Chapter 3 – Product lifecycle management systems

In this chapter we consider the basic functionality of product lifecycle management systems and the adaptation of their functions to the creation and use of product data in the basic business processes of the company. Furthermore, the chapter examines the use of product lifecycle management in the various functions of the industrial enterprise.

Functionality of the systems

By implementing PLM systems corporations are reaching for clear advantages in developing their business. This means that a great deal is usually expected of system projects. How do the systems cope at a practical level with set objectives, staff wishes and the demands of the business environment? This success depends on several factors, but mainly on how well the user organization has defined its own needs and goals and on how the commercial software available on the market is fitted with these demands. In the following, we look at the typical properties of product lifecycle management systems and explain the development potential in their deployment.

1. **Management of the status/state of files:** The PLM system is able automatically to control the state of files or file attachments and their lifecycle status. The creation of a new file or the updating of an existing file can be carried out in PLM systems in the following ways:

   (a) A designer in the R&D department who is editing a design file, informs the system that he is editing a certain design. In other words the person in question *checks out* the design file for updating. The file is located on the file server. The PLM software identifies the user's information and privileges. The user opens the work on the system and creates a lock on the file, so that no one else can change the file while it is checked out. The designer then updates the file – a CAD drawing for example – in the system. After the changes or updating, the file is returned to the management

of the system by checking the file back in. These functions are usually called the *check out* and *check in* functions of the system.

(b) The designer prepares a CAD drawing, completes the planning work on his own PC or workstation and saves the finished file to the management of the PLM system. He notifies the system of the attribute information (Meta data), related to the file so that it can be classified in the desired standard way and placed in a suitable location in the system. Alternatively, this attribute information can be retrieved from the heading field of the CAD drawing and automatically copied to metadata.

2. **Creating an item:** The creation of a new document, such as a CAD drawing, the creation of a component item, or the approval of a component to be procured are typically performed in manufacturing companies according to the workflow illustrated in figure 8. The lifecycle status of a document or of a component item changes as the workflow proceeds. The designer prepares a certain drawing, for example, and a senior designer or the leader of the planning team checks it. The department manager accepts the document and sends or releases the document for distribution. Correspondingly, the establishment of the component item can involve a component engineer opening a new component on the system, filling in some information on the item, and attaching some additional component information. The sourcing representative checks the component (when a procured component) and the department head accepts it for procurement and manufacturing.

Over time, changes are made in the documents, in which case the document becomes a new version or revision. The version is given a number or letter mark, for example A, B, C, D … Usually only checked and released files are recorded in the file vault, in which case the PLM system keeps a log about the history of events related to the document, in other words the system traces the items and documents for:

- Viewing
- Copying
- Changes
- Commenting
- ECR (Engineering Change Request)
- ECO (Engineering Change Order)
- Printing

3. Distribution management is implemented in situations like that described above, in which approved documents are distributed in a process utilizing workflows. The PLM system takes care of the distribution automatically according to

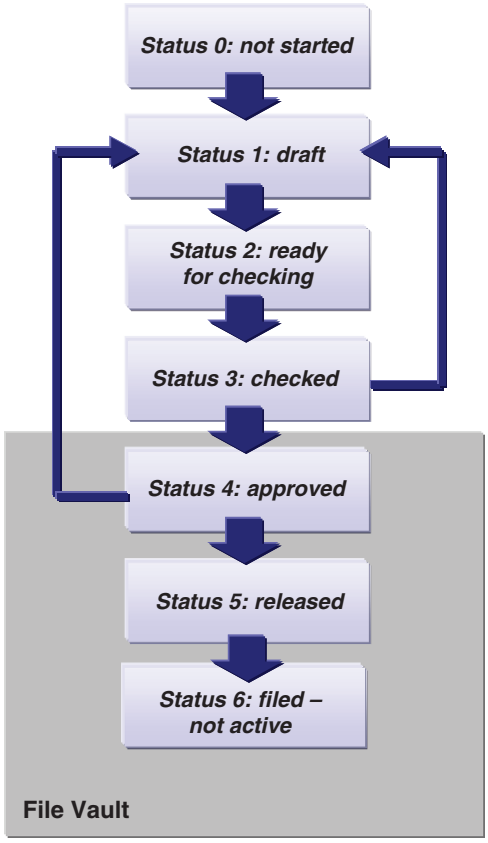

Figure 8. Example of the stages of a document's life in a PLM system.

the workflow processes and principles defined to the software. The product structure allows other related documentation to be enclosed with a document when a reference is needed. This helps PLM system users to handle larger amounts of information when necessary.

