

PRIME

A Knowledge Management approach for the Extended Enterprise

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Die Notwendigkeit für eine leistungsfähige Zusammenarbeit im Rahmen eines Erweiterten Unternehmens (Extended Enterprise), die nicht nur auf einen Hersteller beschränkt ist, sondern auch in den Produkt-Lebenszyklus involvierte Unternehmen und Einzelpersonen mit einbezieht, bedingt eine wesentliche Lösung des Problems der Aufnahme und Zuteilung von Produktwissen. Dieser Artikel beschreibt einen Lösungsansatz für ein „praktikables Produkt-Wissensmanagement für das Erweiterte Unternehmen, unter Beachtung industrieller Anforderungen und dem Begegnen der Akzeptanz aller am Produkt-Lebenszyklus beteiligten Personen“ auf Basis der PRIME Arbeitsbeschreibung.

The need for an efficient collaboration within the Extended Enterprise that is not limited only to the manufacturer but also comprises all companies and individuals involved all along the product life cycle leads to significant demands of resolving the problems of product knowledge capturing and sharing. This article describes an approach to the desired “practicable product knowledge management solution for the Extended Enterprise, which satisfies industrial requirements and meets acceptability of all persons involved in the life cycle of a product” based on the PRIME workbook.

1 Introduction

Knowledge management is based on knowledge. It is important to differentiate between knowledge, information, and data. A general classification of these terms can be typified: Data becomes information when it is organised, information becomes knowledge when it is placed in actionable context. Regarding knowledge, the grouping into the subclasses explicit knowledge and tacit knowledge should be taken into account. In broadest terms, that classifies the knowledge that can be written down (explicit) and the knowledge that cannot (tacit). Explicit knowledge can be processed by IT systems, codified, recorded, archived and protected by the organisation. Tacit knowledge exists in people's heads. Tacit knowledge is extremely difficult to transfer, explicit easier.

The European research project PRIME – Product Integrated Knowledge Management for the Extended Enterprise (Growth - GRD1-2001-40408) /1/ intends to provide “a practicable product knowledge management solution for the Extended Enterprise, which satisfies industrial requirements and meets acceptability of all persons involved in the product life cycle”. The main objective of PRIME is to focus on product related knowledge existing within the Extended Enterprise (EE), which can be used or applied during the complete product life cycle (PLC) from planning over product development to maintenance and disposal. Product knowledge is the core of an enterprise, as it is used for their actual activities and developments. Such knowledge enables a company to be able to realise product or process innovations or further developments in a limited timeframe with an assured quality. In times where innovation is recognised as a central focus for value-creation, and where the innovation cycles are becoming shorter, time becomes a determining factor. And the development, manufacture and support for complex products is not restricted to only one manufacturer, and it is also vital for improvements to include the customer of a product with all his experiences and suggestions into these processes. In this context, it is indispensable for enterprises to ideally manage the knowledge within the EE. The aim is to make the product related knowledge generated throughout the PLC available as a common source of knowledge and enable it to be shared, reused etc. by all actors in the EE, e.g. suppliers, manufacturers, maintenance and service personal.

These requirements represent the defaults for the PRIME system. The objective is to find a practical solution for the capturing of such product related knowledge (both explicit and tacit), to structure captured information systematically according to the life cycle of the product and to make knowledge available and applicable to the users of the PRIME system to support efficiently their field of activity. The pre-defined PLC within the PRIME context includes six key phases common to the engineering products as a whole i.e. feasibility, concept, definition, development, production and support.

