Current Trends in Product Lifecycle Management

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Abstract

Efficient and effective Product Lifecycle Management, as an evolution and enhancement of Product Data Management, is of strategic importance for virtually any company. Hence, it is crucial for companies to analyze and evaluate recent trends in information technology (IT) and their implications on Product Lifecycle Management. In this paper, the results of an interdisciplinary study conducted by Siemens AG, a major international technologies firm, and two universities are presented. The study identifies four current trends in IT and then evaluates their potential implications on Product Lifecycle Management. Finally, the IT trends are ranked according to their short and medium term effects on Product Lifecycle Management.

Keywords

Product Lifecycle Management, Cloud Computing, Enterprise 2.0, Mobile IT, Service-Oriented Architecture.

INTRODUCTION

The development and production of innovative products and the ability to respond promptly to changing markets is essential for maintaining the competitiveness of companies in an increasingly global environment. The competitive pressure is twofold. Demand-sided customers utilize an increasingly transparent market to compare product features and prices. On the supply side, firms are challenged by increasing global competition from virtually any part of the globe. As a consequence, companies are forced to implement shorter product lifecycles and reduce costs over the entire lifecycle of their products. Furthermore, decreasing vertical integration in production requires an intensive cooperation between suppliers and manufacturers (which has gained increasing attention within the framework of supply chain management). Therefore the need for flexible on- and cross-site product development processes is evident. This also implies the need to improve the availability of product-related knowledge within a company and across its borders. A way of achieving this is to break up information hierarchies along the lines of the design of processes for collaboration systems (Sendler 2009).

A strategic approach to address these challenges is product lifecycle management (PLM). PLM is of increasing importance; it can be seen as an evolution and extension of the well-established product data management (PDM). To make PLM successful it must be integrated into a company's overall IT strategy and in particular in its product innovation process. The use of information technology today allows for globally distributed development and production. Particularly, the early phase of product development can be optimized significantly by IT solutions. In these early production development phases, strategic decisions on the design of the product are of special importance and require interdisciplinary teams, covering e.g., expertise from planning, procurement, and production (Eigner and Stelzer 2009). PLM addresses these challenges and offers companies a framework to holistically support the product lifecycle. Within this context, major challenges are an increasing amount of data and the need to provide information for ever more flexible operational procedures. Hence, it is of

strategic importance to analyse and evaluate current and future trends in information technology with regard to their potential to further improve PLM solutions in companies.

Therefore the objective of the paper is to identify IT trends and their implications on product lifecycle management.

The remaining paper is structured as follows. In the following section we briefly discuss important fundamentals of product lifecycle management. Then we define the current IT trends that are considered in our analysis. In the next section we analyse the potentials of these IT trends for product lifecycle management. The paper concludes with a joint discussion and a summary.

FUNDAMENTALS OF PRODUCT LIFECYLCLE MANAGEMENT

Product data management and IT-based product lifecycle management are central concepts of the product development process. Historically, product lifecycle management can be considered as an evolution and enhancement of product data management. Therefore, we derive the concepts of PLM out of PDM.

Product Data Management (PDM)

The first PDM systems were developed for manufacturing companies in the field of CAD in the mid-80s of the last century. PDM systems were initially focused on the management of data generated in development and construction. The enhancement of the CAD systems, e.g., the support of 3-dimensional engineering drawings, led to a need to closer link the product to its product structure in PDM systems and, therefore, also to release and change management, version control and configuration management (Eigner and Stelzer 2009).

In summary, PDM is the holistic management of all product-related information and data (product model) in connection with the management of processes (process model) with the objective to generate product configurations (configuration model).

Product Lifecycle Management as an Evolution of Product Data Management

Product lifecycle management is a conceptual approach which considers a product over its entire lifecycle. Each lifecycle phase consists of particular rules, produces and information sets that are requirements for the following phases. The consistent integration of all data in the product lifecycle resulted in a complete lifecycle management with PDM as a backbone. In the following paragraphs, the concept of product lifecycle management is derived step by step:

Product. Each product has a lifecycle which must be managed. Generally, the term product may refer to all types of services and products. Hence, the initial narrow focus of PDM on manufacturing has broadened: today companies in virtually any sector (food industry, utilities, service sector etc.) can apply PDM resp. PLM.

