Product related Data and Knowledge Management in the intelligent enterprise

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Abstract

Within the Esprit Working Group 21108, Integration in Manufacturing and Beyond, our subgroup is concerned with the management of product data and knowledge in the extended enterprise and the learning organization. Our focus is on concepts and approaches and methods for creation, capture, maintenance, management, and use of knowledge about products and manufacturing processes in the extended enterprise and the learning organization. Eventually, our work will deliver an inventory of research directions and topics that has been validated by both industrial practitioners and R&D experts. This working paper reports on our current understanding of the problems of product data and knowledge management. It is a means for engaging in a "roundtable" discussion with industrial practitioners and R&D experts.

1. INTRODUCTION

Within the IIMB working group (EP 21108, Integration in Manufacturing and Beyond), sub-group 4 is concerned with the management of product data and knowledge within all the processes (product and process design, manufacturing and assembly, materials planning and control, order entry and scheduling, maintenance, recycling, ...) of the extended enterprise.

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. The emerging requirement to support product takeback at end of life and resource recovery must also be addressed.

Just as product development requires the management of product data, learning requires the management of knowledge. We see a shift from PDM (Product Data Management) to PDKM (Product Data and Knowledge Management). The explicit deployment of learning can be found in the organised reuse of knowledge and experience in, for example, design and production planning. Product and process data can be viewed as knowledge needed for production. From that point of view the move from product Data management to product Knowledge management is only gradual.

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 organization.

2. DEFINITION AND SCOPE

Definitions

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.

- **Product:** *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*[1].
  Given the trend towards so-called "service level agreements", it becomes convenient to include also services around the product, when using the term product. This definition requires that a product is a "materialised" object. Though we recognise that pure services (like insurance, banking) also provide products that may need data and knowledge management, we leave these immaterial products out, since they are beyond the scope of this paper.
- **Product data:** we make a difference between content data and administrative data. Product content data comprises all data needed to execute all product life cycle phases (design, manufacture, assemble, sell, distribute, install, operate, maintain, take back). 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.

Product data can be distinguished from process data. Process 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 focusses on content data. Administrative data is left out of the scope.

- **Product Data Management:** Product Data Management (PDM) is the discipline of making product 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 (adapted from [2]):
  - § 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.

Scope of PDKM

The diagram in figure 1 clarifies the scope of our working group. The diagram has been drawn by combining Nonaka's idea of the "Spiral of Knowledge" [3] with the activity layers in production management [4,5]. The diagram shows that the scope of Knowledge Management goes beyond the management of explicit or articulated knowledge. Explicit knowledge is laid down in representations and can be learned from these representations. PDKM in the context of IiMB/SG4 focusses on the management of explicit knowledge. The upper part of the diagram seems to be beyond the scope of IiMB/SG4.

The cycle or spiral of knowledge is decomposed into four knowledge cycle layers which have been given colours and numbers for ease of reference:

- **Red/1:** Improve the existing product and process. Focus is the engineering change process. Relatively short cycle times, within a product creation/realisation project.
- **Green/2:** The green cycle is focussed 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.
- **Blue/3:** 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.
- **Black/4:** Technology development cycle. It concerns the “research and predevelopment” activities of the blue cycle. (this cycle could be seen as part of the blue cycle).

