main sites; one located in Europe and one in Asia. With a large company, such as company C, the amount of business divisions creates a need for a complex PDM solution which will cater to all divisions with equal efficiency. Currently, there are multiple PDM systems which are being replaced by Teamcenter. The current global PDM system reflects the coexistence implementation style.

Company C, like so many others, is trying to move toward a transactional hub, but current data latency issues for data movement across the world this is a hard goal to achieve. There are two main sites with a single central database which will result in faster data queries. An additional future feature will be a cloud portal which lessens the need for multisite transfers and creates a faster connection to the central database.

Figure 3 shows the PDM architecture for company C. The main site and sub-sites are all on the same creation level and feed to a global PDM system. This data can then be moved to the global ERP system. From a PDM-ERP connection perspective there is only one ERP system at Company C. This makes data transfers to ERP simple. There is one PDM to ERP connection located in the EU and another in Asia.

There is very strict access management built into the PDM system, which increases data protection as a user is allowed to only create, modify, or view materials in their own user group. Data is owned by one site with replicas at other sites, but the strict data access management keeps anyone outside the correct user group from tampering. There is also an enterprise content management (ECM) in production which allows all items to be covered by a change item. This allows drawings to be watermarked and sent to joint ventures and partners before its approval is finalized. When the final approval is performed the watermark is removed.

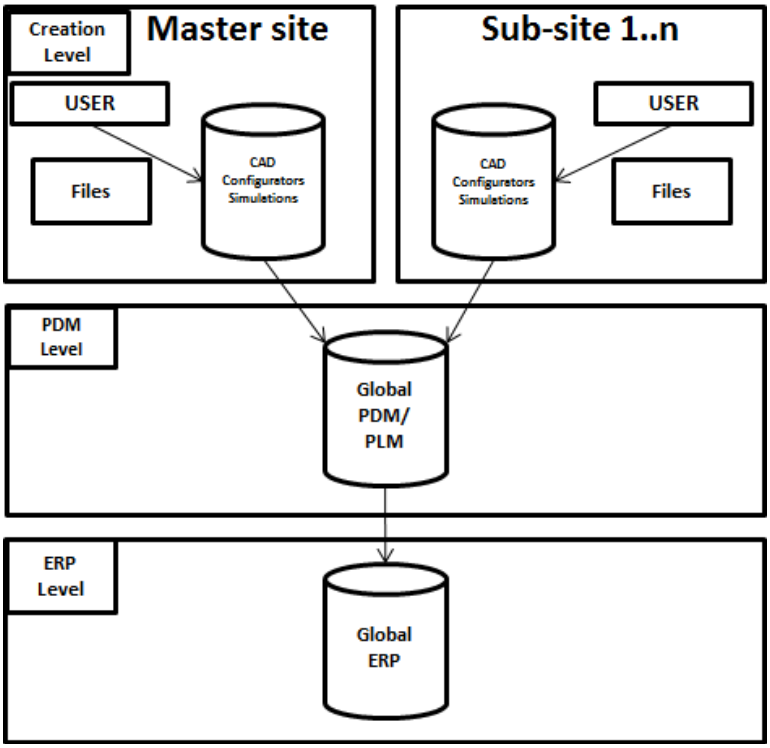

Fig. 3. Company C: PDM Architecture

Data is moved in the PDM system and then released to the global ERP. Design approvals are monitored by multiple stakeholders, which makes workflows very complex. This allows for quality insurance and change management of designs. Items can have two flags: approval and sent to ERP flags. This is useful since long time components are sent to the ERP before they are approved in the PDM system and are essentially placeholders for purchasing.

Currently no assembly structure skeletons are available. Assembly data is handled through a material master since configurators are not connected to the PDM system at this time. This causes materials to be released to the ERP system before they are approved in the PDM system. Approvals are not moved between sites; instead they are moved between the PDM and ERP systems. One product approval has a dedicated workflow to send data to the ERP and another is embedded into change management. Many things are done during the approval process including the creation of CAD PDFs and PDXs files. Thus new checkpoints need to be established to keep track of what has been delivered to the ERP system. This causes workflows to become a bottleneck when there is an internal failure or when data does not meet the checkpoints of a workflow.

One challenge is the growing user base. Currently, the number of users is around 1000, but through a PDM merger project the number should double. Most multisite issues are reduced by merging sites which eliminates the need for replicas. Not all

problems are solved with a global ERP and by merging sites and transfer speeds suffer from latency between sites with site consolidations e.g. Norway to Finland.

