From Product Data to Product Data and Knowledge Management - Requirements and Research Perspective

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Abstract

As a subgroup within the Esprit Working Group 21108, Integration in Manufacturing and Beyond (IiMB), the authors are concerned with the management of product related data and knowledge in the extended enterprise considering the paradigm of the learning organisation. The focus of the work is on concepts, approaches and methods for capture, maintenance, management and use of data and knowledge about products covering the whole life cycle from idea generation, via product and process design to operation and recycling of a product. This working paper reports on our current understanding of the problems and requirements of product data and knowledge management in the extended enterprise.

Keywords

product data, knowledge management, extended enterprise, virtual enterprise

1 Baseline: From PDM to PDKM

Product data are needed to design, manufacture, install, operate, maintain and finally dismantle the product as required by the customer and by societal regulations. Product data must be managed as a shared resource for maximum availability for all business functions creating and using product data during all phases of the product life cycle. The use of IT-tools to support the management of product data requires a good understanding of the product data structures and the product development process.

However, today products are becoming obsolete more and more quickly. The value of both, pure product data, and the ability to produce and deliver a product according to these data, which was the baseline for being competitive on former stable markets, become less important for a company for being competitive on global markets. Customers are continuously asking for added value along with the physical product. Increasing services are the name of the game. To offer these services a deeper and better understanding of the product and the process, including all phases of the life-cycle is required.

In addition increasing requirements on product liability request a deeper understanding of products to be produced. Whereas the manufacturers responsibility for the product terminated in the past with the delivery of the product, today the manufacturer is confronted with a lifetime responsibility (extended responsibility) of each of his products. Product takeback at end of life and resource recovery have to be considered as regular phases of the product life-cycle.

Decreasing product life-cycles cause an increasing speed of innovation. In other words, in future a firm will have to more or less innovate constantly, and do so within increasingly short spans of time [Demarest, 1997]. The key question for a company will be, "Do we innovate fast enough, often enough and efficiently?". The sufficient management of product related knowledge will play a vital role in assuring a clear "Yes" in answering this question.

To be competitive in the future the self-understanding of a company has to be developed into that of a highly flexible, continuously learning organisation. Accordingly, we see a shift from PDM (Product Data Management) to PDKM (Product Data and Knowledge Management). Whereas the management of product data was adequate in the past, a learning organisation requires the management of product data and knowledge.

The objective of our group is to extend the existing concepts of PDM to PDKM. More specifically, the group will investigate concepts, approaches and methods for creation, capture, maintenance, management, and use of knowledge about products and manufacturing processes in the extended enterprise and the learning organisation.

2 Relevant Definitions and Scope of PDKM

The purpose of this section is to come to a definition of Product Data and Knowledge Management. Therefore we start with definitions of product and product data. Then we discuss the difference between data and knowledge, subsequently define data management, product data management and product data and knowledge management.

2.1 Definitions

According to Krause et al. a product is a "materialised, artificially generated object or group of objects which form(s) a functional unit. The materialisation may contain mechanical parts, electrical components, electronic components, hydraulic components and other elements. If the product has processor and storage capabilities, the computer hardware and software fulfilling the foreseen functions are also part of the product. Products may be made of different materials and manufactured by different processes in a variety of lot sizes." [Krause, Kimura, Kjellberg, Lu, 1993]. Given the trend towards so-called "service level agreements", it becomes convenient to include also services around the product, when using the term product. Though we recognise that pure services (like insurance, banking) also provide products that may need data and knowledge management, we leave these "non-physical" products out, since they are beyond the scope of this paper.

