Chapter 2 – Fundamentals

This chapter introduces the basics and the central terminology of product lifecycle management. The chapter presents the area of application of PLM and the core functions of an information processing systems adapted to the practical realization of product lifecycle management.

Product data or product information

Product data refers in this context to information broadly related to the product. Product data can be roughly divided into three groups:

1. Definition data of the product
2. Life cycle data of the product
3. Metadata that describes the product and lifecycle data

The definition data of the product – determines physical and/or functional properties of the product – i.e. form, fit and function of the product – describes the properties of the product from the viewpoint of a certain party (e.g. customer or producer) and connects the information to the interpretation of the party in question. This group includes very exact technical data as well as abstract and conceptual information about the product and related information. This group of information also includes the images and conceptual illustrations that characterize the product. So more or less this set of information could be characterized being a complete product definition. The wide spectrum of information and the difference in the contents of definition data can easily cause problems, owing to different interpretations and contexts.

The life cycle data of the product – is always connected to the product and the stage of the product or order-delivery process. This group of information is connected to technological research, design and to the production, use, maintenance, recycling, and destruction of the product, and possibly to the official regulations connected with the product.

The Meta data – is information about information. In other words, it describes the product data: what kind of information it is, where it is located, in which databank, who has recorded it, and where and when it can be accessed?

The concepts of product data or information model and product model, for which the term product structure is nearly always used as a synonym, and the acronym BOM (Bill of Materials) are also closely connected to the product data. Actually, BOM refers to a manufacturing part list (i.e. not a hierarchical structure) so it is not strictly speaking the same as a product structure. The part list is typically a single-level, flat list of the necessary components used by the manufacturer in assembling the product. The list does not contain a product structure, assembly or component hierarchy.

A product data or information model is a conceptual model of the product in which information on the product and the connections between various information elements and objects are analyzed at a general, generic level.

The product data – the information about the product to be created – lies at the core of the integration of the functions and business processes of a manufacturing company. The creation, development, handling, division and distribution of information connect the immaterial and material expertise of the organization. An actual physical product includes both. On the other hand, intangible products, for example software and services, always lack the physical aspect. Therefore it is extremely important to try to concretize the functions and the features of an intangible product to the same level as for physical products, i.e. transforming the functions and features into information objects (items) that can be handled as they were physical entities.

The external and internal functions of the company use and produce product data in their daily business. The internal functions that produce product information include the planning, design and engineering functions related to the product, as well as the procurement, production and customer service organizations. The external functions that produce and utilize product data include, for example, collaborative partners in maintenance services, design and engineering, manufacturing and assembly.

The need for the collaborative use of product data will appear clearest in the functions closest to the actual product process for the whole life cycle of the product – in networked product design and creation and in the networked functions of manufacturing and after market services. The control of product data is very much emphasized by companies operating in a networked environment.

Product Lifecycle Management (PLM)

Product lifecycle management, or PLM, does not refer to any individual computer software or method. It is a wide functional totality; a concept and set of systematic methods that attempts to control the product information previously described. The idea is to control and steer the process of creating, handling, distributing, and recording product related information. According to the definition by Kenneth McIntosh some years ago:

Engineering data management – EDM (currently the appropriate acronym would be PLM) is a systematic way to design, manage, direct, and control all the information needed to document the product through its entire lifespan: development, planning, design, production, and use.

In daily business, the problems of product lifecycle management typically become evident in three different areas:

1. The concepts, terms and acronyms within the area of product lifecycle management are not clear and not defined within companies. This means that the information content connected to certain terms is not clear and the concepts how to utilize to the product related information are even fuzzier (for example the definition: what is product lifecycle and what are its phases).
2. The use of the information and the formats in which it is saved and recorded vary. Information has usually been produced for different purposes or in some other connection but it should still be possible to utilize it in contexts other than the task for which it was produced: in a different locality or even in a separate company. An example might be the use in e-business sales, of a product structure originally created during the design phase. The lack of an integrated information processing system often means that the product structure must again be manually fed into the e-business sales system.
3. The completeness and consistency of information produced in different units, departments or companies cannot be guaranteed. This problem arises when the product data is produced and stored on different data media or even as paper documents, and when the parties concerned have different approaches to the protection and handling of information. One practical problem can be clarifying the location of the latest version of a certain document.

> For example, in many companies a file server in the local area network is the agreed storage place for completed and released product documentation. However, shortcomings in the processes, standards, and tools for information production and management can cause some erosion of the operations model in practice. People and organizations begin to update the same information on their own storage, for example on their own workstations, and they share information from there. Nobody knows for sure whether the latest version is located in the agreed place.