4.4 Company D

Company D is a multinational company with headquarters in Finland and they have more than 10,000 employees. The main design sites are located in Europe, Asia and the USA. Company D has design teams in 15-20 countries and it is an inherent feature that each sales representative has a technical specialist or designer for support. This adds many more countries where small change design work is done. This company is going through a large PDM project moving from a cluster of systems to one centralized PDM-ERP system. This means that Company D is moving from a coexistence implementation style to a transactional hub. This new centralized system is the first platform which enables a global PDM-ERP environment.

Data ownership is handled poorly. Items can be viewed and edited by different user groups, but with such a large company there are many divisions and outside sources that need to manage the data. Data is not locked unless it is being modified by CAD tools.

Figure 4 shows the PDM architecture of company D. Data is created at main and sub-sites and moved to a regional cache database which is located in e.g. Europe or Asia. It is then replicated to the global PDM database located in Finland. Only the metadata is available instantly in the global PDM system as it takes time for the information to transfer. However, this shows designers what information will be available almost instantaneously. The data can then be moved to the global ERP system.

Design data is approved in stages and they do not move directly into the ERP system. There are different workflows for approving items and other workflows which combine the approval and transfer processes. A designer who does research and development has a stricter approval process while order engineering designers can approve their own work to a certain status which allows production. The different status can be used to see if an item is meant for further production or if it is just a one-time assembly.

Data is moved between sites through a store and forward cache system. Data is moved into a central database with the metadata sent straight to the destination system. The central database then moves the data to the destination site at its own pace. Currently, this is an on-demand type of cache system. This means that when design data is saved in the PDM system it is sent to a country cache after which it is moved to the central database. The metadata is moved first which will show up quickly while the actual CAD data will appear when the full transfer is done.

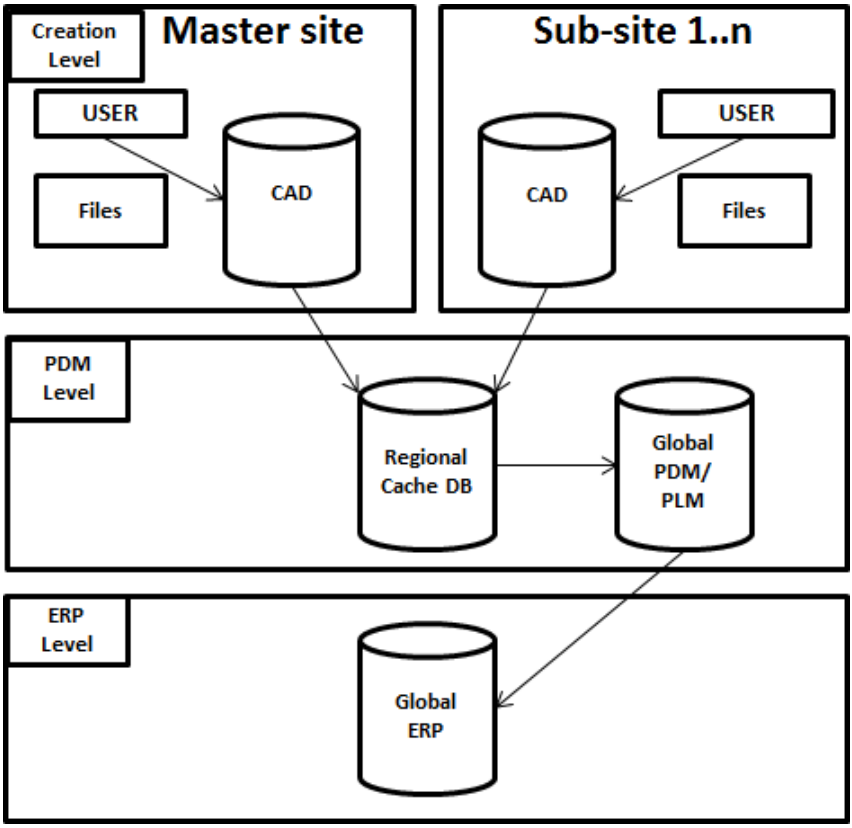

Fig. 4. Company D: PDM Architecture

Currently, most data moves from PDM-ERP, but some aspects are starting to flow from ERP-PDM e.g. sales orders. The most crucial improvement would be to performance; large data amounts are difficult to move in a short period of time.

4.5 Company E

Company E is a large multinational company with headquarters in Zurich, Switzerland. It employs 150,000+ employees with 16,000 employees in the business unit this PDM system serves. The main PDM sites are located in Europe and Asia. There is currently a large PDM project underway in which many new PDM sites are added into the global PDM collective. Company E has a coexistence implementation style and each site has its own PDM and ERP systems which communicate through a multisite collaboration system.

Assemblies are approved through the PDM system and they are sent to the ERP system during the approval process. Product structures are first sent to ERP as an assembly structure skeleton which is used as a base for the final assembly. Approved items will be flagged, but there is no indicator that it has been sent to ERP. This has caused some problems when drawings or structure data is missing.