4. Searching and browsing information are very central functions of PLM systems. Kenneth McIntosh has proposed that in companies operating in the field of manufacturing industry, the planning engineers expend 15–40% of their working hours doing routine searches of the information and retrieving routine information from separate systems. Information searches are made possible through the classification of the information and are facilitated by creating attributes or help information, which describes each item and helps the system to analyze the information on each item (e.g. document, component, etc.) in the system. This enables the system user to study the contents of documents that

have been classified as the same type even though the contents of each document would not strictly correspond to the set search criteria. At the same time, the maximum use of existing information is secured and the needless creation of new items prevented. It is often easier to create a new item than to find out whether it already exists, possibly under some other code or name. This is very typical in large companies where items can be established by other departments or other designers in the same company. In the end the finding and analysis of information always depends on the exactness of the metadata and on the definition and configuration of the system. However, attribute information can be used to clarify data structures and the relationships between pieces of information. Classification, lifecycle phase, and attribute information allow the following searches for information to be carried out in standard PLM systems:

(a) What is the status of each drawing in a certain project?

(b) What has changed in a certain document? Who made the change and when?

(c) What changes have been made in documents related to a given project within the last two months?

(d) List all the resistors used in production, of which the resistance is greater than 5 Ω but less than 10 Ω

(e) List all allowed suppliers for 20-Ω resistor RES123456

5. The management and maintenance of product structures is one of the most important functions of the whole PLM system, because these features provide the basis of many other basic system functions. Some properties of version management, structural presentation of information, and change management, as well as configuration management, are typically based on product structure management. Likewise, the product structure itself makes the presentation of the relationships between the separate parts of product and assemblies possible. The product structure can be based on a generic product data model or directly according to a product unit based part list or BOM (Bill of Materials) as it is commonly but falsely called in colloquial language. A BOM in this context refers to a structured part list to which a hierarchy has been given in addition to the mere flat list of parts. In PLM systems, the product structure can typically be filtered so that certain parts of the structure are emphasized while others are hidden. This filtration or filtering is used to facilitate the examination of large and complex product structures.

Furthermore, special views of the product structures can be created when necessary. In certain cases, the system might contain only one product structure for

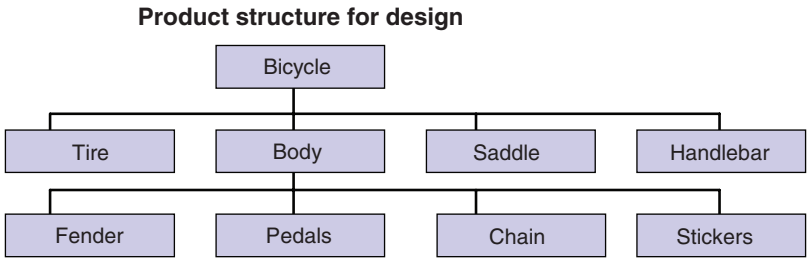

Figure 9. Product structure from the engineering point of view.

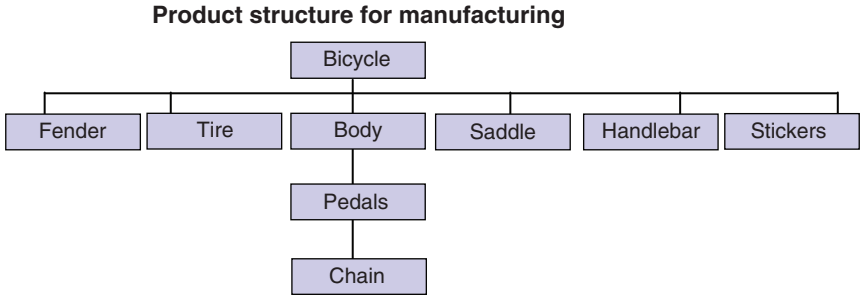

Figure 10. Product structure from the manufacturing point of view.

each generic product and there will be only view of it. The same product structure is examined from different viewpoint – in different views – in different circumstances. Figures 9 and 10 show two typical differing views of the same product structure – from manufacturing and engineering viewpoints. Modern PLM applications, on the other hand, can handle several product structures for the same product. However, the maintenance of several different product structures for one product can become impossible in practice, because the management and updating of relations between the separate product structures is such a huge task for complex products. The saving, management and maintenance of an individual product unit's product structures is worth careful consideration, because it is not always reasonable owing to the large number of individual structures to be recorded in the PLM system. The importance of the recording and maintenance of individual structures will increase continuously, especially when the demands of After Sales services and product life cycle services increase and develop. Maintenance, service and manufacturing companies need to access the complete product information quickly in order to produce maintenance, spare part sales and other after market services efficiently. In this context, we often speak of the installed product base, where the information about the owner and the current location of the product is attached to the individual product information.