Nowadays, product lifecycle management is, in practice, carried out almost without exception with the help of different information processing systems. However, it does not always have to be like this. In many companies, simple actions can be taken to develop information management without a special and dedicated information processing system. An agreement, an operations model, or a set of common practices and standards for information handling can be the basis of development work. The creation and following of common modes of action is the key to improvements in the creation and analysis of information.

It is possible to solve many of the problems and situations described above using information-processing systems that support product lifecycle management. Information processing systems have evolved quickly during the last few years; and yet it has not been possible to remove all problems. The worst problems, at a practical level, result usually from different modes of operation, the wide spectrum of different software used to produce the information, functional differences in software, and the numerous interfaces between different information processing systems.

Product lifecycle management is above all the management of processes and large totalities. How and at what level each company carries out its own product lifecycle management always depends upon the viewpoint from which problems are examined as well as company objectives and strategies in this area. It is therefore extremely important that the operation and core business processes of the company be described in depth before implementing a PLM concept and IT-system. In practice, this means that the required specifications of the TO BE of future processes as well as the PLM concept framework must be set to match the high-level objectives of the business and the future visions of the company. In addition to careful selection of requirements for product lifecycle management, business processes must be described in detail. The resulting product lifecycle management solutions differ considerably as they are based on the individual strategy and business architecture of each company. They reflect different objectives and priorities and emphasize different areas and functions of PLM.

Product lifecycle management concept

The product lifecycle management concept, at its simplest, is a general plan for practical product lifecycle management in daily business at the corporate level, in a particular business or product area. It is a compilation of business rules, methods, processes, and guidelines as well as instructions on how to apply the rules in practice. Usually, the product lifecycle management concept covers at least the following areas:

1. Terms and abbreviations used in this field (definition of product, lifecycle, lifecycle phases, etc.)
2. Product information models and product models
3. Definition of products and product-related information objects (items, structures, product-related documents, definition of product information, etc.)
4. Product lifecycle management practices and principles used and applied in the company (how products are managed throughout their lifecycle, identification of information management principles such as versioning principles, information statuses, etc.)
5. Product management related processes
   (a) Product information management processes
6. Instructions on how to apply the concept in everyday business

The significance of building this kind of product information concept lies in the need to set common business rules for the entire corporation and its business and product areas. A carefully specified concept makes it possible to achieve synergies between businesses and between products. A common product information concept allows for the smooth and speedy implementation of PLM-related processes and practices because the most crucial areas of information have been agreed at common and conceptual levels.

A good PLM-concept is never static; it keeps evolving in tune with the business and its requirements.

Items

The development of product lifecycle management and the use of different product lifecycle management systems are very largely based on the use of items. An item is a systematic and standard way to identify, encode and name a product, a product element or module, a component, a material or a service. Items are also used to identify documents. What an item means depends upon the specific needs and products of each company. In addition to the above mentioned, such

things, as packing, installation tools, moulds, fasteners and software can also be items. The computer software used in production and the NC software for machine tools are often items. From the viewpoint of product lifecycle management, it is essential that items and their classification should be uniform within each company. It is essential also that items form separate classes, subclasses and groups at a suitable level of coarseness according to the company's own or, alternatively, wider international standards. In the electronics industry, for example, diodes might form a component class, with Zener diodes as a subclass. The clear and logical grouping of items into different classes eases the management and retrieval of individual items. On the other hand, an overly exact classification slows operational processes and considerably increases the amount of work required to maintain the items.

Items can be used in the intangibles (e.g. software or services) businesses in the same way as they are utilized in the manufacturing business. When utilizing a PLM-system to support the PLM processes the use of items is naturally required. In practice this means that the functions and features of a software or service must be transformed into items, i.e. encoded, named, and classified. The principles for making items out of service functions is discussed in more detail in chapter 9 – Service industry and PLM.

The structure of the item hierarchy must be documented, and the relations and hierarchies between items and item classes must be taken into consideration when creating an item-numbering scheme. This is referred to as an item hierarchy. National and international standards exist for the creation and unification of items in specific branches of industry. On the other hand, modern companies are widespread and even global entities. The sometimes include units of very different types, as well as bought and merged companies. There can be large differences in item fields and item coding schemes between the separate business units of these companies. A totally congruent and standardized encoding and numbering system is therefore not always the right or necessarily the best solution and a uniform corporate-wide coding scheme is not always something to work for.