Items are locked when they are in use. This means that nothing can use the item at that time, i.e. another designer or approval process. This ensures quality of data at that time. However, this also causes problems when a process or designer has locked an item which needs to be used somewhere else.

Designers are located in multiple locations and can work on the same assemblies or subassemblies. This makes it very important for multisite transfers to work efficiently. Data is sent to other sites on-demand and after the object is located somewhere it is kept up-to-date with a nightly data synchronization. Not all sites are connected to each other as most sites are paired up with one or two other sites.

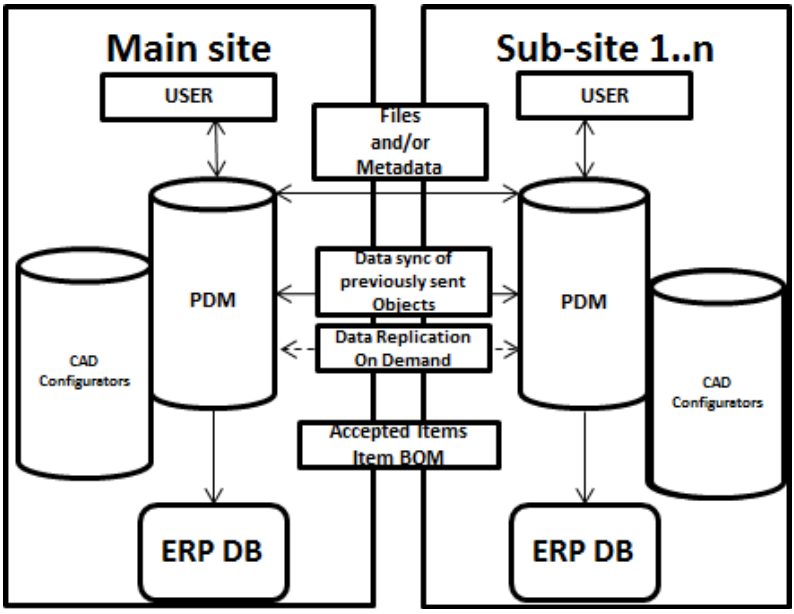

Fig. 5. Company E: PDM Architecture

Figure 5 shows the PDM architecture of company E. Each main site and sub-site is used to create their own data. This data is then replicated on-demand between sites. Each site also has their own ERP system, thus they need to move the PDM data to each ERP separately as needed.

The design process is poorly monitored through Excel spreadsheets and internal communication. Purchases are handled by the ERP system where assembly structure skeletons are run to ensure that long term components are delivered on time.

There have been some issues with multisite transfers. Large assemblies take a long time to transfer and might contain errors. The amount of errors has lessened, but there are still connection difficulties to Asia. The daily synchronizations work relatively well and the number of error messages are manageable.

4.6 Data Analysis

Since computer systems have become common place in the last two decades, PDM systems projects have become more vital for organizations. Each of the interviewed companies was in the middle of an extensive PDM project to improve their product data management. The method that everyone strives for is the transactional hub, because it consists of one large database which encompasses the whole organization. This would make data sharing between sites obsolete and in theory all data would be available for every designer at any time. In practice this is close to impossible to accomplish with the current technology. Data latency to growing industry centers, such as India and China, is high and will cause problems with connection speeds and synchronizing to a central hub. Even with a cache and store system, such as the one Company D has, it is not possible to have 100% accurate data at a central point at all times.

The interviewed companies were a sampling of a broad range of companies with various needs with one midsized company with 100 employees, four large companies with 10,000-18,000 employees. The differences in the companies' PDM structures were extensive and reflected the various PDM needs they have.

The midsized Company A was the only one with a consolidation method solution with no plans to convert in the near future. Their data movement needs are the smallest, but they have a working data transfer system which updates the main site with updated information during a nightly replication process. This eliminates the need for extensive multisite transfers since the data's normal replication need was only to the main site. The sub-sites work on their own projects and there is little collaboration between sites. This makes the main site more important for company A than they are in the other companies where data is moved at a more rigorous pace.

The three large companies – B, C, and D – are all moving toward a transactional hub. Company B's and C's data creation levels are similar, but Company D and Company E create significantly more items than any of the other companies. A transactional hub solution is the one every one of these three companies strides for. It has its advantages, but also comes with its own risks as data ownership becomes a serious issue.

Companies B and C are close in the number of items created in a year. They also have low data movement needs and when a working transactional hub is in place that need will disappear altogether. The methods of data transfer are very different however. Company B is crippled with having to essentially use two PDM software solutions at once, while company C is moving toward a one PDM system solution.