From the PLM point of view, it is not always viable to store all product unit information for individual products in a PLM system due to the large number of products and complex structures involved. The product structure and product data must form a suitable and sufficiently exact description of each product in each situation. Complex products, consisting of tens of thousands of components, become nightmares if information is maintained at too exact a level, so a suitable level of precision should be defined beforehand. The product structure can consist of functional modules, of individual parts or subsections and assemblies, depending on the exactness of the description. The purpose of attribute information is also to clarify the information in the normal data fields and product structure. Attribute information can be of three kinds:

(a) Individual product based information such as the serial number of a sourced component in a certain product

(b) Generic – regarding generic products, product, assemblage, parts

(c) User-specific – remarks and notes

In figure 11, typical attribute information has been added to the bicycle example of figure 9. An essential part of the management and functionality of the product structure is the different reports, which can be printed from the system. The version history of a product, the order of the assemblies and the parts required for it, etc. – can be printed as reports.

6. Management of changes in documents, items and structures (*Change Management*) is one of the key features of a PLM system. The Change management feature provides broad controllability and visibility to the change processes for products in all those parts of the organization needing information about changes in the product. Furthermore, it provides product process traceability for engineering changes made to the design during the product's design history. The change processes usually resemble the previously described management item status. The change management tool brings significant development potential to all the change processes of the company:

(a) Controlled changes – the change process takes place in controlled manner.

(b) Information on completed and forthcoming changes – the information distribution tool can be e-mail, for example.

(c) Electronic system – streamlining and significantly accelerating the change processes.

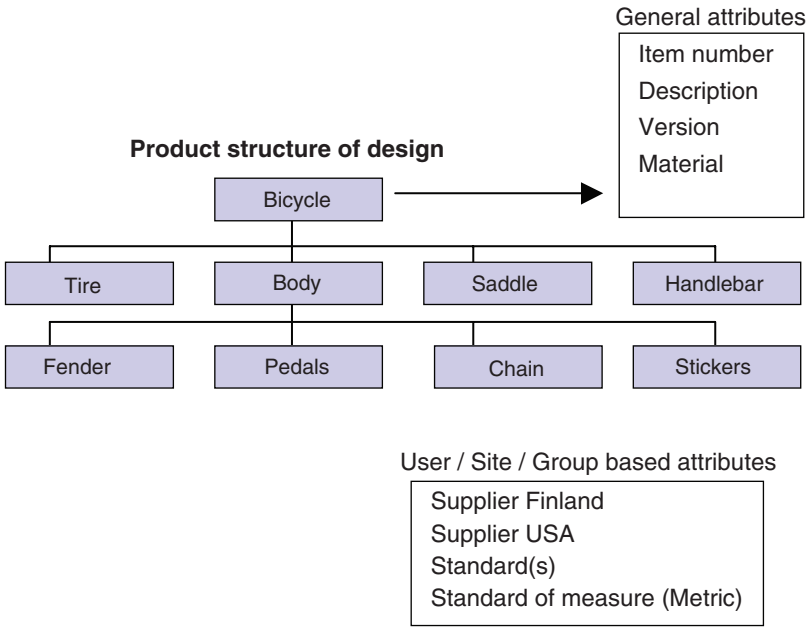

Figure 11. Attribute information for the product structure.

(d) Well-controlled and timed changes to items already in distribution and production (components/documents) become possible in a wide extent. In other words, a certain change can come into force at a certain planned time or it can be triggered by some event. When a component from a particular vendor, currently in production use, runs out from the component stock, the change will come into force and the old component be replaced with a new interchangeable component.

(e) Relations between the various pieces of product information are retained in change situations. Conflicts with existing product information are checked. For example, one can easily check the impact of any design change to a sub-assembly in all products containing the sub-assembly in question.

The following scheme represents a very typical change process in the industrial manufacturing environment at a general level, with its different stages and different internal/external parties:

The change process begins when an *ECR* (Engineering Change Request) is made, or an *ECO* (Engineering Change Order) is made directly. The reason for the change can be, for example, a perceived mistake in the design, an idea for a better functioning solution, or customer demand. The person presenting the ECR defines the subject of the change, the items (parts, assemblies or documents) affected by the change, and a description of the reasons for the change. An ECR can contain valid electric document attachments (such as a CAD drawing) with comments and redlining (highlighted areas to be noted). The ECR is delivered (e.g. by hyperlink or by e-mail in the PLM system) to the persons responsible for the changes according to the workflow defined on the system. Additional documentation related to the change can be collected and the persons responsible for the changes can discuss the measures to be taken. Negotiations can go through the PLM system, or use voting functions or e-mail.