Product data can be devided in general into "content" data and "administrative" data. Product content data comprises all data needed to support and execute the various phases of the life cycle of a product (e.g. design, manufacture, assemble, sell, distribute, install, operate, maintain, take back). Product content data are needed to realise, to operate, to maintain etc. a certain product. Examples of such data are: requirements, design specifications, construction details engineering notes, analysis reports, process specifications, maintenance specs, process reports, status data, etc. Administrative data are for instance the order data as clustered under MRP-type data (product-id, quantity, time, resource, when, where, by whom, by what). Also data for planning and controlling the engineering process is considered as administrative data. Administrative data are needed to organise the realisation, the operation, to maintenance etc. of a certain product. Administrative data are status data on both the product and the process to be used by management to control the progress of a project or the operations. This document focuses on content data.

Product Data Management: Product Data Management (PDM) is an activity of making product (content) data available and accessible to all parties involved in the product life cycle and to support and enhance all business processes that create or use product data.

Knowledge: What is the difference between data, information and knowledge?

- Data are symbols referring to facts;
- Information is data that reduces the uncertainty for the user with respect to some decision;
- Knowledge is data that:

  - enables someone to perform a task by the context dependent selection, interpretation and valuation of data;

  - takes time to learn (internalise and train) before it can be used effectively;

  - can be documented for dissemination.

Like with information, the difference between data and knowledge depends on the situation of the receiver. What matters for us is what makes the difference with respect to the management of data versus that of knowledge. An important difference is that it takes TIME to acquire, to document and to learn knowledge, while data can be observed, registered, looked up, used and forgotten again without considerable time. Time is not relevant in managing data, it is in managing knowledge.

Product knowledge: Product knowledge is all product data that has to be internalised before it can be applied, that can be applied repeatedly, that is applied to perform some life cycle support task.

Product Knowledge Management: PKM is the discipline of making, by technological and organisational means, product knowledge available, accessible to and applicable by all relevant parties involved in the product life cycle and of supporting and enhancing all business processes that create or use product data. PKM is also concerned with knowledge acquisition, recording, learning and unlearning (forgetting/modification). PKM needs process data for enhancing the business processes that use product data and knowledge.

Data and knowledge carrier: since data and knowledge have to be captured in and transported from one user to another via a certain medium. Data and knowledge can be implemented in one of the following carriers (according to [Kerssens-van Drongelen, et al.; 1996]):

- Brainware, actually people’s heads;
- Paperware, such as text and paper drawings;
- Physiware, such as prototypes;
- Digiware, such as electronic files, databases, and knowledge bases.

Data and knowledge can be structured in, for example, documents, which can be implemented in either paperware or digiware. Virtual prototypes of products are examples of digiware, while a wooden mock-up is an example of physiware. (Within this paper we will focus on digiware, while especially brainware is out of focus.)

2.2 Scope of PDKM

Figure 1 clarifies the scope of our working group. The diagram has been drawn by combining and adapting existing approaches such as the „Knowledge Spiral“ of Nonaka [Nonaka, Takeuchi, 1995] and the activity layers concept in production management [Goossenaerts, 1997], [Inagaki, 1993].