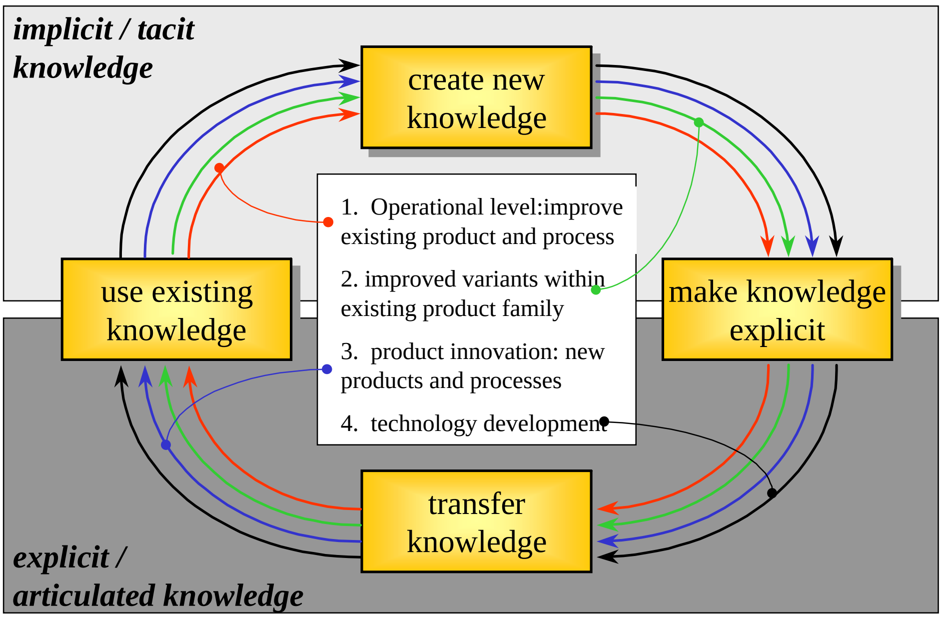

Figure 1. The scope of product knowledge management.

In each knowledge cycle layer, knowledge goes through a number of phases:

- *Make knowledge explicit*: The secrets of the specialist are analysed and put into words. The implicit way of working is translated into an explicit description or theory that can be communicated.

- *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 (knowledge is only transferred after it has been learned by new people). This is a process of *standardisation*, in which one goes from an explicit theory to explicit methods.
- *Create new knowledge:* New knowledge is created when design problems are solved.

Current PDM scope covers the "green/2", "red/1", and "blue/3" 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. Compare with Data management versus Information Management. The first 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. Information Management is concerned with the question where uncertainty can be reduced.

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 on the "green" and "red" cycles. In this view, the ingredients for extending PDM to PDKM are: *a)* Capture of design intent; and *b)* Reuse of existing data.

Other future PDKM challenges are at the "blue/3" and "black/4" cycles: the extension from PDM to PDKM implies a shift towards other product life cycle stages. Also the management of the "knowledge sources", internal as well as external sources (extended enterprise), is becoming an important issue.

3. CURRENT SITUATION REGARDING PDKM

In this section, we describe the situation encountered in current organizations with respect to product data and knowledge management, as well as currently available solutions. The description of the current situation will be structured according to the several levels in an organization dealing with product data and knowledge management. These levels are:

- Individual
- Group/project
- Organization
- Network

We base our discussion on the definitions of data, knowledge, and data and knowledge *carrier* as presented in the second section.

The problems presented in this section are largely taken from several case studies that have been performed by Master Students of the University of Twente. An extensive description of how these case studies have been performed and the findings thereof are described in a Working Paper [6].

Individual

At the individual level, product data involve data on the specific product to be produced in the project at hand, as well as data on the characteristics and requirements of downstream processes that will act on the product. Process data are data on the status of the current process for usage by management to manage and control the project. Process data typically are passed to management during project meetings or through project reports.

Knowledge is needed to be able to use and generate product data. We can distinguish several types of knowledge [7]:

- *Knowledge of problem situations:* this is knowledge of problems that can be anticipated when performing specific tasks;
- *Declarative knowledge:* this is knowledge of (technical) facts and principles accepted as true by a (technical) discipline, as can be found in text books but also in documents describing findings from previous projects;
- *Procedural knowledge:* this is knowledge about actions, manipulations, etc. which, according to the doctrines of a (technical) discipline, can/should be applied on declarative knowledge and data in order to perform a certain task;
- *Strategic knowledge:* this is knowledge about the total set of actions, manipulations, etc., which can be anticipated as necessary to reach the defined goal.