Product Life. The definition of the product life is context-dependent as well as user-dependent. E.g., for a customer the product life is the period of time that she/he uses it (e.g., from purchasing until it is disposed of). In contrast to this, the product life is normally longer for the producing company. It starts with the idea for a product and concludes with the end of the production resp. with the end of the service period for the product (Sendler 2009). The individual phases of product life are discussed in more detail in the following paragraph.

Product Lifecycle. Product related data are generated throughout all phases of a product lifecycle. For example, production is based on the designs and specifications of the development. In this context, the product lifecycle describes the process consisting of seven phases (Eigner and Stelzer 2009):

- Idea and Concept
- Product Design / Verification / Development
- Production Planning / Work Preparation
- Production (Manufacturing, Installation, Procurement)
- Product Sales
- Product Usage and Maintenance
- Product Recycling

Product Lifecycle Management. Product lifecycle management is a strategic management approach for a product over its entire lifecycle. However, PLM is often differently understood and wrongly reduced to an IT system that is self-contained. Nevertheless, PLM actually touches all areas of a company that are associated with the product including its related processes and resources. Examples include: processes, organizational structures, methods and supporting IT systems (Eigner and Stelzer 2009). The objective of PLM is holistic, project-wide information management, as well as comprehensive process automation and a perfect harmony of all participating members

along the product lifecycle. Inspired by the model of Kiritsis (2011), the product lifecycle can be decomposed into three main phases:

- Beginning of Life (BOL). This phase contains the concept, design and production of the product. First, an idea of a product is developed. Then, product concepts and their implementation and verification are developed. The participants belong to various disciplines of development, such as mechanical engineering, electrical engineering, and software engineering. Finally, production (possibly with supplies) is monitored.
- Middle of Life (MOL). In the middle phase, the product is used by consumers. In this phase, the challenge is to understand the customer and to maintain and/or repair the product. Communication and cooperation along the paths of distribution are very important. Information about use of the product including (construction) errors is important.
- End of Life (EOL). When the product is eventually withdrawn from the market, the final phase of the product lifecycle begins. Possibly the product is returned to the manufacturer to be dismantled and recycled. Of importance here, for example, are details of product parts and materials, which can again be reused or recycled.

Specific information systems have already been developed in support of product lifecycle management. Full coverage of all relevant information is an essential requirement of a PLM system. This includes specifications, CAD data, process descriptions, test protocols and the full history of the origin of a product and its components (Dammann et al. 2010).

CURRENT TRENDS IN INFORMATION TECHNOLOGY

Recently Gartner (Claunch and Cearley 2012) published a top ten list of strategic technology trends for the year 2012. Gartner identified the following as "megatrends": Cloud Computing, Mobile IT and Social Media.

In our analysis we adopted these megatrends, except Social Media, and enriched them by Enterprise 2.0 (which roughly comprises Social Media in our context) and Service-Oriented Architecture (SOA). The main reasons for replacing Social Media by Enterprise 2.0 is that Enterprise 2.0 roughly comprises Social Media and has a stronger business focus. Service-Oriented Architecture (SOA) was chosen since service-orientation has become a universal paradigm for current IT structures. Therefore we get in alphabetical order:

- Cloud Computing
- Enterprise 2.0
- Mobile IT
- Service-oriented architecture (SOA)

These are analysed in the context of PLM in the following section.

IMPLICATIONS OF CURRENT IT TRENDS ON PLM

Introductory Note

To analyse and evaluate the current IT trends we use an identical structure for all four trends:

- Introduction
- Examples: IT Trend for PLM
- Evaluation on PLM
- Case Study (Evaluation of a Software Product)

Cloud Computing

Introduction: Cloud Computing and PLM

For an effective and efficient PLM the applications (business logic and data) must be available at all times regardless of the place where they are needed. Furthermore, PLM systems should be scalable to smoothly adapt to the needs of a company. However, a significant number of recent IT systems are not advanced enough to meet the growing needs of PLM (Halpern et al. 2012). Hence, bringing PLM into the cloud could possibly be a solution to bypass the current shortcomings of present IT systems.