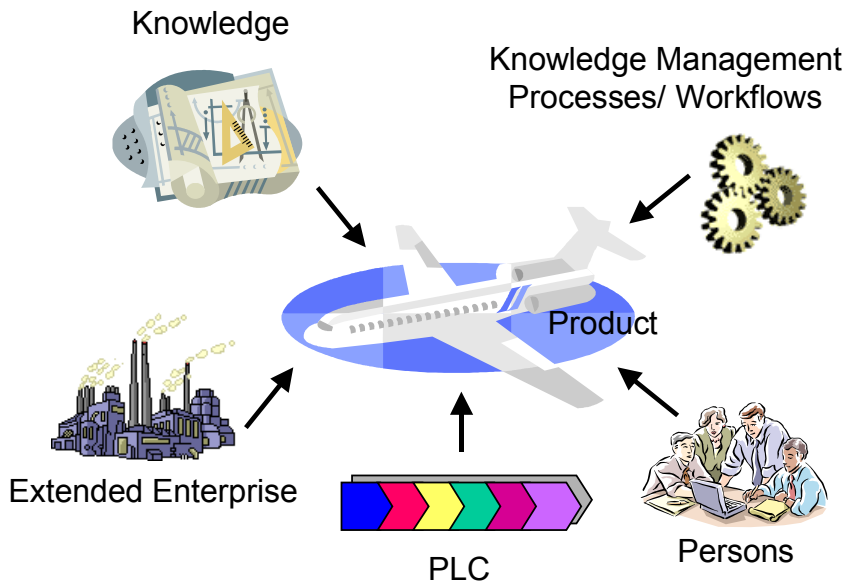


Figure 1: PRIME methodology components

2 PRIME methodology components

The PRIME methodology is not a development from scratch. It integrates successful approaches, techniques and methods to a new innovative approach for the networked enterprise. What makes PRIME different from existing knowledge management approaches and its competitors is the concept of taking into account and integrating the following aspects:

- Approach for the Extended Enterprise
- Support of the entire product life cycle
- To use knowledge not data
- New way of working in the knowledge management world
- Encourages co-operative working and virtual team building

In general, the PRIME methodology is based on the individual components Knowledge, Knowledge Management Processes/ Workflows, Product Life Cycle (PLC), Persons and the Extended Enterprise, which have all a significant impact on a product, as displayed in **Figure 1**. The interaction of these components to support the development of a product up to its maintenance and disposal within one interrelated concept is novel.

The key idea behind the EE concept is to develop means supporting the collection of all useful knowledge throughout the EE for new and existing process and product developments, and to develop this knowledge into a means of fostering industrial innovations. Innovation by combining the ideas and feedback from all parts of the product life cycle, including customer interaction with existing products and new product ideas and including maintenance or service engineers, including suppliers and including pooling of knowledge between multiple sites

(**Figure 2**). Innovation is a critical factor for the success of industrial companies.

The EE concept involves a lot of persons respectively actors not organised within only one enterprise. Therefore, the PRIME users are assigned to a general role model underlying to the methodology, that intends to fulfil the following goals:

- To combine the tasks of the Knowledge Managers and Experts for the optimisation and utilisation of the knowledge management processes.
- To build up small teams of Knowledge Managers and Experts who work closely with the business units or the product.
- To create a hierarchical, organisational knowledge management structure (responsibility, security, organisation).