Problems that can be mentioned at this level are:

1. People do not always have the right knowledge and skills and need additional training for which a policy must exist;
2. Knowledge needed for executing the task is not always readily available, because:
   - it is not known to a person who else has this knowledge;
   - it is not known to a person where it can be found;
   - commitment to share knowledge with or use knowledge from other persons is missing;
   - the particular resources (people and means) are not available (for example, tools to support versioning or dimensioning);
   - it may cost too much time or money to get the knowledge and skills needed;
3. Knowledge and experience relevant for future use is not always explicitly made available. This may be improved by means of both organizational and technological solutions, such as project evaluations or explicit product models;
4. Knowledge of the particular contribution of the task to the project is not always known very well. Consequently the customer needs with respect to the data or knowledge to be provided by upstream or to downstream people and systems are not always known.

Group/Project

On the group/project level, we consider that data and knowledge must be shared among members of a particular group, for example, a (multi-disciplinary) team or a task group.

The data are the same as mentioned at the people level. An important aspect to be mentioned is that (part of) the data must be sharable among group members. The same holds for knowledge to be used at this level. Some knowledge may remain private to each team member, but there are parts that need to be shared among two or more members of the group. Sharing knowledge is needed, for example, because arguments in terms of underlying knowledge must be given for particular decisions or decisions have to be made in collaboration. For good collaboration, knowledge of the shared rules and norms is needed in a group. This type of knowledge is, however, outside our scope.

Data and knowledge can be shared in several ways and with several means. Sharing of data and knowledge can be performed either synchronously or asynchronously using the carriers mentioned above. Possible means are:

- Meetings/reviews;
- Presentations;
- Project documents;
- Product models;
- Process models.

The problems on this level include those mentioned on the individual level, but in addition the following problems could be mentioned as well:

1. Project managers have insufficient authority to force people to attend project meetings, which limits the exchange of data and knowledge;
2. Document systems are often private and not easily available to others;
3. Company document systems have not been designed for reuse, but only for liability reasons;
4. People are not committed to share their knowledge with others. This problem may be intensified by an inappropriate accounting and reward system used by the organization.
5. People are not committed to use knowledge from others (not-invented-here-syndrome). Again, inappropriate accounting and reward systems can intensify this problem;
6. Data cannot easily be shared, because computer systems are not integrated;
7. Since CAD systems are often still used as electronic drawing boards, the data cannot easily be used in other systems, for example, to generate a bill of materials.
8. Misunderstandings between representatives from different functions/disciplines within the team, created by different frames of reference, different cultures, etc. in combination with multi-interpretable means of knowledge transfer (data-models, presentations, projects documents, etc.)

Organization

At this level, we consider the organizational knowledge base, which has to be shared across groups and time. Data and knowledge used at this level are similar to those mentioned above. Additional data needed on this level may concern current technological developments, market/customer data, or data about competition for use in strategic decision making. To be able to use these data, strategic knowledge is needed.

Process data on this level consist of performance data of organizational parts (e.g., performance of projects, performance of functions) to be used by management to adapt or improve the organization.

The data and knowledge relevant to this level cross the departmental borders. Shared product and process models are examples of knowledge which must be available on this level.

Problems at this level include those mentioned on the group/project level, but in addition the following problems could be mentioned as well: different point of views, stemming from a different use of the knowledge in various situations; and limited or lacking interoperability of systems.

Network

Data and knowledge to be shared at this level include data and knowledge of the above mentioned levels. The problems identified at this level are, besides those already mentioned above, differences in culture, language, reference models, legal arrangements, interoperability, and standards.

At the network level, all issues raised at the previous levels remain to be considered. A new aspect is added due to the distribution of people over several locations and over different time zones. This aspect is not only added when a number of different organizations cooperate to achieve some task, but may also be added when several departments of one organization are distributed over different locations. The distribution aspect, hence, affects both the group/project level and the organization level.

Current solutions

Current organizational solutions: quality function deployment; project and product evaluations; lunch meetings; teams; co-location; job rotation; education; resource management; project management; total quality management; reward systems; technology transfer points; etc.

Current technological solutions: Intelligent CAD systems; dedicated (knowledge-based) design systems; Internet as a search and browsing tool; full-text retrieval systems; document management systems; who knows what databases; product data management systems (limited).