Product data can also be controlled effectively without an entirely congruent field of items. Ready made solutions exist, based on cross-reference tables, which will tell you, for example, what name or code is used in Company B for item 1 in Company A. These tools can be used to integrate different marking systems and scattered item fields in large corporations. On the other hand, unifying the item world is an excellent way to integrate acquired companies and their operations at the level of daily business. The integration of companies becomes very apparent and concrete at a practical level from the use of common

items and a common item creation and numbering process. For this reason, the significance of items and a unified item base can be very important from the viewpoint of operations and cost efficiency. To achieve this requires an item management strategy because unification of large item bases can be very laborious and costly.

Product lifecycle management systems

A product lifecycle management or PLM system – what is usually meant by the term PLM – is ideally an information processing system or set of IT-systems that integrates the functions of the whole company. This integration is done through connecting, integrating and controlling the company's business processes and produced products by means of product data. At the practical level, the adoption of PLM is still too often restricted to only certain areas of certain business processes, such as product design and development. Kenneth McIntosh has proposed that PLM can be the operational frame of CIM (*Computer Integrated Manufacturing*) – one of the isms of industrial business. In other words, it is a system or set of systems, which integrate the functions of the whole company with the help of information technology. PLM is above all a connecting technology, not an individual technology islet or information processing system like a CAD (*Computer Aided Design*) system. A specialized IT-system can be very efficient in its own area but such systems usually cause bottlenecks elsewhere in the company's data flows and at the level of practical implementation in corporate IT-systems. The most important business processes, the product process and the order-delivery process, in manufacturing industry are cross-functional and cross-organizational.

The task of PLM, in one sense, is to provide the necessary conditions for connecting separate information data systems, processes and automation islets. Additionally, PLM should command a wide variety of information systems and thus give birth to integrated totalities. Commanding the totality of various processes brings considerable value to companies by seamlessly integrating information from organization-wide processes using different information processing systems.

Figure 2 illustrates the core processes of an industrial enterprise. It shows how the core processes are cross functional and cross organizational.

Figure 3 illustrates how a PLM system is positioned as a common and central databank within the field of operation of the process oriented manufacturing enterprise described in figure 2.

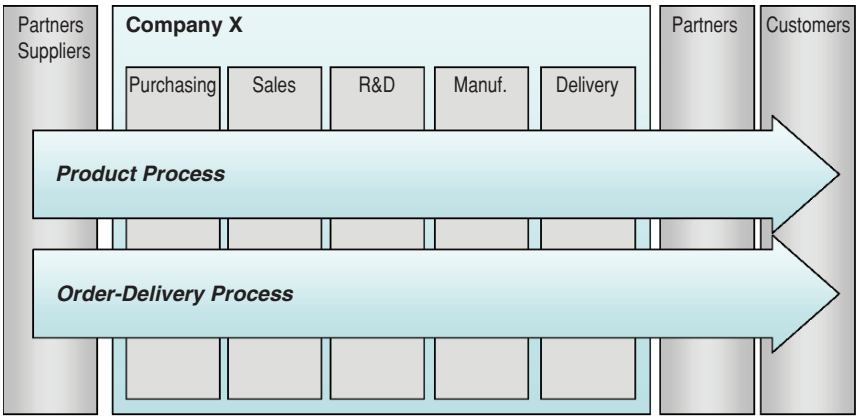

Figure 2. The core processes and functional verticals of an industrial enterprise.