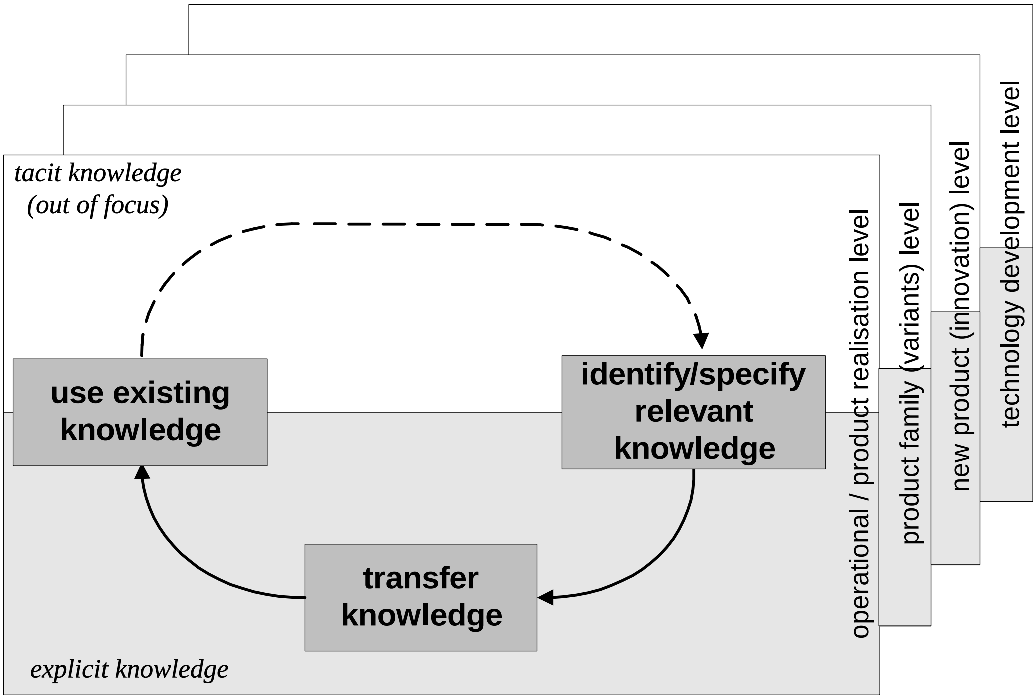

Figure 1. Defining the scope of product data and knowledge management (PDKM)

According to Nonaka knowledge creation is a continuous and dynamic interaction between tacit and explicit knowledge. This interaction is shaped by shifts between different modes of knowledge conversion: from "socialisation" to "externalisation", to "combination", to "internalisation" and again to socialisation and so on [Nonaka, Takeuchi, 1995]. As the range of knowledge is increasing with each turn this process can be better described by a spiral rather than by a cycle. The diagram shows that the scope of Knowledge Management goes beyond the management of articulated or so-called "explicit" knowledge. Explicit knowledge is knowledge that can be laid down (documented) in various types of representations and can be transformed, elaborated, learned, etc. from these representations. The upper (white) part of the boxes in Figure 1, including processes such as problem solving, sharing experiences and thereby creating tacit knowledge (e.g. shared mental models and technical skills), is beyond the scope of our work. Although this paper is focusing on the management of explicit knowledge about products we believe that both, the management of explicit knowledge as well as the management of tacit (implicit) knowledge are closely linked with each other and have to be considered at the same time. Accordingly, we think that compared to PDM, for PDKM the understanding of whole processes within an organisation becomes more important.

Applying the activity layers concept to product data and knowledge we can differentiate four knowledge cycle levels (or spirals).

Operational (product realisation) level: Improve or adapt the existing product and process. Focus is the engineering change process. Relatively short cycle times, within a product creation/realisation project.

Product family (variants) level: This cycle is focused on the development and production of „variant“ products: e.g. other members of the same product family, or newly styled products, based on existing technology. The cycle time is extended: the lessons learned for the first product are applied to the „variant“ product.

New product (innovation) level: Development of new products, based on new technologies and/or intended for a new market. In the „Make knowledge explicit“ stage the implicit way of working is translated into a new „theory“ instead of new product descriptions. The cycle time is relatively large; it spans a product generation.

Technology development level: This level concerns the „research and predevelopment“ activities of the "new product" blue cycle. (this cycle could be seen as part of the blue cycle).

In each knowledge cycle layer, knowledge goes through a number of phases. From our point of view we distinguish 3 relevant phases dealing with the management of product data and knowledge:

Identify / specify relevant knowledge: The secrets of the specialist are analysed and put into representations like concepts, words, etc. The achievements of the implicit way of working is translated into an explicit description or theory that can be communicated (Tacit knowledge is being made explicit).

Transfer knowledge: Make explicit knowledge the property of the organisation (as a whole, or the relevant part). Results in design manuals, workbooks, operational procedures, and trained people. This can be seen as a process of standardisation, in which one goes from an explicit theory to explicit method, representation, etc.

Use existing Knowledge: Make best use of knowledge that is available within an organisation. Available knowledge has to be identified, evaluated and (re-)used to optimally support a certain activity.