4. VISION ON PDKM IN THE INTELLIGENT INDUSTRY

Research and development directions and topics on PDKM should be related to a vision on the development trends of globally competitive industrial companies and networks. Below such a vision is given by focussing on three fundamental challenges of future industries: the development of agile extended enterprises, the product and process life cycle orientation, and the digitalization of the development process[8]. For answering each one of these challenges, information infrastructure enabled PDKM is seen to play a key role.

Challenges of future industries

Research on PDKM should be geared towards meeting three fundamental challenges in the development of industries:

Agile extended enterprises: Cooperative arrangements in which several smaller companies come together to provide complex, customer defined products offer a number of advantages. In this way competition may exist for each core competence, for each component, production step or service. Moreover, because their use is not restricted to the product or service range of the (large) main manufacturer, resources such as expensive machine tools or expertise can be deployed for a wider range of products or services. Obsolete technologies and processes, and excess capacities can easily be identified and eliminated , and the competence portfolio -- the range of different core competencies and technologies mastered by an industry -- can grow more quickly. Because of the increasing specialization of manufacturing industry (the usage and recycling of more materials, the increasing precision and tooling needs of production processes, the rise of micro-electronics, software, mechatronic and intelligent systems) the growth of the competence portfolio in an industry is an important measure of its progress.

Hence the company of the future will meet a growing pressure to exchange technical data with suppliers, customers and the public. There will be a need for efficient and effective communication and more explicit/articulated knowledge

Extended enterprises will be formed around new product families based on new technologies. The product, the production process, the marketing and distribution process will be developed in parallel with the extended enterprise and its supporting systems. All will have to be put into harmonious and effective operation at the same moment. This requires, besides strong modelling capabilities, conscious management of all the data and knowledge that is needed for design and operation of all processes. The ability to control the ‘flow of knowledge’ in time and space will be a critical success factor.

Product and process life cycles: The recent attention for the life cycles of products, services, processes and production resources originates from the increasing customer orientation, the waste problems, the prevention of technical accidents, and environmental pollution. An increasing number of parties, among whom are also customers and public authorities which issue regulations on safety, pollution and recycling, influence the life phases of products and need access to the related data. Engineers have to include the full product life cycle in the development process. In the future more and more goods will circulate between the domains of production and consumption. It is expected that the manufacturer will become responsible for his product in all life cycle phases (including take back of used products); that the public authorities will demand documentation for a life cycle assessment of products in all life cycle phases; that environmental management certification and eco-audit will be required; that general pollution limits will be lowered; and that tax systems will be based more and more on pollution emission and resource consumption.

Concurrent engineering for the full life cycle demands that explicit/articulated product and process knowledge are systematized in at least two dimensions, across engineering disciplines and throughout the life span of the deliverables of engineering and manufacturing processes.

The digitalization of the development process: Citing from the Final Report of the AIT Pilot Phase project: “The business process of the future will have two main phases. Firstly, a virtual phase, where the product, the manufacturing processes, and the manufacturing system will be designed and validated by means of computers and software. Secondly, the physical phase, where the actual realization of the product is achieved”. The virtual phase of the development process (not to be confused with the “virtual organisation”) requires very demanding computing, reasoning and communication with data, information and knowledge on products, their components, production and product processes, resources, and business processes. Creating and working with product and process data and knowledge requires a lot of time and expertise, and is also complicated by the need to simultaneously validate heterogeneous models that are typical for specific engineering disciplines (mechanics, electronics, material science, production engineering, business economics). Moreover, different models are used during the successive phases of the development process. Ideally, models should be exchangeable, it should be easy to reuse them, and to perform joint analyses and validations, as, for instance, in a so-called digital mock-up. Harmonization should be performed across the boundaries of the different engineering disciplines and life phases of products and production resources. Product configuration for products with many variants is one of the functions that should be supported by PDKM platforms.

PDKM platforms should enable the digital development process as the core of the innovation processes in virtual and extended enterprises, while offering also functions to track intellectual property rights, to ensure data security and perform economic justifications.