Company D is the only one with a working transactional hub solution currently in use with a store and cache system. It negates the need for multisite transfers and it seems to be working efficiently. However, their data ownership processes are poorly handled, unlike in companies B, C and E where data ownership is done efficiently.

Company E has the largest need for data transfers, but they also have the weakest multisite system. Company E is using a coexistence method which works with a large number of main sites. Many assembly designs are split between sites, which causes a high need to move data through a multisite solution. This data is moved manually and

after the data exists at another site it is replicated automatically when changes are made. This lessens the burden of having to move updated information manually. However, this does not lessen the strain on the system and causes problems with ERP since new data needs to be manually sent to the ERP system.

Even with such different types of companies they also have their similarities. Four out of the five interviewed companies used Teamcenter as their main user oriented PDM system and SAP as their main ERP system. This can be due to the fact that each company has their main PDM teams in Finland.

Table 1. Company summaries

	A	B	C	D	E
PDM/ERP software	Aton, LEAN, AB+, SAP	Aton, Teamcenter, SAP, other ERP systems	Transition to: Teamcenter, SAP	Transition to: Teamcenter, SAP	Teamcenter, SAP
MDM type	Consolidation method	Consolidation method -> Transactional hub	Coexistence method -> Transactional hub	Consolidation method -> Transactional hub	Coexistence method
Number of sites	1 main site	1 main site, 3 major sub-sites	2 main sites	7 main sites	7 main sites, 3 major sub-sites
Company size	100+ employees	16,000+ employees	18,000+ employees	10,000+ employees	16,000+ employees
Product lifecycle	30+ years	10-40+ years	30-40+ years	15-30+ years	20-30+ years
Estimated item creation per year	15,000	20,000	16,000-40,000	120,000	50,000-100,000 per site
Data movement needs	Low, All sites are connected to PDM-ERP. No other data movement necessary	Low, some modules are designed at different sites	Low, Only one ERP	Low, Only one ERP and global PDM	High, many multiple site design projects
Data movement between sites	Automatic from sub-site to main site, multisite transfer from main site to sub-sites.	Only on-demand, users can only move replicated material, others by admins	Data approvals not moved between sites but between PDM and ERP	Store and cache system. Data is moved from central database	Multisite transfer, replicated data synched each night
Data movement between PDM and ERP	During approval	During approval, no backwards compatibility	Its own approval process, sends a sent to ERP flag	Its own approval process	Each site sends to their own ERP during approval process
Data ownership	No handling	Only admins can change ownership	Very strict access management	Poorly	Items are owned by site, locked when in use

4.7 Case Summary

A store and cache mechanism, like the one used by company D, is a good method to move data between sites as it negates the need for manual data transfers with one central database. It moves the metadata instantly to all sites, which allows designers to see what data is available, even if the actual CAD data has not been moved yet.

Company C has a very strict access management system which monitors data ownership and authoring. This is a very useful as each designer only sees what data they need. This allows for less accidental data tampering. Company C also has different approval flags; sent to ERP, basic and final approval flags. This is useful, as a designer can instantly see what status an item has. As they have a single PDM and ERP systems data approvals do not need to move between sites, but are moved inside the PDM and ERP systems themselves.

Companies A, B and D have stable working environments where the multisite works well and efficiently according to their data movement needs. Company C is currently undergoing a large PDM project to move away from a multiple PDM system solution to a single PDM system solution. Company E has the most problems with their multisite system, but this is due to the large quantities of data that need to be moved compared to the other companies.

There were some clear similarities between the five companies, such as each of the large companies had chosen to use Teamcenter as their main PDM software and SAP for their main ERP software. This could be due to the fact that all were large machine manufacturing companies where the main PDM site was located in Finland and so the study is quite limited to their point-of-view.

5 Conclusion

Data management is an important part of a company's business structure as it controls everything from design to manufacturing. This study looks at how global design effects data management in a multinational company through the use of product data management and enterprise resource planning systems. In this environment, design data moves between the PDM and ERP systems within one site and between sites through a multisite connection.

Five different companies were interviewed to see how different companies handle their multisite connections through different master data management solutions. The best method to gain a working solution was to nullify the need for a multisite system and instead focus on rendering a working transactional hub. This makes sharing designs simpler and more efficient. The downside of this system is the long distance and current infrastructure in places such as China and India which causes bad data latency issues.

There were some clear similarities between the five interviewed companies, such as each large company had chosen to use Teamcenter as their main PDM software and SAP for their main ERP software. This could be due to the fact that all were large machine manufacturing companies where the main PDM site was located in Finland. This could have skewed the results to favor a similar view.

Global design is a very important research subject which will only expand as more companies turn to multinational solutions. As technology advances some issues such as data latency can be rectified. This will cause global PDM and ERP solutions to become more popular.

Acknowledgements. This study was partly funded by Academy of Finland grant #259454.

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