Examples: Cloud Computing and PLM

Cloud computing allows companies flexible access to IT services and data over the Internet. So, one can cooperate with other team members and customers easily using just a web-browser. Cloud solutions are scalable and may provide benefits like consumption-dependent payment plans when an infrastructure-as-a-service model has been outsourced to a service provider. This allows a fast adoption of computing power to respective needs. Studies have shown that cloud computing can be more cost efficient than in-house solutions (Parihar 2012). PLM, implemented as a platform-as-a-service model may help to increase productivity. Also, there are already

software-as-a-service (SaaS) models that offer PLM components as cloud-based applications over the Internet. The benefits of cloud computing for the product lifecycle management can be characterized as follows (Halpern et al. 2012):

- Cost Savings. Low investment costs for software and hardware since the "central components" are offered by the service provider. This also implies that the number of IT staff needed in the company can be reduced.
- Free Resources. Companies can deploy PLM systems with fewer resources (time, budget and people) in comparison with internal solutions. Companies that do not have sufficient IT expertise gain considerably from cloud computing and can continue to concentrate on their core business.
- Easy Maintenance. A company is also released from IT maintenance tasks since these are performed by the IT service provider in the cloud. The PLM system is virtually applicable from the first day and PLM applications in the cloud can be flexibly adapted to the needs of a company.
- Facilitated Cooperation. Cloud computing offers the possibility to exchange data easily. This is independent of the operating system, installed applications, and other parameters. So PLM integration, both internally and across company borders, becomes much easier when the PLM system runs in the cloud.
- Location Independence. Companies with distributed locations are enabled to standardize their applications. Cloud computing offers identical applications independent of location, operation system and whether they are accessed by PC, mobile devices or smartphones.

Evaluation: Cloud Computing and PLM

Cloud computing offers the opportunity to reduce costs and to speed up the introduction and maintenance of PLM solutions. By accessing a standard PLM solution in a cloud a company reduces its investments into local IT structures and reduces the risks that are imminent to IT projects.

Case Study: Autodesk 360

The Autodesk 360 software was introduced as a cloud-based PLM system in February 2012. It is comprised of three main components (Autodesk 2012):

- Autodesk 360 Nexus. This is the core of Autodesk 360 consisting of cloud-based applications including functionality for project management, requirements management and service management. These applications can be used on the basis of SaaS on-demand.
- Autodesk Vault. Autodesk Vault is an established PDM system from Autodesk and provides applications to access product and project data others.
- Autodesk Buzzsaw. Autodesk Buzzsaw is a cloud-based collaboration platform that allows the exchange of drawings and documents between distributed teams or with external suppliers.

Sendler (2012) points out that the first release of Autodesk 360 already provides basic PLM functions but cannot be considered a holistic cloud-based PLM system. However, taking into account that Autodesk 360 has been released very recently, future versions may provide an interesting option for cloud-based PLM.

Enterprise 2.0

Introduction: Enterprise 2.0 and PLM

Online collaboration is becoming increasingly important; today, many project teams consist of members situated at different locations and in different companies. One of the main goals of Enterprise 2.0 is to provide a platform that suits the needs of such project teams. Studies (Bertoni and Chirumalla 2011) show that Enterprise 2.0 is of particular importance when knowledge has to be exchanged across any kind of border (spatial distance or across companies etc.). Since the BOL phase of the product lifecycle requires the most intensive exchange of knowledge, this phase should be supported by Enterprise 2.0 concepts particularly.

Examples: Enterprise 2.0 and PLM

Potential applications of Enterprise 2.0 in PLM are:

- Product Idea and Concept. The "wisdom of crowds" theory says that groups are smarter than individuals (Surowiecki 2007). Hence, companies should establish maintenance and support of internal and external networks to leverage the wisdom of crowds and increase the chances of developing better products. Enterprise 2.0 supports this by the provision of a company's own social network structure. Therefore,

Enterprise 2.0 provides a useful supplement to the clearly structured processes as specified by PLM. The extension of Enterprise 2.0 on the customer side provides a powerful way to collect and utilize customer requirements. This integration of customers is called "open innovation" (Chesbrough 2006). Customers become co-developers of products (Stocker and Tochtermann 2007) and thus break out from their passive role as consumer.