Information Infrastructure-enabled PDKM

In the future, a PDKM platform will not only have to support the individual company, it will rather have to support the extended enterprise and the virtual company, in their involvement in whole product life cycles. The vision of an information infrastructure of which the PDKM functions of individual companies will form an integral part, emerges. From an information infrastructure we expect that it provides access to all information which is relevant and useful in a given situation, for any authorized user, during any life phase of a product, at any moment and at any place. On the one hand an information infrastructure should hide various application systems and the information and communications technology infrastructure, on the other hand it should offer primitives enabling individuals, groups, organizations and networks, to rapidly activate relevant information and applications supporting them in taking decisions and performing activities.

This information will be distributed in space and time. In the situation in which the information is produced it is neither predictable when, where, by whom, and for which purpose the information will be used later on, nor where it will be stored in the future. The ownership of access-rights may change, as the ownership of goods. Assembly information and part lists that have been defined during the development phase of a car must be accessible up to ten or more years after the production of a car, to support its disassembly. And the life-cycle models of the parts must be available for ensuring their proper processing.

The life-cycle orientation urges us to provide harmonized and stable solutions for the provision of product-related information to companies, public authorities and citizens. An operational information infrastructure should keep globally available all potentially relevant data, in accordance with the prevailing access-rights. In principle, each family of products may give rise to a class of services to cover the whole life cycle of the family and its occurrences: need evaluation, design and development, production and packaging, transportation, usage, maintenance, re-manufacturing, recycling and disposal.

Also the virtual development process relies heavily on an information infrastructure, for instance for exchanging specifications and digital mock-ups between sub-system suppliers and automotive or aerospace companies. We are still lacking modelling agreements which would enable us to join the partial models that originate from different engineering disciplines. Such agreements are required for an efficient and effective virtual phase of the development process.

An information infrastructure should ensure that models are exchangeable, easy to reuse, and allow joint analyses and validations. The vision of achieving an information infrastructure emphasizes the need for a principle-based harmonization across the boundaries of the different engineering disciplines and life phases of products and production resources.

Other needs concern the property rights on digital mock-ups. These should be recognizeable and enforceable to avoid situations where digital mock-ups of components would be used unproperly after employing them for analysis in the digital mock-up of a larger system.

5. INFORMATION TECHNOLOGY AND PDKM

This chapter discusses three topics:

1. the requirements for PDKM systems for companies on the basis of the organizational levels described in chapter 3;
2. the requirements for a PDKM infrastructure for agile extended enterprise, on the basis of the envisioned development trends in industry as described in chapter 4;
3. the classification of current information technology trends that are likely to contribute to meeting the three key challenges listed in chapter 4.

The presentation of requirements is organized 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 organizational levels in the three phases of making explicit, transferring, and using knowledge. Since our group focuses on the lower part of the knowledge cycle picture the knowledge creation is not discussed separately here. Furthermore, detailed classification of the requirements according to the four knowledge cycle levels is omitted as it requires further elaboration. At this stage in our work 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.

5.1 Requirements for PDKM Systems

This section focuses on requirements for the sofware systems that would allow and improve PDKM in companies. In the following we explain shortly the requirement lists that are itemized in figure 2 starting from the requirements for being able to use knowledge, proceeding to the needs to make knowledge explicit and finally reaching the needed conditions for transferring knowledge.