When it is clear what and what kind of changes will be made to the product, the persons responsible for the changes make an ECO (Engineering Change Order). This change order can be based on the earlier ECR. Alternatively, the change can be carried out without any change requests, i.e. the ECO is made directly. This demonstrates one of the greatest benefits of the change management features in PLM systems: if necessary, a large number of change requests can be collected quickly even in a global organization. Product changes can be bundled up and collected as one ECO, which will be put through quickly with its negotiations, inspections, and approvals and released to production. In other words, the ability of companies to react to different situations requiring product changes can often be significantly accelerated using these methods.

All the relevant information and files managed by the system are usually connected to the ECO for updating. When the ECO is ready and all necessary information has been collected from the system, the system “knows” the character of the measures to be performed and can inform all interested parties of the product changes to be made. Likewise, persons trying to retrieve documents being updated from the system are told that the desired documents are being changed at present. The actual workflow for the change process follows the example shown in figure 12. When the planned changes have been made, the persons responsible for the changes check the overall situation and release the documents, items or structures for distribution. This is often referred to as the publication or liberation of items or structures to production, in other words *Release*.

The updated and completed documents are recorded in the file vault; the system automatically gives a new version number to different documents, components or structures, although usually the versioning of the items and structures can also be changed manually. With the component items, the release of a change, the change in a version or in the life cycle phase of a component item, usually

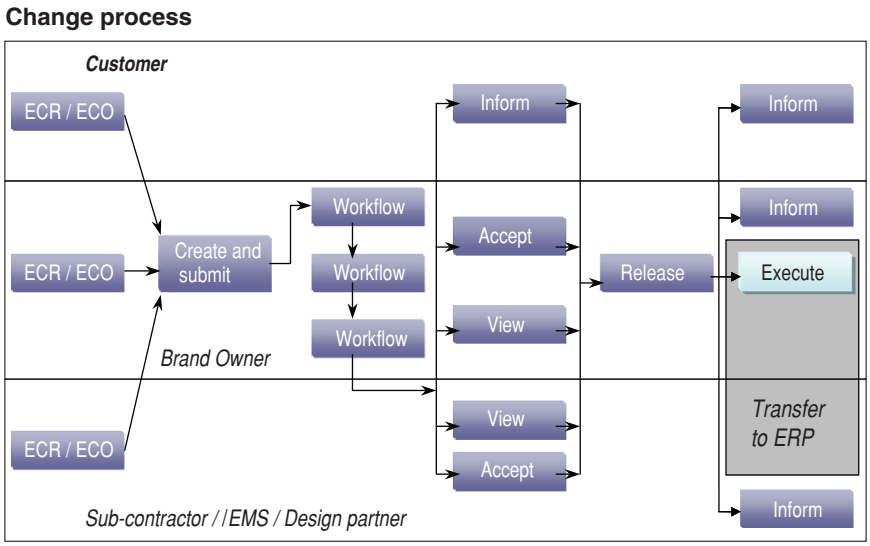

Figure 12. Change process.

triggers the transfer of item information into the ERP (Enterprise Resource Planning) systems. In other words the manufacture or procurement of the new component implemented in the change can be started.

Finally, the system informs interested parties of changes made by means of an *ECN* (Engineering Change Note). Figure 13 illustrates the product structure of the simplified bicycle, which, in time, contains changes made to the bicycle and a version history.

7. The transfer of files and file type conversions between the applications in the system is arranged so that the creator, user or reader of the file does not need to know its actual location because the usage environment can be LAN, WAN or the Internet. The system fetches the file, converts it, and automatically opens it in a suitable application. The information has been often recorded in a general standard format (for example Adobe's PDF) for examination and viewing. Conversions of file type or saving format often arise from the use of separate CAD and CAM programs.

8. In PLM systems, the communication and management of tasks or messages form a foundation for Concurrent Engineering. The system takes care of the required messaging so that all its users get the relevant information about all those actions, which may affect their own work or require action from them. Furthermore, the system provides a communication forum for daily working.