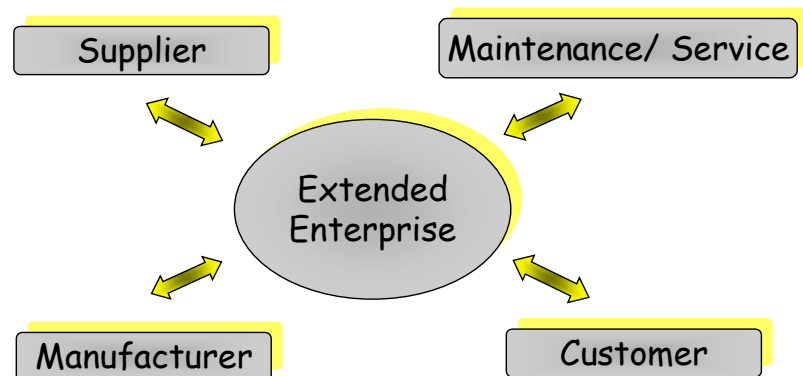


Figure 2: Structure of an Extended Enterprise

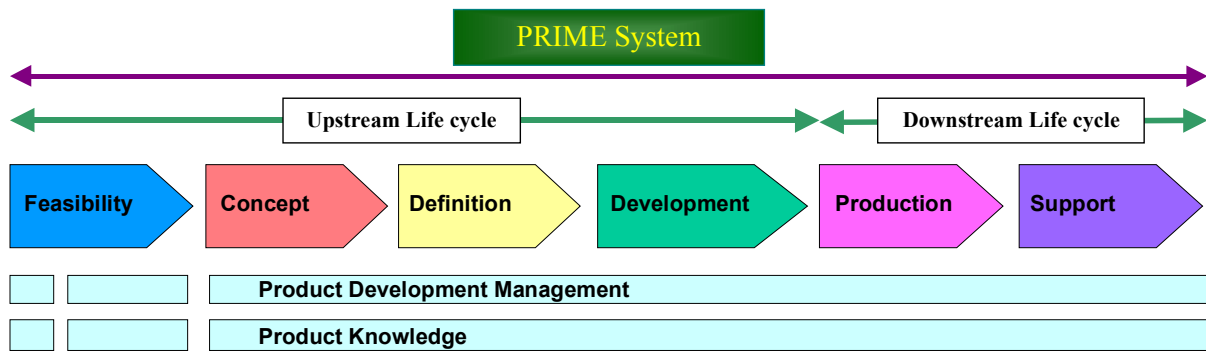


Figure 3: PRIME common product life cycle

The PRIME methodology is designed to cover the entire PLC. It is necessary to model business concepts throughout the whole PLC so that different work teams can act in a compatible and exchangeable way. The outcome of this is a common PLC (**Figure 3**). The common PLC defines six life cycle phases. These are classified in two separated life cycle stages: upstream and downstream life cycle.

The upstream life cycle contains the operational procedures:

- Requirement investigation,
- R&D, Planning, Detailed product design, and
- Production organisation: Production Process Planning (P³), Production Resource Planning.

Whereas the downstream life cycle comprises:

- Material acquisition, transport, inventory and supply;
- Production preparation: equipment, devices, machines, tools;
- Production: manufacturing, assembling, integration;
- Test, change, dispatch, stocking, installation;
- Service/ maintenance.

To integrate all these components and the product related knowledge effectively to the product development process, mature knowledge management processes organised and administered by knowledge management workflows are necessary. An appropriate approach has been developed within PRIME methodology. The following section will describe the important vertices in detail.

3 Knowledge Engineering Workflows

The PRIME system approach intends to represent a flexible framework mainly having the function of an information system, from which a community of actors belonging to the EE can extract information and will also be able to add new knowledge. Thereby, the system framework is characterised by flexibility and interaction. The framework is designed by three basic functionalities: *Knowledge extraction*, *Knowledge replenishment*, *System Administration*. **Figure 4** offers an overview of the functional workflow components of the proposed PRIME system.

As one main component, the System Administration represents the basic instrument to establish, organise and control a product knowledge related project. The administration defines the complexity, classification and allocation of a project in respect to the involvement of partners. Generally, a mature concept and administration of a product related project is very important for the successful accomplishment.

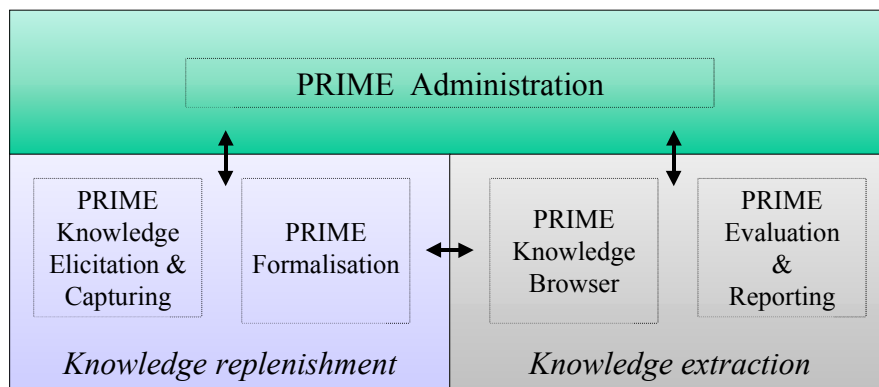


Figure 4: General workflow components covered by the PRIME system

The knowledge inside the PRIME system is not

static, but will be added and updated during the complete PLC. Therefore, the component Knowledge replenishment depicts a significant requirement of the overall system. This component includes two separate workflows: *Knowledge Elicitation & Capturing, Formalisation*. The Knowledge Elicitation & Capturing workflow covers the entry of knowledge in its original format (informal/ quasi-formal) to the PRIME system. The entered knowledge can be new, complementary or corrective. The opportunity to feed the system with knowledge is given within PRIME to the assigned actors of the EE, this means also that this covers the complete PLC. To support and improve the systematically processing and reuse of knowledge, the entered information has to be converted into an explicit, model-based representation. This task is covered by the Formalisation workflow. Depending on informal or quasi-formal knowledge, the formalisation procedure maps in detail the contained information components of the natural language based representation onto the related entities of an underlying information model.

The main power and benefit of a knowledge management system lies in the efficient (re-)use of the knowledge available within the system. For the Knowledge extraction, one can identify two separate workflow components: *Knowledge Browser, Evaluation & Reporting*. The browsing workflow describes the proceeding of the knowledge search, that is not only restricted to a simple free text search. It offers also the possibility to perform an advanced search to improve the quality of the results. Additionally, enhanced navigation, help and feedback features complete the basic functional range. The component Evaluation & Reporting covers the report generation based on the system internal knowledge and additional evaluation. Not only the pure information facts are important to the user, but to get also support from the system to gain knowledge, incorporating complete processes, structures, products etc. over the PLC. In the following, the single workflows will be described in detail.