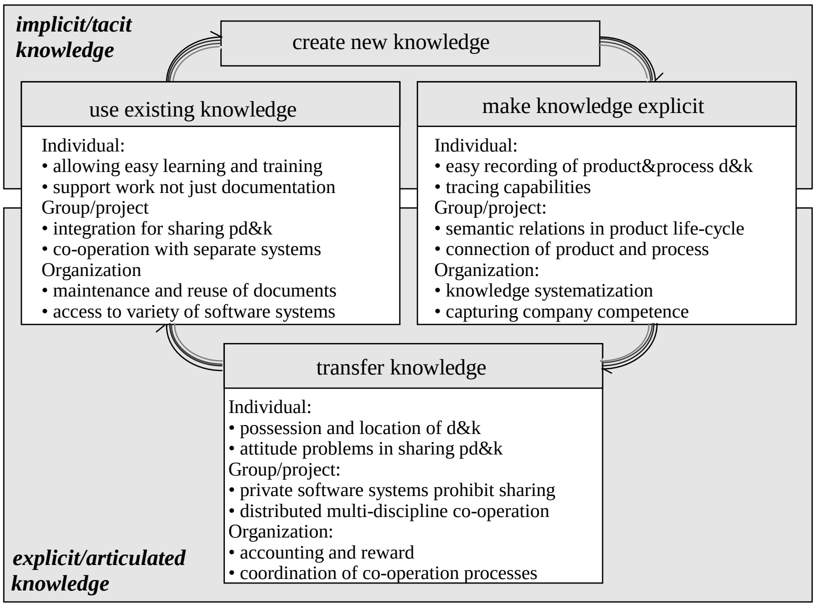

Figure 2. Requirements for PDKM systems.

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.

Organization: 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.

These requirements will have an impact on *presentation and access* services.

Make knowledge explicit

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

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

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

These requirements are related to *awareness and availability*.

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.

Organization: Accounting and reward systems must favour sharing of knowledge accross company. Communication and co-operation of distributed departments must be coordinated through product processes.

These requirements are related to *distribution and heterogeneity*.

5.2 Requirements for PDKM infrastructure

This section focuses on requirements for the sofware tools that would allow and improve PDKM in agile extended enterprises.

Presentation and access

Product data and knowledge must be maintained for decades. 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.

Awareness and availability

Means for detecting eliminating unnecessary data and knowledge are necessary as the amounts grow huge. Facilities for communication, coordination, 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.

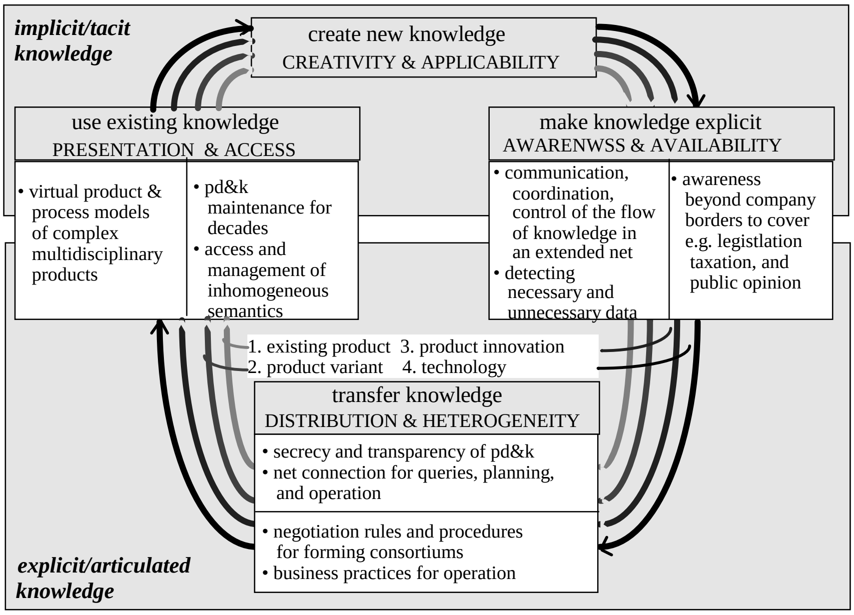

Figure 3. PD&KM infrastructure requirements of an agile extended enterprise.

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 formalized.

5.3 Information Technology Trends

Figure 4 gives an initial classification of current information technology trends grouped according to the phases through which knowledge goes (Figure 1) and the three key challenges listed in chapter 4.

challenges / phases	AGILE EXTENDED ENTERPRISE	DIGITALIZATION OF DEVELOPMENT PROCESS	PRODUCT&PROCESS LIFE-CYCLES
PRESENTATION& ACCESS	data mining [9]	heterogeneous engineering models	product and process life-cycle models
AWARENESS& AVAILABILITY	capturing competence	product realization	ontologies, semantics
DISTRIBUTION& HETEROGENEITY	practices, etiquette	distribution	flow of knowledge

Figure 4. Information technology trends.

6. FURTHER WORK

We intend to refine the research questions presented above in the coming year. 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. We will have our ideas validated by a review board of industrial practitioners with experience in working in extended and virtual organizations.

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