The current PDM scope covers the „**product realisation**“, „**product family**“, and „**new product**“ cycles, with the knowledge management role of PDM translated in the reuse of existing data. The distinction between PDM and PKM is concerned with the way the data and knowledge are managed. Thus it can be compared with data management versus information management. Whereas data management is only concerned with storing, retrieving and protecting data after is has been entered, information management is concerned with what data should be managed and for which business functions/processes.

Extending this line, Knowledge Management is concerned with where and when certain knowledge and skills are needed, and structuring, planning and supporting the processes that created and diffuse the knowledge. Knowledge management can be seen as the capturing of knowledge during the product creation process (in Philips, the product creation process means the combined product, process and market development process) and the use of it in downstream processes (manufacturing, service, etc.). In this sense, we are talking about knowledge management within the „**product realisation**“, and „**product family**“ cycles. In this view, the ingredients for extending PDM to PDKM are to capture the design intent [Jong, 1986] and to reuse existing data [Wognum, 1997]. Other future PDKM challenges are within the „**new product**“ and **„Technology development“** cycles: the extension from PDM to PDKM implies a shift towards other product life cycle stages.

3 Requirements for PDKM Systems from an organisational point of view

This section focuses on requirements for the software systems that would allow and improve PDKM in companies. We describe the requirements for PDKM systems from an organisational perspective. The description is being structured according to the several levels in an organisation dealing with product data and knowledge management. These levels are:

- Individual
- Group/project
- Organisation
- Network (Virtual Enterprise)

The presentation of requirements is organised in accordance with the scope described in section 2. The knowledge cycle of figure 1 is redrawn in figure 2 in order to consider the organisational levels in the three phases of identifying, transferring, and using knowledge. A detailed classification of the requirements according to the four knowledge cycle levels is omitted as it requires further elaboration. Accordingly the list of needs and trends are only illustrative, they are far from exhaustive. The aim is to further expand these lists to form a basis for developing a coherent understanding of the field of PDKM and the contributions from information and communication technologies to the field.