- Product Design and Development. Enterprise 2.0 creates effective and dynamic virtual teams. Such virtual teams are not only important in the Product Idea and Concept phase of PLM but also in the Product Design and Development phase. In addition to improved cooperation, Enterprise 2.0 enables the capturing and reuse of product information directly from sources at the time when the information is created. This approach reduces the need to collect product information in a rather intricate separate step which normally takes place at the end of the Product Design and Development phase. For example Wendenburg (2009) observed that the integrated feedback saves time and money in the manufacturing sector in comparison to the classic separated information feedback at the end of the Product Design and Development phase.
- Product Sales and Usage. In the MOL phase Enterprise 2.0 supports communication between the company and its customers. Classic Web 2.0 features like blogs, wikis and podcasts can be used to inform and support the users of a product. Furthermore, they can be used as marketing and public relations channels. Blogs are also good resources for a company to access unbiased opinions of the customers on a product and the company. Inside a company these Web 2.0 features can also be used to improve communication – for example the car manufacturer Opel podcasts training units for its sales staff (Back et al. 2009).
- Product Recycling. In the EOL phase Enterprise 2.0 can be used to inform customers, for example about how to recycle the product and about product replacement options, i.e. successors or new releases of the product or how parts of the out-phased product can be continued to be used.

Evaluation: Enterprise 2.0 and PLM

In summary, Enterprise 2.0 enables and improves the communication between a company and its customers and business partners (e.g., in a supply chain) as well as inner-company communication. Over the PLM phases the intensity of a particular communication channel may vary but the importance of communication is evident in all phases.

Case Study: PTC Windchill SocialLink

Windchill SocialLink by PTC (Parametric Technology Corporation) is an example of the use of Enterprise 2.0 in the product lifecycle management. It is based on Microsoft SharePoint 2010 and provides an environment for product development teams: the primary goal of the software is to improve the interaction during the entire BOL phase. People with common professional interests organize themselves. A major benefit of SocialLink is the access to the product data of the PDM system of Windchill PTC: this allows the team-wide provision of product data out of a single source and obviously leads to an improved collaborative process. For example, a team member can provide a link that refers to a question about a specific component. SocialLink offers Enterprise 2.0 features such as blogs and discussion forums that are fully connected to the product data in the Windchill PDM system. Product development teams can find experts within the organization and use a real time channel to communicate with them. Hence, PTC Windchill SocialLink supports most of the features that were discussed and presented in the previous section as characteristics of Enterprise 2.0 for product lifecycle management.

Mobile Applications

Introduction: Mobile Applications and PLM

The number of employees working outside their offices is going to increase significantly in the next few years. According to Forrester Research (Pelino 2011) the percentage of employees working outside their offices has reached 22 percent in 2011 already and this share is expected to almost double to 42 percent by 2015.

PDM is an important source for the management of product information and development activities like product development or maintenance services. In particular the product development requires many interactions and decisions that need to be taken timely at any time. Obviously, this requires that the most current data are available anytime anywhere (Zeidler et al. 2012).

Currently PLM systems can be accessed by classic devices like desktop PCs or laptops. Laptops are increasingly portable regarding battery life and weight (e.g., see the new lightweight laptops with long battery life promoted by Apple, Intel and AMD). Hence, this new laptop generation will further improve mobile access to PLM. Tablet PCs seem to be also a very promising platform for the mobile access to PLM systems. In contrast to this, due to

their small displays smartphones are only partly suitable for PLM, e.g., for communication, but they have limits, e.g., complex 3-dimensional drawings require bigger displays for optimal use.

Examples: Mobile Applications and PLM

This section considers the potential of Tablet PCs for PLM in more detail. In a study of Tech Clarity (Brown 2011) Tablet PCs are identified as excellent mobile interfaces between companies and their mobile employees.