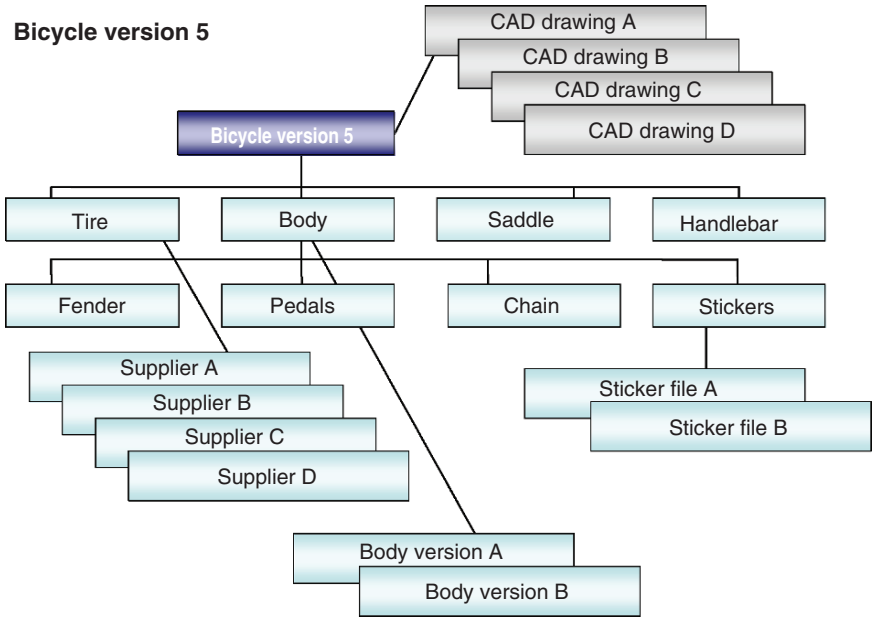

Figure 13. Product structure and version history of the bicycle.

9. One can adapt PLM systems to the management of (raster) image information, if necessary. Companies often have a large archive of paper drawings and paper documents from old manufactured and maintained products, and from production devices and facilities. These can be easily scanned into electronic form and the management of the scanned information can be moved to PLM systems. This greatly improves the controllability of the archives and the distribution of the documentation.

Use of product lifecycle management systems in different organization verticals

Product lifecycle management is used by a wide variety of organizations, including companies, communities, and government institutions. Product lifecycle management can provide solutions to many different kinds of problems. On the other hand, there are plenty of universally applicable functions in all commercial product lifecycle management systems, which can be adapted according to the demands set by the business environment. The main stress in product lifecycle management systems has long been in the area of planning, design and

engineering functions for the manufacturing industry. However, the development and evolution of PLM system applications towards the needs of the networked industries of the information era has increased their utilization also in sales, marketing, and, especially, after sales.

On the other hand, the use of PLM systems is characteristic also in connecting subcontractors and collaboration partners to the operation of the principal company in all processes throughout the whole supply chain. The core processes of manufacturing businesses are typically the product and order-delivery processes. These two basic processes can be roughly described as follows:

> (a) The product process is the NPI (New Product Introduction) and life cycle process of the product on a generic and abstract level, rather than on a physical product level (i.e. information about the product, the product data – items, structures and documentation). The product process is divided into two separate main stages:
>
> 1. NPI (New Product Introduction) – bringing the new product to the market
> 2. The maintenance and development process of a product already on the market
>
> (b) The order-delivery process is the life cycle process of the actual physical product as seen from the viewpoint of the individual product. The process extends into the field of extended order delivery, i.e. the supply chain. In other words, the after sales functions are also included in the process. The time perspective of the process for capital goods can be as great as from 10 to 30 years.

These two core processes are often heavily integrated. Figure 14 describes the transfer of information from the product process to the order-delivery process. In the beginning of the product life cycle, information about components and parts to be sourced and procured is delivered from the product design to sourcing and procurement. Applicable configuration rules and structures are also usually communicated very early from design to sales. When the product reaches its NPI launch the actual product design information can be communicated to production. Naturally, prototypes and pilot series are produced before the NPI. In the later stages of the product life cycle, changes to the product design are transferred to production, and product and spare part documentation to after sales, during the maintenance phase of the life cycle. Figure 14 also illustrates how the ownership of product data is divided between the PLM and ERP systems. The black line starting from the product process and ending at the delivery process represents the route of an individual product through different processes and