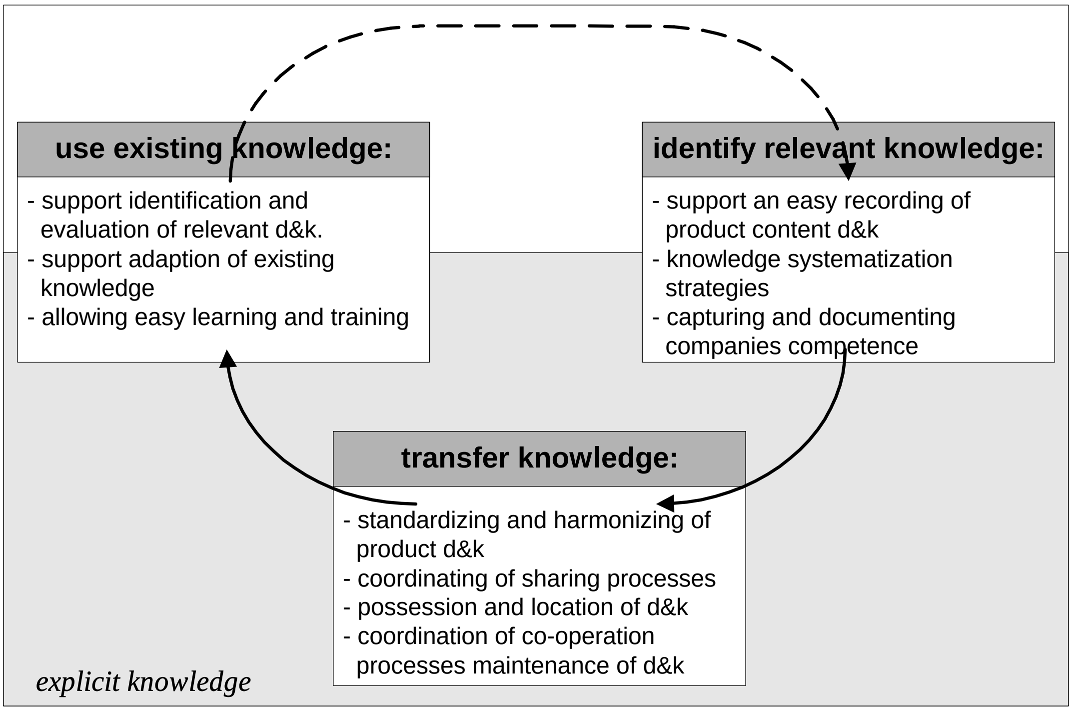

Figure 2. System requirements for improving PDKM in companies

In the following we explain shortly requirement that are itemised in figure 2 starting from the requirements for being able to use knowledge, proceeding to the needs to identify relevant knowledge and finally reaching the needed conditions for transferring knowledge.

3.1 Use of existing knowledge

Individual: Employees need skills and training for understanding the product and process data and knowledge; Computer systems must support e.g. product design or manufacturing planning instead of just allowing documentation.

Group/project: Computer systems (CAD, CAPP, PM) must be integrated to allow sharing of data and knowledge. Means are needed to manage co-operation when product and process knowledge is maintained in separate systems.

Organisation: Document management systems must be built to allow maintenance and reuse instead of just for liability reasons. Access is needed to the product related knowledge scattered into a wide variety of computer systems.

Network (Virtual Enterprise): Company specific systems have to be integrated. Network wide available data and knowledge have to be made accessible for potential users. Property aspects as well as reliability aspects of data and knowledge have to be considered. Human aspects related to the reuse of data and knowledge (such as the "Not invented here" syndrome, the insufficient trust in the quality of data and knowledge produced by others) have to be overcome.

From a systems point of view *presentation and access* services of PDKM systems will play a dominant role in assuring the use of existing knowledge.

3.2 Identify relevant knowledge

Individual: Employees need motivation and means for easy recording of the product and process knowledge and even failed experiments. Tracing capabilities are needed to locate right information.

Group/project: Semantic connection between e.g. CAD and PDM systems is needed. Process and project management systems require a connection to product data management systems.

Organisation: Knowledge systematisation is needed to make the company less vulnerable when people change jobs. A company's competence of products, processes and projects must be captured.

Network (Virtual Enterprise): At this level partner recognition and trust between partners play an important role. Accordingly knowledge of the partners competencies is important.

From a systems point of view *awareness and availability* services have to be considered while developing PDKM systems.

3.3 Transfer Knowledge

Individual: During the product processes it is necessary to access product data or knowledge that is in the possession of another person or at another location. Attitude problems in sharing e.g. product design data and knowledge must be handled.

Group/project: Private document systems must be developed to not prohibit sharing product data and knowledge through the life-cycle. Distributed and multidiscipline groups have difficulties in collecting the members into meetings.

Organisation: Accounting and reward systems must favour sharing of knowledge across company. Communication and co-operation of distributed departments must be co-ordinated through product processes.

Network (Virtual Enterprise): Cultural and legal as well language differences have to be overcome to be able to distribute and share knowledge.)

These requirements are related to *distribution and heterogeneity.*

4 Requirements for PDKM infrastructure

This section focuses on requirements for the software tools that would allow and improve PDKM. According to the three phases of the knowledge cycle discussed above, specific "services" (in terms of functionality's) have to be provided by PDKM systems.

4.1 Presentation and access services

Product data and knowledge must be maintained for decades. The problem of ageing systems plays an important role Access and management of semantics is needed for the product and process knowledge in truly distributed inhomogeneous computer systems. The presentation of virtual product and process models of complex multidisciplinary products increases the representation and computation requirements of product and process models.

