CRANFIELD UNIVERSITY

PABLO BERMELL-GARCÍA

A METAMODEL TO ANNOTATE KNOWLEDGE BASED ENGINEERING CODES AS ENTERPRISE KNOWLEDGE RESOURCES

SCHOOL OF APPLIED SCIENCES

PhD THESIS

CRANFIELD UNIVERSITY

SCHOOL OF APPLIED SCIENCES

PhD THESIS

Academic year 2001 - 2007

PABLO BERMELL-GARCÍA

A METAMODEL TO ANNOTATE KNOWLEDGE BASED ENGINEERING CODES AS ENTERPRISE KNOWLEDGE RESOURCES

Supervisor: Dr. Ip-Shing Fan

April 2007

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

ABSTRACT

The encoding of Knowledge Based Engineering (KBE) software applications is becoming a prominent tool for the automation of knowledge intensive tasks carried out using Computer Aided Design (CAD) technology. However, limitations exist on the ability to manage the engineering knowledge models embedded in these executable KBE applications. This research proposes a metamodel to annotate encoded KBE applications. Resulting from the annotation, XKMs become explicit knowledge resources whose content can be better accessed and managed.

The attachment of metadata to data sets in enterprise repositories is a necessary step to identify and index them so they can be queried, browsed and changed. The sophistication of metadata models for these data "items" ranges from the simple indexing using numbers to more sophisticated representations describing their context information (i.e. author, creation date, etc.), their internal structure and their content. Current engineering data repositories like Product Data Management and Product Lifecycle Management systems offer predefined metamodels to annotate a range of engineering data items including CAD files or special types of documents. At the moment, there is no metadata model specifically designed to annotate KBE codes. In this situation, an undifferentiated metadata model needs to be used for XKMs. However, in this case the only information retained by the system about them would be context metadata.

Once an instance of the metadata is attached to an XKM, it can be used as its identifier within an enterprise data repository. The proposed metamodel contains abstract entities to annotate XKMs.

The resulting descriptive model for an XKM pays attention to its internal structure and its operation at different levels of granularity. The particular design of the proposed metamodel positions it at a level of abstraction between non executable domain knowledge models and executable KBE applications. This design choice is made to support the use of the metadata not only as an informative model but also as an executable one. The achievement of this target is becoming possible through the emergence of semantic modelling standards that allow the description of data models independently from the language of implementation. Using this approach, the generation of code and metadata is made automatically using mapping rules resulting from the semantic agreement between models and specific syntax rules.

The immediate application of the developed metamodel is to annotate XKMs within PLM systems. The approach shall contribute not only to systematically store instances of XKMs but also to manage the lifecycle of the engineering knowledge encoded within them. The proposed representation provides a more comprehensive approach for non KBE language experts to understand the code. On this basis, the change on the metamodels can be automatically traced back to the code and vice-versa. During the research, evidence has been gathered from the community of KBE technology users and vendors on the need to support this research effort. In the long term, the research contributes to the use of PLM systems as a platform for engineering knowledge management.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance of his supervisor, Dr. Ip-Shing Fan and the Cranfield University staff for their guidance and valuable advice.

Special thanks are for the organisations that have funded parts of this research. This includes the UK's Engineering and Physical Sciences Research Council, Airbus UK, GKN, Aircraft Research Association Ltd. On the other hand, the author deeply appreciates the interest and patience that the professionals from organisations like Boeing, Parker Aerospace, Corus, Dassault Systems, and TATA/INCAT have demonstrated through participation on the interviews and validation meetings carried out during the research. In this group, special mention goes to Adrian Murton from Airbus UK for his advice and support. At last but not at least, the author also wants to express his gratitude to the Director of Standards, the Chairs and the members of the Manufacturing Technology & Industrial Systems (MANTIS) Task Force at the Object Management Group for their support and advice in the submission of the "KBE services for PLM" RFP.