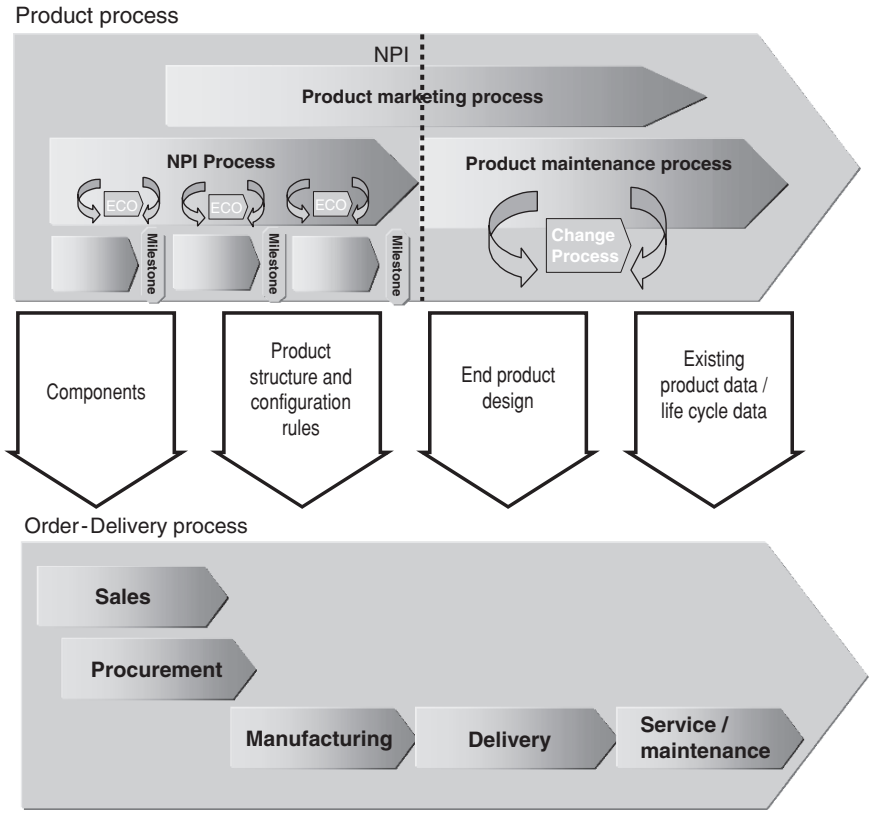

Figure 14. Product and order-delivery processes and their relation.

information processing systems during its life cycle (CAPP = Computer Aided Process Planning).

Product development and engineering

The Product development and engineering functions have traditionally been among the most important areas of application for product lifecycle management. Most existing PLM features typically serve this area. The management of documents is quite important from the viewpoint of engineering and product development. The amount of data created and stored is often very great. A perfect command of this data, so that the desired information is easily available and quickly distributed, requires an advanced information administration system. The designers create

engineering, assembly and workshop drawings, strength calculations, testing information, and part lists that can easily grow into an information unit containing thousands of files. Managing the status of the files, workflows, items, product structures and changes is essential in an advanced planning environment, possibly operating according to CE principles, in a value network that extends beyond the boundaries of the company. The information creation process of product development and engineering is very difficult to control and its quality will be poor if the design information is unreliable. A smooth workflow and distribution of information, and the utilization of existing documentation, drawings and tried and tested solutions for their part increase the effectiveness of the engineering and reduce mistakes. Functional change management is also an essential part of the flexible engineering organization, which makes efficient, high quality product development and engineering activity possible. The task of a change management tool is to minimize design errors, a large part of which result from uncontrolled changes – often known only to their originator – made to plans that have already been accepted. The other main task of a PLM solution in this area is to ensure that the right information about changes goes to production or to the contracting parties involved. The third general task in this area is to ensure the updating of the right document version – in other words to ensure that an old document is not updated if a newer version of the drawing or document is already available.

Production

Traditionally, the business features of the company's product lifecycle management have been distinctly least utilized in production or manufacturing. On the other hand, it has often been claimed that the possibilities for utilizing PLM systems in production are limited. The interface between engineering and production can be quite problematic from the organizational, geographical and especially from the information flow points of view. The progress of information may be bad in spite of many development operations and in spite of many process improvements. A PLM system can build a lasting bridge between production and engineering. The change management tool makes it is easy for designers to inform production about changed components, changes made to plans, and the deployment of new versions of drawings. Correspondingly, production can define planning changes through the change management tool so that the manufacturability of products can be improved. Integrated production – CIM (Computer Integrated Manufacturing) – can gain from PLM systems facilitating the transfer of information because they offer the means to integrate the different manufacturing systems with the engineering tools. Production can use PLM to manage changes to information on production devices, and thus improve, among other things, quality control, device calibrations, and traceability.