Tablet PCs are optimized for mobile use (full-day battery-life, lightweight, immediately available after pressing the power button, HD display, multi-touch capability). So, an effective implementation of tablets in PLM would enable employees to access information anywhere and anytime and to capture ideas on the spot transmitting them back to the PLM system directly without delays. Hence, they enable more effective communication and therefore provide increased productivity.

The benefits through PLM can be further strengthened by tablets and mobile applications as the following examples show. Decisions can be made anytime anywhere, in particular also outside the office. For example, sales orders can be approved and immediately transferred to production even when the responsible manager is traveling. The display and monitoring of complex 3D designs is possible at any location. Service technicians can access virtually any important information immediately independently of where and when they need them. In summary, the mobile Internet has greatly expanded connectivity and enables the meaningful use of mobile applications in the PLM.

Taking a more detailed look at the implications of increased employee mobility in the major phases of a product lifecycle we get:

- Product Design and Development. Technical service staff are often with customers, e.g., to install and service a product. Any observation by the technical staff can be directly recorded via a mobile device in a PLM system and may help to improve the product or its successor.
- Production. Employees in the production phase often need access to information (such as installation instructions, product design or manufacturing planning). A mobile device allows for accessing all this information in the vicinity of a production line. The information can be retrieved when it is actually needed. This leads to time savings compared to the traditional search for correct information on paper.
- Product Usage and Maintenance. When a product is serviced, a direct connection to PLM via a mobile device has two distinct advantages. On the one hand, technical staff have direct access to the latest product information such as the latest manuals (e.g., 3D models of the product). On the other hand, information obtained in the service process may help to improve product usage and the design of new products.

Evaluation: Mobile Applications and PLM

Mobile PLM makes it possible to access crucial information anytime and anywhere. Hence, one of the main advantages of a mobile PLM environment is in the timely provision of up-to-date information in the context in which it is needed. Furthermore, any information on the product obtained in the field can be recorded easily and possibly help to improve the usage of the product or the product itself.

Case Study: Siemens' Teamcenter Mobility

Siemens' Teamcenter (Siemens AG 2012) is software that supports the management of design data in a collaborative PDM system for the automotive industry. It virtually covers the complete product lifecycle. Recently Siemens introduced Teamcenter Mobility as a mobile extension of Teamcenter. It runs on Apple iOS and hence can be used on the iPad. On an iPad it enables mobile access to all current product data that are managed by Teamcenter. Hence, Teamcenter Mobility enables sound decisions regardless of when and where they are needed (Siemens AG 2011).

Service-Oriented Architecture (SOA)

Introduction: Service-Oriented Architecture and PLM

The possibility to integrate a diverse selection of applications into the PLM process is an important success factor for product lifecycle management. This allows accelerated exchange of data and improves the quality of the products (Silcher et al. 2011). However, today many PDM systems do not have efficient interfaces to interact with or integrate third party software. Most of the interfaces are rather simple point-to-point connections to systems like computer-added-engineering (CAE), enterprise resource planning (ERP) or supply chain management (SCM).

This indicates challenges as follows:

- Maintenance. Obviously, point-to-point connections are suboptimal when the number of applications is rising since the number of interfaces increases exponentially. This means an increase in the heterogeneity which leads to increasing demands to manage the IT infrastructure.
- Data Heterogeneity. Another problem arises from the heterogeneity of data that are optimized for each application. This leads to data redundancy and inconsistencies, media breaks etc.
- Advanced Software Technology. The functional orientation of applications represents a further challenge. The software is locally optimized to suit the needs of e.g., a department. However, PLM, as a cross-cutting function, requires a holistic approach of the applications. An extension of the functionality of existing applications, accompanied with the introduction of new software, would further increase the complexity of the software (Silcher et al. 2011). Therefore, new concepts are required to tackle these issues.

The introduction of SOA to PLM can improve the problem of heterogeneous interfaces by the use of web services. A middleware would be required to integrate all applications in the product lifecycle. Usually this is achieved through an enterprise service bus (ESB).