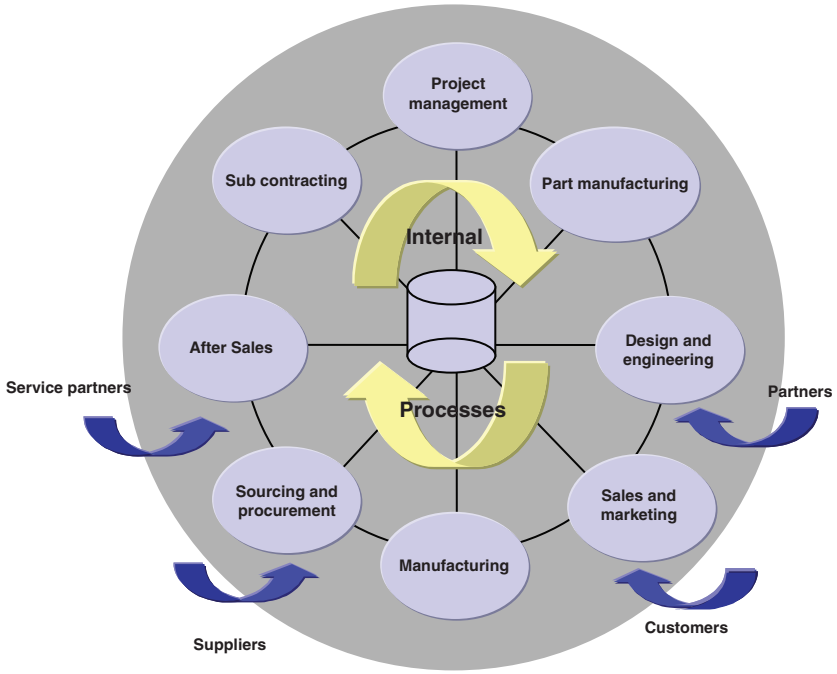

Figure 3. The PLM system often creates a wide totality of functions and properties with which to support the different processes involved in the creation, recording, updating, distribution, utilization, and retrieval of information.

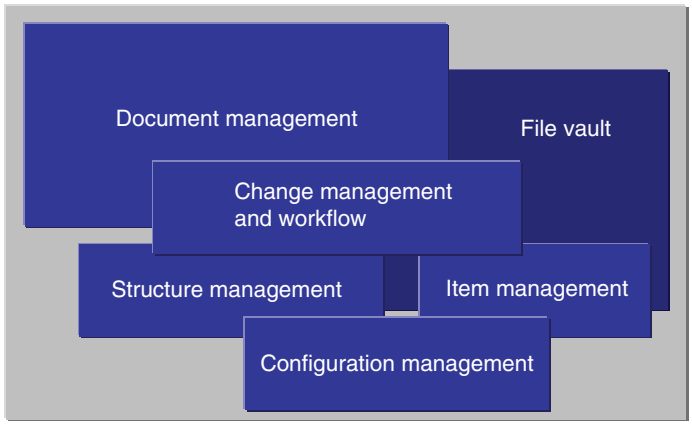

Figure 4. Product lifecycle management entities.

Typical features of such systems include (figure 4):

(a) Item management – one of the basic functions of a PLM system is the management of items. The system controls the information on the item and the status of the item as well as processes related to the creation and maintenance of items.

(b) Product structure management and maintenance – the PLM system identifies individual information and its connections to other pieces of information with the help of the product structure, which consists of items hierarchically connected together.

(c) User privilege management – the PLM system is used to define information access and maintenance rights. The PLM system defines the people who can create new information or make, check and accept changes, and those who are allowed only to view the information or documents in the system.

(d) Maintenance of the state or status of documents and items – the system maintains information about the state and version (e.g. sketch, draft, accepted, distributed, obsolete) of each document and item, and about changes made to them: what, when, and by whom.

(e) Information retrieval – one of the main tasks of a PLM system is information retrieval. PLM systems intensify and facilitate the retrieval of information so that:

- It is possible to utilize existing information better than before when creating new information. All the existing information on a given subject, such as a particular product, can be easily accessed: documents, components, perhaps a design solution of proven quality.

- It is easy to find out how a given piece of information is related to other information, for example to find out where else a given design solution, part or component is used. (This is very important for change management – when implementing changes in this piece of information.)

(f) Change management is a tool with which the latest valid information about changes, such as version changes to a product or component, are recorded in documents or items, which are then made available in the right place and at the right time.

(g) Configuration management – varying the physical properties of similar products and switching inter-changeable assemblages or components. Configuration management allows products to be customized according to customer wishes.

(h) The management of tasks (messages), also known as workflow management, is one of the basic properties of a PLM system. The communication and division of tasks is carried out through graphical illustration of the chain of tasks and by e-mail or a task list. The management of tasks makes possible the radical intensification of communication in the organization, especially in a decentralized – even worldwide – environment.

(i) File/document management involves index information on files contained in the system. In other words, it is a question of metadata – information about what information is located where.

(j) Information loss during updating is avoided. The PLM system controls the copying of files and ensures that the master copy is preserved until the files have been successfully updated.

(k) Backup management – the system automatically logs backup copies.

(l) History/System log – a database of events which ensures that that all measures – such as updating documents or changing

component items – made within the sphere of PLM management can be tracked, if necessary (Product process traceability).

(m) File vault (electronic vault). The system also includes a file vault, or storage place for files. It is the place where files – the actual data – or file attachments are recorded. The file vault is usually located near the group of persons who create, update and administer the files. In practice, the vault is a file server on the same LAN (Local Area Network). The files on the PLM system file server are managed by the system so that correct and controlled revisioning principles, user privileges and information maintenance are maintained.