The author wishes to express his deep gratitude for the support by his friends and family. In this group the list is long and well mixed across the categories. Immeasurable acknowledgements go to Ali Yarf Abbassi, Jose Garcia-Fornieles, Fan and their growing families (in order of appearance: Lucetta, Fanny, Claudia, Paula, Sherine, Miguel and Annabelle). This outstanding group of people are my family in Cranfield and it is very hard to imagine how all these years would have been without them on the side. Life after work has not been bad in the UK thanks to people like Konstantia, Ramin, Georgios, Anna, Luke, Chrystel, Gabriella, Simon and many others that lived and passed by 12 Rutland Road, my home during the time in Bedford. While I believe that the UK hosted me with fantastic people, a great deal of the support during these years came from outside the country. I know very well that leaving home to go and study/work abroad is a rewarding experience that I will never regret. However, there is a "human cost" in being separated from the close ones back at home. I paid this tax on first instance in the name of my parents, to whom this piece of my life is dedicated for their unconditional support not only during these recent years but far before that. My brother, his family and my sister are as much part of this as Ramon and María Dolores. There is a long list of other family members and friends that have been on the supporting team outside the UK. My cousins Paco/Nieves and Ramon/Gloria deserve the big letters that I cannot use here due to Cranfield's thesis formatting rules. Manuel, Salva, Ciro, David and Monica and all the ones surrounding the group are the family that I choose through a lifetime rather than the one I was given. Big thanks go to them for receiving me back home with true friendship. My Oklahoma University buddies (Manolo, Ana Maria, Pepe, Isa and a long etc.) have also special mention here for their distant support since we had a fantastic time together back in 1998/1999.

Finally, while I write this part on the revised thesis document it comes to my mind a thought that I heard recently. The short version of it is that life goes through "ages". My PhD. "age" just passed away as others did and I am starting a new one. I hope next "ages" will be at least as good as this one and I wish to any reader of the result of this one to enjoy it and keep challenging the thinking behind this piece of work.

To my parents Ramón y M. Dolores

A mis padres Ramón y M. Dolores

AUTHOR'S PUBLICATIONS

Bermell-García, P., Fan, I-S., Li, G., Porter, R., and Butter, D. Effective abstraction of engineering knowledge for KBE implementation. In: Culley, S. (Ed.), WDK-28. Design management-process and information issues. International Conference on Engineering Design, ICED´01, 2001. ISBN:1860583555

Fan, I.S., Li, G., Lagos-Hernández, M., Bermell-García, P. and Twelves, M. A rule level knowledge management system for knowledge based engineering applications. In: Proceedings of DETC'02. ASME International 22nd Computers and Information in Engineering. Montreal, Canada. ISBN: 0791836223

Bermell-García, P., Mulet, E., Vidal, R. and García-Fernández, L.A.; Fan, I.S. A multi-agent system to support engineering design. Workshop on Intelligent Agents in Design. Artificial Intelligence in Design'02 Conference. Cambridge, U.K.

Vidal, R., Bermell-Garcia, P., Mulet, E. and García-Fernández, L.A. Definición de una arquitectura para la asistencia en el diseño de productos. Proceedings of the International Conference on Project Engineering. Barcelona, Spain, 2002. ISBN: 84-600-9800-1.

Bermell-Garcia, P.; Fan, I.S. A KBE system for the design of wind tunnel models using reusable knowledge components. Proceedings of the VI International Conference on Project Engineering. Barcelona, Spain, 2002. ISBN: 84-600-9800-1.

Fan, I.S. and Bermell-Garcia, P. Virtual concept model using design knowledge. Proceedings of Virtual Concept 2003, Biarritz, France.

Camelo, D. Vidal, R., Bermell-Garcia, P. and Mulet, E. El uso de tecnologías de la información en la gestión de grupos de investigación. Proceedings of the VII International Conference on Project Engineering. Pamplona, Spain, 2003. ISBN: 84-8021-217-9.

Mulet, E., Vidal, R. and Bermell-Garcia, P. Influences of the representations on designing and implications for computer-based design synthesis. In: Gralen, K. and Sellgren, U. (Eds.). Research for Practice – Innovation in Products and Processes. International Conference on Engineering Design, ICED´03. 2003. ISBN: 1904670008

Bermell-Garcia, P., Fan, I.S., Claus, R. and Kaufmann, U. (Eds.). "KBE services for PLM" Request for Proposal, dtc/05-09-11. The Object Management Group, (2005). WWW document: http://www.omg.org/cgi-bin/doc?dtc/2005-9-11 (accessed 8th June 2006).

Bermell-Garcia, P. and Fan, I.-S. A. Practitioner requirements for integrated Knowledge-Based Engineering in Product Lifecycle Management. International Journal of Product Lifecycle Management. (In press).