After sales

The use of PLM systems has increased strongly in after sales. Many capital goods manufacturers and engineering industry companies have built completely new business areas in after sales and the significance of this business has lately increased quite noticeably. When products develop quickly, new product versions are always appearing on the market. This sets great demands on spare part sales and maintenance services, especially for those competing in worldwide markets. The management of documents, product structures and items are in an important position. Information about the necessary spare parts and the versions of manufactured and delivered products can be quickly retrieved and easily maintained by PLM systems. The new Internet technology has made the utilization of PLM systems and the examination of the complete documentation of a product possible, for example, on maintenance sites and by partners all over the world, wherever networks can be accessed.

In global markets, maintenance services are often offered by local contracting parties. These partners must have secure access to information so that telephone, e-mail and fax inquiries from customers will not strain the manufacturer's customer service organization excessively. With PLM systems, it is possible to support information *PULL* – distribution functioning on the pulling principle: people finding and retrieving the information they need. In other words, a customer who needs information or product data can retrieve it through the Internet. Great attention must then be paid to the user privileges and information security of the data management systems and the networks.

The management of customer service documentation, the maintenance of customer's product structures, and the efficient management of spare part items are also easily handled by PLM systems. Furthermore, the processes of the physical production of the product documentation can be automated so that for example the printing of the spare part manual can be automated through PLM systems. The property that makes it possible to collect and print the spare part documentation connected with the product structure of each product and automatically produce a book for each product version can be built into a standard PLM system.

Sales and marketing

The sales and marketing functions of a company are also favorable application areas for PLM systems. The system is especially suitable in the order-delivery process for supporting the sale of products produced and configured according to customer wishes. Modular customer-specific product configurations are always created with

the help of preset configuration rules, so in many cases, when the product and the configuration rules are sufficiently complex, the PLM system is an almost essential support for the tendering process. The management of product structures, part lists, documentation and specifications considerably accelerates the creation of tenders, because the necessary information can be quickly accessed and used. A PLM system is, almost without exception, a precondition also for a functioning front office sales system, i.e. a sales configurator, with which the sales features, properties and price information of the product are controlled. When customized products are sold to customers, the product configurations are built by choosing from the features wanted by the customer and from property alternatives available in the sales configurator so that the product matches the wishes of the customer. The result of the configuration is a product that meets the customer's requirements and, from the supplier's point of view, is logical, operational, allowed (accords with the configuration rules), and has a faultless product structure. When a sales configurator is used, the pricing information on the product is more exact and it is impossible to select forbidden combinations of modules. In order to operate properly, a sales configurator requires constant maintenance of product structures and functional change management so that the product configurations agreed with customers will be faultless and will result in an up to date part list. When used for change management and the maintenance of items and product structures, together with sales automation systems, PLM considerably accelerates the build-to-order process and at the same time the whole order-delivery chain. Furthermore, expensive mistakes caused by the compilation of wrong configurations are avoided.

In the area of the product process, product marketing is very closely connected to the NPI process (i.e. bringing new products to market) and to the product maintenance process at different stages of the product's life cycle. In this context, product marketing can be closely compared with the product development; indeed, it is possible for them to utilize PLM systems of much the same type as for the actual product design and engineering. The early production of marketing material can be seamlessly connected to the milestones of the gate model of a product development project, using the workflow features of PLM. In this way, the simultaneous operation of very large and even global product development projects can be supported by product marketing.

Sub-contracting

PLM systems offer an excellent tool for supporting the daily operations of subcontractors and manufacturing services. Subcontractors can be connected to the principal's business processes with the help of product lifecycle management systems, usually irrespective of the character of the sub-contracting or manufacturing

service. The needs of engineering sub-contracting naturally differ from those of manufacturing sub-contracting. This also leads to the fact that PLM systems are adapted in these cases in different ways. The management of documents, items and product structures is usually an important role, as is the transfer, conversion, management and version management of files. The very different software and systems used for the production and updating of the documentation are often a root of problems in sub-contracting networks, which require the use of efficient conversion tools for the common DXF, STEP, CALS, IGES, SGML and XML standards.

Management of user privileges can be used to give subcontractors direct access to the principal's information processing systems, to certain document classes or to certain documents related to their own work, so that they will have selected rights, such as viewing rights, for the information. The communication between the separate parties can be controlled and the necessary product management functions effectively supported with PLM systems – utilizing change management, the management of information distribution, information retrieval, and the management of file status and conversions. In this way, the principles of CE can be carried out even in decentralized engineering activity where many different sub-contractors are used.