Geographical and network architecture restrictions usually lead to the actual file servers being decentralized over the whole company network, so that files can be delivered quickly to the users and applications that need them most. In such cases, the PLM system must also be distributed over several file servers, all of which must always have the same version of each file. This can be achieved for example by copying large files to all the servers at quiet times – at night, for instance – when the network load is low.

The PLM system is typically based on one or several physical servers, which use the PLM application and metadata base to control other databases and file services. The company's or the partner's employee – i.e. the end user of the system – can access product data from servers in different parts of the information network containing the actual information and files. A file located on a device other than the users own workstation or PC is obtained physically from the source server as a copy or as a so-called virtual copy. When a file is fetched as a copy, a copy is normally created for the user and the original file is returned to its original location. When the file is fetched as a virtual copy, it is not copied onto a workstation or PC; instead, pointers are created to the original file. Sometimes the most efficient solution, especially for large files, is to make working copies on the user's own PC, thus avoiding time-consuming file transfers in the data networks.

System architecture

Commercial PLM systems typically have many features in common. All systems contain certain features, functions and techniques, which are functionally identical irrespective of the system. Such system-independent functional units include:

The file vault is a centralized filing system for information files or, in practice, a concentrated databank, usually a file server or set of file servers (Electronic vault, file vault, central filing system). In another words, it is a warehouse for information data, stored in files, which meets certain set demands. This kind of information consists of documents at various stages of their life cycle, such as CAD drawings that have been accepted and are ready to be released for distribution, or other kinds of documents such as Microsoft Word files.

The metadata base (Metadata base) is needed to maintain the structure of the whole system. The task of the metadata base is to handle relationships between individual pieces of product data, the structure of the information, and the rules and principles needed to ensure the systematic recording of the information. The metadata base keeps a record of the product data produced by the different systems and applications functioning within the sphere of PLM.

The application carries out the PLM functions of information and metadata base management and appears to the user as a variety of different user interfaces. The task of the software is to make possible all the PLM functions, data transfers, and conversions in accordance with the principles of PLM. The PLM application usually also acts as a link between different applications and systems within the sphere of PLM and makes the connections between the separate databanks possible.

Figure 5 illustrates basic system architecture of a PLM-system. It shows how the functional core elements of the system are related to each others. The PLM application is capable of version management: the system identifies different versions of the same file based on their newness or some other desired key. However, the PLM system cannot interpret the content of the files that it controls. The user must feed in the necessary information (e.g. file name, creator's name, link to product structure – in other words, metadata), when creating the file on the system. On the other hand, the system can automatically produce and identify the information in question if the necessary case-specific routines have been created for this. An example of this might be extracting information from the heading area of a CAD drawing.

Even though the system cannot directly identify the content of the information under its command, this might become possible in the future. The system user can request searches of the system, which the system carries out by searching the contents of documents managed by the system. Other common properties of PLM applications include managing the acceptance and release of produced documents, the management of change processes, and user announcements of changes made during process workflows.

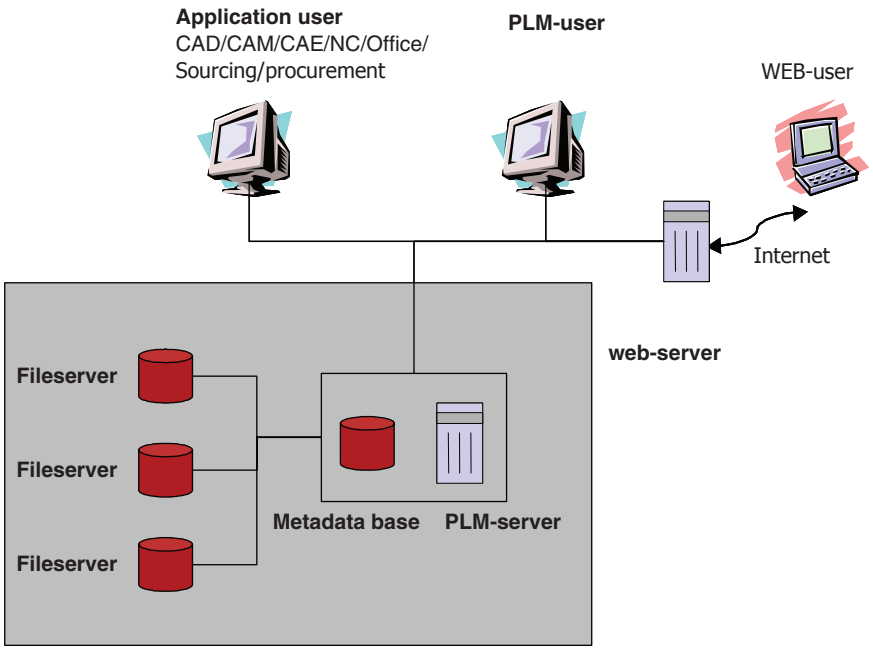

Figure 5. Example of a PLM system architecture.