3.1 System Administration

It is vital for the success of a project that its basic strategic, operational and conceptual orientation is precise, elaborate and feasible. Within PRIME, basic tasks are pretended that are necessary for the implementation of the system within the EE, including the assignment of roles. The overall workflow includes the components for the strategy

and concept design, the system design, the determination and the strategy update or enhancement. The administration tasks are only performed by the Knowledge Management Officer (KO) and the Knowledge Engineer (KE).

According to the guidelines of the PRIME system, the KO has to design the framework for the planned project, taking into account the schematic resources culture, infrastructure, purpose, and strategy. The global task of 'Strategy & concept design' in the knowledge and EE context includes the sub-tasks:

- Definition of the PLC
- Definition of the roles of actors
- Definition of KM methods to be executed by KEs
- Definition of the KM plan

By defining the framework, the KO generates a productive system. In the following, the KE takes over the design of the system. The sub-tasks that are related to the system design are:

- User and authentication management
- Definition of product knowledge classes
- Controlling user inputs
- Assisting users
- Instantiating internal information model to enable creating the knowledge repository

The system design is not restricted to one certain stage during the PLC. In contrast, the administration of a running product related project within the EE is a continuous procedure. It is necessary to update on changes (user, partner, software, security etc.) or bugs, to monitor and control the system maintenance, react on a change within the lifecycle, and to offer support to the users of the system. The instantiation of the internal information model of the PRIME system is one central aspect for the efficiency of the system, as this model represents the common basis for the knowledge tasks.

3.2 Knowledge Capturing & Elicitation

It is obvious that a product knowledge related system is only useful, when the system contains sufficient knowledge on the related area of expertise. An empty or obsolete system makes no sense. Therefore, it is very important that the system offers the facilities for the efficient and precise acquisition of knowledge. Which method will be applied is not limited by PRIME. In a broader sense, the acquisition of knowledge can be divided into the tasks Capturing and Elicitation.

To acquire expert knowledge, it is first of all necessary to identify the appropriate information and the sources for gaining relevant know-how. The knowledge sources can be external (documents, manuals, catalogues etc.) or internal (expertise, know-how). The type of the information is also not definite. Computer-accessible knowledge can be found from a formal, quasi-formal to a very informal format. The identification and entry of useful and necessary knowledge and its sources, including the valuing and filtering, will be performed by experts. Supported knowledge items are i.e. text, audio, video (informal) or CAx, generic model-based files (quasi-formal). The capturing of knowledge from outside that has been identified as useful and sufficiently valid should be accomplished carefully to not feed the system needlessly and to keep it concise. Beside the entries from the knowledge expert, there exist methods to elicit know-how through different techniques (i.e. interviewing). Which techniques will be applied can be selected independently. This task has to be performed by the KE. Also the organisation and management of the entered knowledge belongs to the KE. It is necessary to check the user inputs on consistency, quality, completeness and adaptability and group the information for later relieved knowledge retrieval. Sub-tasks that has to be carry out are i.e. distilling, refining, orienting, packaging and assembling.

The EE approach enables also users of the product (i.e. maintenance or operative staff) to incorporate product related knowledge. They can enter feedback on their experiences with the product and its installation/ operation. These information are intended to support and improve the re-design of similar products. Also the expert will add, improve or correct his knowledge of the product and its related processes based on his personal development process by experience and learning. Especially here it is important to control, group and allocate the information in respect to the related product.

3.3 Formalisation

The knowledge that has been captured and organised will be in a model or language dependent representation. Such formats are often tool dependent and will not be interpreted in the same way by different users/ experts. To enable the independent processing of the acquired knowledge, and to achieve an explicit, unambiguous, common interpretation/ understanding of the information, it is necessary to formalise the knowledge. The For-

malisation of explicit or tacit knowledge follows two main objectives:

- Transformation of natural language based knowledge into an explicit description
- Extraction of implicit knowledge

The formalisation analyses the single conceptual components of language, as there are i.e. functions, properties, behaviour, physical and system architecture. The identified components will be mapped onto the relevant instances of the underlying information model, based on the "ISO/WD PAS 20542 Industrial automation systems and integration – Product data representation and exchange: Systems engineering data representation" standard. Such a neutral representation permits a systematic processing, and the integration of a standard enables a possible greater compatibility with other tools. This finally offers the possibility for the adoption of PRIME in a larger domain.