LIST OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOTATIONS

AI Artificial Intelligence

CAD Computer Aided Design

EKR Enterprise Knowledge Resource

ICT Information and Communication Technology

ISO International Standards Organisation

KBE Knowledge Based Engineering

KE Knowledge Engineering

KM Knowledge Management

MDA Model Driven Architecture

MDE Model Driven Engineering

MOF Meta Object Facility

MOKA Methodology and Tools Oriented to Knowledge Based Engineering

NIST US National Institute of Technology and Standards

OMG Object Management Group

OO Object Oriented

OWL Ontology Web Language

PDM Product Data Management

PLM Product Lifecycle Management

RDF Resource Description Framework

STEP Standard for The Exchange of Product Model Data

UML Unified Modelling Language

W3C WWW Consortium

XKM Executable KBE Model

XML Extended Markup Language

Chapter 1

INTRODUCTION

1.1 Research context

In the recent decades, many enterprises have realised that their corporate knowledge has to be carefully managed in order to respond to the fierce competition arising from the global economy. In these conditions, performance indicators such as "cost" and "lead time" are directly related to the efficient creation and use of engineering knowledge. At the same time, the research community is pointing out that traditional methods for managing information and knowledge in engineering operations may not suffice in handling the conditions of distributed innovation to deliver product/service systems.

Engineering design teams are required to add value to organisations beyond product design towards manufacturing, servicing and ultimately retirement and disposal operations. Software technology is responding to this through networked data management capabilities. For instance PDM and PLM technology connect the engineering view of the product with other enterprise functions responsible to deliver products to the market. For some organisations operating across regional boundaries and at the global scale not only the ability to exchange engineering data but the use of these networked IT solutions has become a need for coordinating collaborative engineering work in a cost efficient manner.

Considering the important role of the knowledge capital, significant research efforts have been put in place to understand its creation and management as any other enterprise asset. The processing of knowledge consists of transforming interpretable information in a particular context into decisions and then into actions. In general, knowledge creation is a cognitive process based on making associations with other interpretable sources of information existing either on a tacit or explicit form. Modern Knowledge Engineering (KE), attempts not to mimic this cognitive process but to use a modelling approach to make explicit the maximum amount of concepts and procedures that are relevant to carry out a task. Knowledge-Based Systems (KBS) are the implementation in computer systems of an infrastructure to model the knowledge that supports the decision making in particular domain tasks. The complexity behind the creation and use of knowledge in some engineering organisations has forced the creation of specific teams to control the process. These dedicated units are composed of multidisciplinary teams whose responsibilities include knowledge acquisition and modelling, the software engineering behind KBS and the maintenance of the systems.

Knowledge Based Engineering (KBE) is a particular technology to build KBS in the product design and development domain. KBE is characterised firstly by the close interface with CAD modelling tools and a high level programming language that can be used to specify engineering task models. The archetypical application of KBE systems is the automation of repetitive and slightly variant design task models. Secondly, the object oriented modelling framework available in KBE systems enables a high degree of scalability of the models. This feature has been used in automotive and aerospace domains to build large KBE implementations supporting product engineering tasks such as the design of aircraft wings or Body-In-White models in automotive vehicle designs.

KE and Knowledge Management (KM) are emerging bodies of research. Their objective is to develop the underlying concepts behind the usage, implementation and management of systems supporting knowledge intensive tasks. The concept of knowledge intensive tasks has its antecedents in acknowledging the existence of a "knowledge level" as it was postulated by Newell (Newell 1982). In a world without this notion, much of the knowledge for solving domain problems that is constantly created and used exists on a tacit form. Certain types of knowledge that are perceived as important create the case to be transformed into interpretable sources of information using containers like books, drawings and computer files (Figure 1-1).

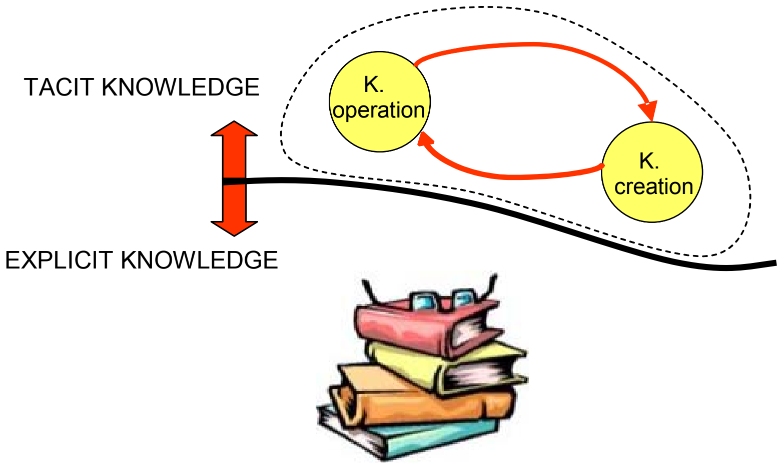


Figure 1-1. Knowledge creation and use without the notion of "knowledge level".

The emergence of the "knowledge level" has fundamentally influenced the process to retain and capitalise the expertise in organisations. Under this perspective, the knowledge is another asset that has to be stored maintained and distributed, usually through computer information systems. As a consequence, the simple knowledge creation/operation model has become a more technologically sophisticated process. Especially when we consider its storage, maintenance and distribution is done in networked information systems. The increase in sophistication imposed by a technology-mediated management of knowledge is illustrated Figure 1-2.