In many PLM systems a link or association is created, on the basis of the document or file type, to the application – such as word a processor – that should be used for the proper creation and handling of the file. This allows the system to start a suitable application and deliver the desired file to it. The PLM system usually contains some information conversion programs, which can be used to convert product data into a second or general format for viewing by the system user. Nearly every PLM system contains an e-mail interface or can utilize the company's existing e-mail system. In spite of these general features, which are common to all systems, there are considerable differences between various systems and system architectures.

The reasons for these differences are:

- The properties and requirements brought by differences in the scope and scalability of the systems.
- The different types of functions required within different branches of industry due to different priorities and emphases.
- System suppliers approach the whole PLM concept from different directions.

Suitable operating system platforms for PLM applications are typically Microsoft, UNIX and Linux. As a network solution, an Ethernet network supporting the TCP/IP protocol is usually required. Modern PLM applications also offer the possibility to act and function globally, through the dedicated data network of an international company or through the Internet. The use of a PLM system on the Internet usually involves the use of normal Internet browsers. So the PLM system can be used via generally available Internet browsers such as Opera, Netscape or Microsoft Internet Explorer. As was stated earlier, the PLM system requires one or more databases to operate. Different suppliers' systems differ in this respect. Some systems require a particular kind of database, which is sometimes a proprietary brand belonging to the system supplier. However, most PLM systems are independent of particular database providers. They nearly always support such widely used SQL relational databases as Oracle, MS, SQL-Server Informix, Sybase, Progress or DB2. System environments involving the use of several different database types present a greater challenge to the PLM system and naturally to integration and data transfer between different systems.

Different applications can usually be connected to the PLM system by links of different levels.

Usually the following four different levels are distinguished:

1. Encapsulation: Reference information for the file identifies an application that can open it (e.g. e-mail attachments or files selected in Windows Explorer)

2. Information exchange between systems: File-based data transfer

3. Database integration: Different systems use a common databank

4. Platform or middleware integration or EAI (enterprise application integration) use of a separate software layer (middleware) that transmits and moves the required information between different systems (described in more detail in chapter 5)

Modern PLM systems are based on an object-oriented architecture and technology in which separate document or file types are contained as objects. Each object belongs to its own object class, which PLM applications process by rule. For example, when the Print command is selected from the File menu the program checks whether it is a graphics file. The software knows this from the

object class. If it is a graphics file, the program allows the command; otherwise, the command can be denied.

Information models and product structures

Information model

An information model is a conceptual model that describes relationships between the most important information entities in a corporation. Large corporations usually need a number of information models, such as a customer information model, product information model, financial information model, and delivery information model, to define the requisite pieces of information to be supported, for example, by product and customer information management. The main purpose of this kind of top-level information model is to describe how these information sub-models relate to each other (figure 6).