Examples: Service-Oriented Architecture and PLM

PLM-Bus architecture

Silcher et al. (2012) propose a concept for a SOA-based PLM architecture. The implementation of an ESB is based on standards such as XML and Web services. This provides a high degree of flexibility, reusability, and less effort for maintenance compared to an IT integration based on individual point-to-point interfaces. The flexibility is achieved through the description of Web services with WSDL. WSDL allows a service broker to transparently capture the properties of a Web service. Thus a service request can be associated automatically to a particular Web service that meets the requirements of the user of the service.

During the product development phase several applications are used in parallel to design the different properties of a product. Obviously these applications need to be connected to exchange data. For example, a CAE tool with features like simulation data management or virtual reality needs to be fed by design data created with CAD applications. An ESB supports the required data integration. Main advantages of an ESB are the integrated transformation services and routing. Any application can call a standardized service without any knowledge of the actual internal data format and the actual location of the service within the network.

Evaluation: Service-Oriented Architecture and PLM

In summary, the following benefits of SOA-based PLM systems can the identified:

- Flexibility. New or changed business processes can be implemented quickly, often basically just by a new combination of existing services. Hence, a company can react to new market requirements flexibly and quickly.
- Cost Savings. In the medium term SOA can lead to reduced costs in the development and maintenance of IT systems. This can be achieved by reusing existing technical components and by a homogeneous SOA infrastructure.
- Outsourcing. The standardization of services may support outsourcing and hence cost savings and complexity reduction for a company.

Case Study: Aras Innovator

An example of implementation of SOA in the product lifecycle management is Aras Innovator. It is a freely available open source software that is based on a service-oriented architecture (Aras 2011). Aras Innovator includes several preconfigured solution models. All program features are offered as Web services. The system uses only Microsoft technologies, such as Windows Server, SQL Server, and the NET Framework. It is individually sellable and can be easily expanded if necessary. Aras Innovator uses a metadata template to describe applications, functionalities and data patterns. The metadata template defines the corresponding business processes within the system which then use the required Web services. This approach is called model-based SOA of Aras. In traditional software engineering approaches, architectural models are generated first and then the corresponding program code is written, compiled, tested and finally used. In contrast to this, in the SOA model-based approach the entire model, including business logic and system definitions, is stored in a central database in XML format. The APIs send and receive XML messages and thereby allow for linking to the system architecture of Aras Innovator. For example, interactions with ERP systems (like SAP and Oracle) or PDM systems (such as Siemens Teamcenter or PTC Windchill) are possible (Aras 2011). In summary, Aras Innovator can be regarded as a promising application utilizing SOA for PLM.

DISCUSSION AND CONCLUSION

In our analysis we have two dimensions: PLM on the one hand and the four identified IT trends on the other hand:

- PLM. In an economy characterised by increasing global competition, effective and efficient management of the lifecycle of products is of crucial importance for virtually any company.
- IT Trends. IT is regarded as one of the most important factors to enhance the performance of organisations. Hence, it is important for virtually any company to continuously monitor and analyse IT trends with the objective to discover potential IT tools that further increase its competitiveness.

Approximately since the change of the millennium service-oriented approaches have gained increasing attention in information technology. The four discussed IT trends, Cloud Computing, Enterprise 2.0, Mobile IT, and Service-Oriented Architecture, are important concepts within this paradigm change from functional structures towards service orientation. It is important to note that these IT trends are not disjunctive but additive. This means that, for example, Cloud Computing is an enabler for Mobile IT since applications and data organized in a cloud make them accessible anytime and anywhere - including on mobile devices. In addition Enterprise 2.0, as a strategy to further optimize the communication within a company as well as towards its suppliers and customers, can take advantage from cloud concepts and can utilize Mobile IT as communication channel. Finally, Service-Oriented Architecture can be considered as the technological glue between these IT trends.[1]

A detailed analysis of these interactions would go beyond the scope of the paper. The focus of our paper is to separately analyse the implications of these trends on PLM rather than a detailed analysis of the dependencies of the IT trends. So, although being aware of the dependencies of the IT trends we discuss their implications on PLM separately in the following paragraphs.