Product life cycle management is based on a product lifecycle model. According to this model, the view of the product and of the product structure will change at different stages of the product life cycle. Figure 15 illustrates one example of

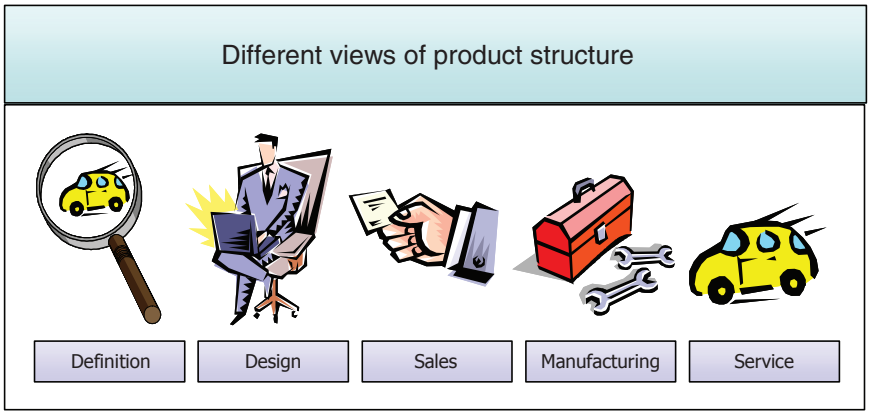

Figure 15. An example of separate stages in the product life cycle. Different views of the product are seen from the viewpoints of the various organizational verticals – product development and engineering, sales, production and maintenance – that support the product life cycle from the product and order-delivery process perspective.

different views of the same product, which are related to different stages in the product life cycle. The various areas of the business process, which are related to the different stages of the life cycle – design, production, sales, marketing, and after sales – have been considered earlier in this chapter. The use of PLM systems according to the life cycle model will support the separate business functions in most organizational verticals during the whole life cycle of the product. It is therefore suitable in many respects for a business backbone in many companies operating within different branches of industry.

Sourcing and procurement

The significance of PLM has increased significantly of late also from the sourcing point of view. When companies concentrate solely on their own core business, they become more and more dependent on their suppliers while, at the same time, the share of procurements in the production costs of the product increases. The life cycles of products and components are shortened. The significance of product changes increases and sourcing becomes increasingly dynamic. The significance of product management in the development of sourcing and procurement activity also increases considerably. From the product management point of view it is good to divide sourcing into two different life cycle processes:

1. Developing new products (NPI – New Product Introduction)

2. Accomplishing volume production

The old truth, that 80% of the cost of the product is determined during the product development phase, has not been falsified. During the development process for a new product, the amount and speed of product changes can be extremely high; product structure, documentation, technical specifications, software, and other product data, which directly affects component and software acquisition changes continuously. This indeed is perhaps the biggest opportunity to develop the effectiveness of company processes and to improve the quality of processes, daily operations and products by utilizing PLM systems. Sourcing decisions will affect the product most dramatically at this stage. It will also be most difficult to make sourcing decisions at this stage. The availability of desired components can be poor. The delivery time for some components can be measured in months. Sudden changes can occur in suppliers. Procurements based on faulty and outdated information often lead to expensive mistakes growth of the component warehouse, corrections during production, and faulty products. PLM systems can be facilitate and intensify sourcing during the NPI phase. By developing

the sourcing process and subjecting it to the workflow management of the PLM system, some stages of the processes can be automated and the flow of information can be accelerated. Version management and approval circulations can be made more efficient and controlled even in large and global organizations.

Later in the product life cycle, during mass production, the sourcing concerns of product management continue to provide the same challenges as at the product launching stage, but the focus moves to the large volume of components. Meanwhile, the number of changes made in the product decreases and the rate of change slows down as the product matures. The cost efficiency of volume production and the constant reduction of manufacturing costs become more significant. The electronic handling and transformation of a large and complex product structure or part thereof, with all its necessary documents and specifications, for partners or for the electronic marts of the Internet, will be considerably easier and more controlled when the product is managed with the help of PLM. Extensive item management in PLM makes it possible to use the product data in the PLM system, together with the ERP system, to follow and analyze the costs of procured product components constantly.

Summary

- The most central functions of PLM systems are:
    - Item management
    - Product structure management
    - Document management
    - Change management
    - Retrieval of information
    - Workflow and distribution management
- The organizational verticals within companies which typically use PLM systems are:
    - Product development and engineering
    - Sourcing and procurement
    - Sales and marketing
    - Sub-contracting and partners (design, software production, manufacturing, and after sales)
    - After sales
    - Production