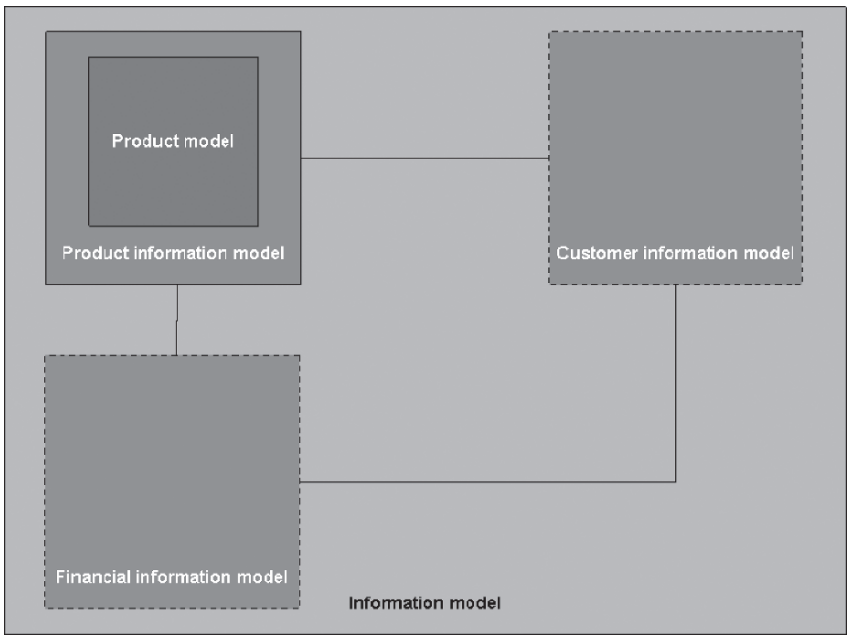

Figure 6. How the information model, product information model, and product model are related.

The product information (data) model

The product information (data) model is a concept model that analyses information on the product and its relationship with other pieces of information by describing them formally and carefully (figure 7). The product information and the connections between pieces of information are described only at a conceptual level in the product information (data) model. The idea of this model is simply to define carefully the concept of a product. The function of the product information model is to analyze the product on a general level, examining its common properties and common forms of information, and to form a generic information (data) model for the product, which is suitable for all individual cases at a general level.

The most important function of a product information model is to describe the needed information entities and their significance from the product point of view; for example, a product must consist of one or more modules, a module must consist of one or more items, certain types of module cannot be connected together, etc.

The product model

A product model – a general product structure for a certain individual product – contains information on an individual product, recorded and arranged according to the product information (data) model. For example, the individual product units' product (data) models or product structures for two similar but customized products might differ even though the products are alike at a generic, product information (data) model level.

In many cases, the product model is also called a generic product structure. In other words, this product structure refers to a general product concept rather than to a unique product unit.

The International STEP (Standard for the Exchange of Product Model Data) standard utilizes the description of product data at the level of concept models.

The generic, or general, product structure is a structure developed for products, the product concepts of which contain several interchangeable and configurable components. The changed physical properties or subsections of the product are called variants. Only a generic structure, containing the possible variants, is created during the product development process. Individual products are formed only during the order-delivery process, when the actual physical products are created and manufactured, and delivered to customers. The generic product structure usually exists because it is not reasonable separately to describe all possible structures, with their numerous variants. Furthermore, the maintenance of structures becomes nearly impossible in practice.