- Cloud Computing. Presently Cloud Computing establishes itself as the next paradigm for the IT-infrastructures of companies. The main advantages are possible cost cuts by a shared use of the IT infrastructure, including such concepts as consumption-dependent payment, flexibility and scalability. Concerns include data protection (if outsourced), security and reliability, especially since PLM data often represent the most business-critical data of a company. Since Cloud Computing draws on technologies like service-oriented architecture, it can be described as a technical "evolution of technology" (BITKOM 2009) rather than an IT revolution. Like other applications PLM could be used in a cloud as a SaaS (Software as a Service). However, at this stage of the development mature cloud-based PLM systems are not available presently. So, in the short run cloud-based PLM solutions are not feasible for companies. However, in the long run mature and sophisticated cloud-based PLM systems will surely be offered.
- Enterprise 2.0. In its core Enterprise 2.0 focuses on communication aspects within a company (including its supply chain and customer relations). One of the main advantages of Enterprise 2.0 is that it supports any kind of communication whether it is planned and structured or spontaneous, anytime, anywhere with anybody. Since product lifecycle management requires high degrees of interaction, Enterprise 2.0 is of significant importance for PLM. The communication networks change over the lifespan of a product. While in the first phase, the Product Idea and Concept phase, possibly inner company communication is intense (marketing, sales, production); in the second phase, the Product Design and Development phase, suppliers are involved in the communication. In the Product Sales and Usage as well as in the Recycling phase, communication with customers is very important. In terms of technology, Enterprise 2.0 can be regarded as rather mature. So, currently the implications of Enterprise 2.0 on PLM must be considered as high. In the medium term, Enterprise 2.0 supporting PLM will even more become a commodity.
- Mobile IT. Presently mobile IT is one of the most dynamic fields in information technology. It is assumed that mobile devices, like laptops, tablets and smart phones, will more or less replace the classic office PC in some years. Further, a merger of laptops, tablets and smartphones can already be observed (e.g., Samsung's Galaxy Note as a cross-over between tablet and smartphone, or the tablets with removable keyboards like Microsoft's Surface as a cross-over between tablets and laptops). Since PLM, in all of its phases, is a highly interactive process, mobile devices can play a key role in PLM. They can also be regarded as "front-ends" to Cloud Computing and Enterprise 2.0 since they provide the physical user interfaces to these technologies. Hence, they make it possible to access these platforms anytime and anywhere. Tablet PCs are particularly suitable - due to their size and computing power - to counter these requirements. Mobile applications enable team members to contribute to the PLM process regardless of

[1] Note, that the SOA hype of 5 years ago has gone and has been replaced by a realistic valuation of SOA. However, the underlying concept, service orientation, has become an important paradigm in IT.

their physical location. In combination with Cloud Computing and Enterprise 2.0 a mobile PLM environment enables the timely provision of information in the context in which it is currently needed.

- Service-Oriented Architecture. SOA, as the technological glue, is a concept to link applications to their underlying services. SOA can offer a high degree of flexibility and agility for IT supported business processes. Therefore, it serves the needs of companies to align their processes constantly to address changing business challenges. These include changing compositions of virtual companies comprised of dynamic networks through the cooperation of manufacturers and suppliers. After the hype of SOA and the (normal) phase of disappointment service-orientation can be considered as a paradigm in information technology today. Regarding PLM, its flexibility and agility supports the need for efficient and effective product lifecycle management. In terms of relevance for PLM we would consider it as an underlying core concept. Since it is already in the phase of becoming mature, it now receives less attention for PLM solutions, behind Mobile IT and Enterprise 2.0.

In summary, service orientation is a new paradigm as an enabler for flexible and agile business process. However, the focus has shifted from SOA to trends like Mobile and Cloud Computing or Enterprise 2.0 that utilize service oriented concepts.

For PLM we would regard the Mobile IT trend as the most interesting field in the short to the medium term. This goes along the lines of the superordinate industry trend beyond PLM. Mobile IT is followed by Enterprise 2.0. We consider it as more mature than mobile. We rank SOA third. SOA is now in its "realistic" phase after its hype and a period of disappointment. We think that Cloud Computing has the weakest implications of PLM presently. This is due to the fact that presently PLM is only rudimentarily supported by applications in the cloud. However, in the medium and the long run the importance of Cloud Computing for PLM will increase significantly and may provide excellent business opportunities for IT service providers today.

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