4.2 Awareness and availability services

Means for detecting eliminating unnecessary data and knowledge are necessary as the amounts grow huge. Facilities for communication, co-ordination, and control of the flow of knowledge. The awareness of data and knowledge has to reach beyond company borders to cover e.g. environmental and other ethical issues stated by legislation, taxation, and public opinion.

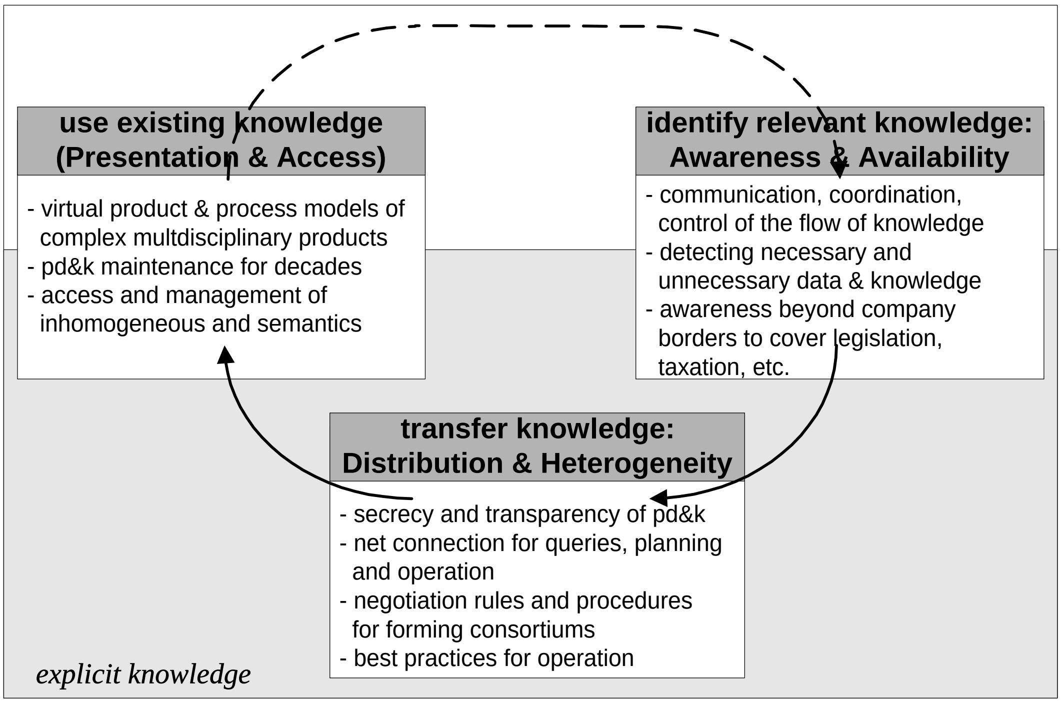

Figure 3. PD&KM system and infrastructure requirements of an extended / virtual enterprise

4.3 Distribution and heterogeneity

The security and transparency of product knowledge to e.g. authorities, customers, and sub-contractors must be controlled. A net must connect the various companies in order to allow queries, planning, and operation. Negotiation rules and procedures as for forming the consortiums and business practices for the operation must be formalised.

The security transparency of product knowledge, for instance, to authorities, customers, and sub-contractors, has to be controlled. Participants in the collaboration have to be loosely or tightly coupled in order to allow querying, planning and operating in a collaborative manner [Ranta et. al, 1999]. Negotiation in form of brokering or mediation has to be specified formally, which allows the consortium to operate according to their commonly agreed, as well as individual business practices [Büchner et. al., 1999].

5 Further Work

We intend to refine the research questions presented above in the coming year. Therefore we will analyse the potential of the current information technology trends (software tools, infrastructure, etc.) to cope with the requirements on supporting the various phases of the knowledge cycles (Figure 1). The result of our working group efforts will be an inventory of interesting research topics. It is expected that research on those topics will lead to solutions to existing problems as well as to new technologies to be used by future industrial companies. We will present our results in a book as well as a number of more specific research papers.

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