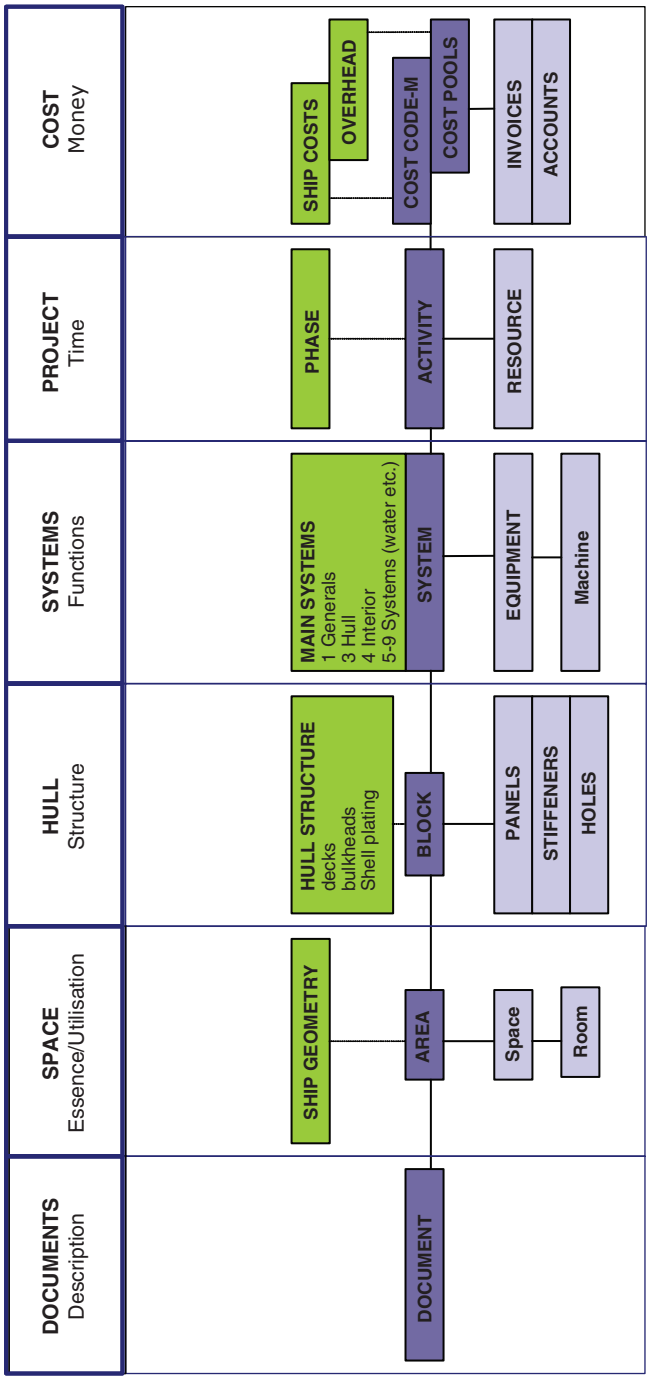

Figure 7. An example of a possible information model for the ship construction industry. In this example the relation of various information entities, which are very essential for a ship, are described. This example contains the tangible product (hull and systems) and intangible product (space) and their relation to project and delivery management as well as to financial models and cost allocation and documentation.

When a product is customized according to customer wishes, i.e. some variation of the physical properties of the product is produced, the process is called product configuration or a configuration process. In this process, a product structure is created from the product model.

Several commercial applications are available for the management of product data or product information and for the system development and system integration of data transfer extensions within and between organizations. They are based on the methods of numerous standards such as XML (Extended Markup Language) or STEP.

Reasons for the deployment of PLM systems

Product lifecycle management systems are implemented in different companies for different reasons. These will vary according to which branch of the company is involved, what products it produces, and above all, what the user wants the systems to do. The PLM system brings extremely useful problem-solving tools and methods for every-day product information and product lifecycle management problems. However, it is wrong to expect the system itself to solve data management problems. For one company a PLM system is no more than a tool to improve the effectiveness of daily business. To others it is an investment, which will help the company to take over international markets. Product lifecycle management continues to be developed while, at the same time, more and more companies are implementing it. This is caused by the complexity and the large amount of data involved in creating, maintaining and delivering products. Ever increasing global competition requires that products be produced more quickly, more economically, and with more custom tailoring according to the customers' wishes. Companies must always be looking for new ways to solve their daily problems. Customers expect ever better and more advanced properties from products. For this reason the products themselves and their production processes have become more complicated even though it has often been possible to simplify the products by developing processes and industrial design, for example through standardization, and with the help of group technologies. Complex products have forced companies to specialize, with large groups of specialists being tied up in product design and planning. The management of the design networks of tens or hundreds of companies with units scattered all over the globe requires new technologies. Developing the quality of products and their production processes is necessary in international competition; scrap and bad quality cannot be tolerated. Increased quality requirements demand planning and a product development process in which information is effectively and reliably handled, recorded and utilized.

It is reported (Pawar & Riedel 1994) that 80–90% of the time needed to bring a product to market – in other words time to market – is used in the product planning and development phase. If a company wants significantly to shorten the time to market of its products, development efforts must be concentrated on the planning stage, where the most significant savings and best results can be obtained. These development operations have brought, among other things, CE (Concurrent Engineering), and the idea that the functions of the company can be integrated using CIM, in other words with the help of information technology. PLM is a valuable tool in this development. The trend in manufacturing industry during the last few years has been to concentrate on the company's own expertise – its core business. This has meant that areas of operation beyond the core of the business strategy have been transferred to outside parties or organizations. They have been outsourced. Sub-contracting chains, alliances, partnership relations and companies specialized in some narrow field of business, such as contract manufacturing, marketing, or documentation of workshop drawings, have been created. The operations model in which companies concentrate on their own core expertise and core business and outsource other necessary expertise as external parts, products and services is called network economy. The cooperating companies form a network, every part of which commands a certain special area. Efficient management of this kind of network requires advanced information technology solutions because the network economy hugely increases the need for data transfer and management. One solution can be to use a PLM system. Companies operating in a heavily networked business environment must be able to make product changes and find required information quickly. Reliable and efficient communication is a condition of life.

Summary

Product data consists of:

- Product specification data.
- Product life cycle data.
- Metadata.
- An item is a systematic and standard way to identify, encode and name a physical product, product or component part, material, service or document.
- The product structure is a model, which analyses the information on the product and how the information relates hierarchically to other pieces of information.

- The product lifecycle management (PLM) system is ideally an information processing system, which integrates the core processes of a manufacturing company and connects, integrates and controls the business processes of the company through the products to be made and through information closely related to the products.