To avoid extra effort and ambiguity, first the KE has to analyse the existing knowledge on possible reuse. Double entries must be avoided to keep the repository consistent and explicit. Identified new, additional or corrective knowledge has to be processed by the KE. Starting from a natural language based representation, the formalisation leads to a rigorous formalised information model representation. The result can be checked on consistency to ensure to have a qualitative, high-value knowledge repository. The formalisation procedure of quasi-formal knowledge is restricted to the incorporation of the respective files including a software reference. Audio-/video information as informal knowledge will be handled similar. As "self-descriptive" knowledge, the respective files will be just incorporated and referenced.

3.4 Knowledge Browser

A knowledge based system makes only sense, when the system offers mature facilities for the extraction or (re-)use of the contained knowledge. It is absolute necessary to find and access that knowledge that is required and requested. The PRIME Knowledge Browser is designed to support the user and not complicate work.

The browser supports two ways of searching. The free text search belongs to the simplest way of searching, but delivers just direct connections. Input from a set of identifying words associated with logical operators invokes a word-based search of the repository and delivers as search result the instances that contain the given words. As this

search method is limited, there exists the possibility to carry out an advanced search. The indexing of the knowledge instances by tags offers the possibility to enhance the search request. The input of free text in combination with tags promises a more accurate and advanced search result, as it is possible with this methodology to gain not just the direct link but also the referenced items of the product, function, property, PLC etc. The user can specify several search criteria for one query within the advanced search. The visual navigation of the knowledge repository and the search results is also featured. A kind of knowledge index based on the categorising and grouping of the content of the repository enables this. Starting from a basic search, the user can navigate following the knowledge type, support information, or PLC state. These areas correspond to the specific expertise of the EE. This sort of visual navigation complies with the natural habits of humans.

The browser is not limited to a one-directional communication to benefit from the knowledge contained in the EE. A web-based forum for discussion and troubleshooting enables the users to resolve certain topics within an expert group. Very important is the establishment of the feedback area. The users will have the possibility to rank the specific knowledge instances and related documents/ files on their usability and helpfulness and to comment on the quality of the information. This enables the possibility to correct wrong, out-of-date or insufficient entries and references within the repository. An inter-active 'Request for Help' service for the solution of operational, methodical or textual problems is available for the users. The internet-based inquiry will be based on email or chat facilities, that support the inter-active dialog for the solving of the problem.

3.5 Evaluation and report generation

Besides the direct extraction of knowledge via the browser, sophisticated functionalities for the user-directed generation of reports based on the evaluation of knowledge are offered. The purpose of the report document is to illustrate a certain part of the EE product knowledge (like technical specifications, work plan, guidelines,...). The reports and evaluations can cover an enhanced domain during the PLC. In the PRIME context, the evaluation of product knowledge aims at the comparison, judgement and trade-off of product related know-how taking into account the three axes knowledge type, PLC state or support information. The evaluation and re-

port generation will be initiated by the user. He can specify/ select out of relevant knowledge mining queries for evaluation, related to the repository structure. Based on the structured product information of the knowledge repository, the system scans and analyses the repository on matching knowledge items and references. The query result will be controlled, grouped and organised by the system. By selecting a report structure, the system will generate the report. If available, the query results of the evaluation will be graphically illustrated. Additional information will be textual-based. Before finalisation, the user can check the outcome of his query. The final report can be exported in supported formats.

4 Methodology workbook

The PRIME workbook [2] constitutes an informal specification document on the PRIME methodology, and aims at guiding the PRIME user, step by step, to the PRIME solution. It comprises an introduction to KM, followed by EE methodologies, the knowledge engineering workflows applied, the roles and tasks assigned to the various actors, detailed description of the KM processes, and the proposed product knowledge models that represent the knowledge structure within the PRIME system.

5 Summary

The PRIME methodology provides an approach for the management of product related knowledge generated throughout the entire life cycle of the product. This knowledge will be shared within the Extended Enterprise and therefore available to all actors of a networked enterprise. It is expected, that the adoption of this approach leads to an improvement of the quality of a product and reduction of time spent on the development of a new product.

6 Literature

- /1/ PRIME consortium: The PRIME Homepage, <http://www.prime-project.org>
- /2/ PRIME consortium: The PRIME Homepage download area, <http://www.prime-project.org/deliverables.html>, 2003