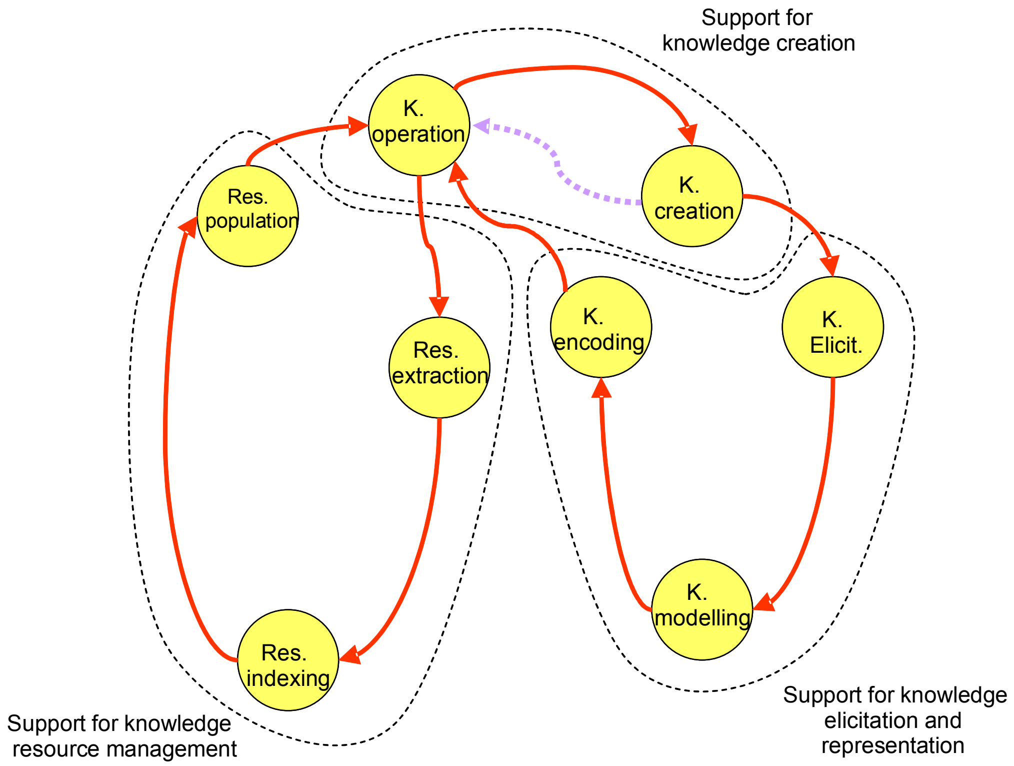


Figure 1-2. A more sophisticated view of the knowledge creation and use model.

A possible route to manage knowledge according to this model consists in supporting its retention and making it available for reuse. This type of knowledge processing requires; (a) its elicitation from the appropriate sources; (b) the use of a modelling approach to organise it; (c) and usually, its encoding into a computer system that can deploy it to address a knowledge intensive task. Examples of this type of support include the development of Knowledge Based Systems or rule-based Expert Systems.

Another view of managing knowledge approaches the delivery to its destination in the form of resources. In this case, it needs to be extracted, indexed for future reference and populated across a computer network. This mode of knowledge management behaves as a searchable electronic library. Then it tends to be closer to general users as knowledge authors since it does not involve the encoding of knowledge for execution by computers. In contrast, the decisions resulting from the knowledge are taken by the humans that access it. Examples of supporting tools for knowledge resource management are the so called Wiki websites or the "help" in a software package.

From this distinction, much research has been carried out on the transformation of knowledge from a tacit into an explicit format. The two approaches help to identify the major schools of thought regarding the computer support for knowledge intensive activities highlighted in Figure 1-2. Their starting points are different as well as the shape of the philosophy of the systems developed in both research fields. The distinctions between them are summarised as follows:

- **Support for knowledge elicitation and representation**. A starting point from this area of scientific research hypothesises that entities at the knowledge level can be formalised and processed using computing techniques. From this notion, AI and

KE research has focused on the underlying concepts to formalise knowledge so computers can support humans in the reasoning to carry out knowledge intensive tasks.

- **Support for knowledge resources management**. A starting point for this research area is less mechanistic than the one adopted in the previous one. The focus is on handling the complexity of the heterogeneous information sources that support knowledge intensive tasks. In this perception of the problem, the research emphasis is on the social sciences rather than on the computing sciences. Resulting from this, most of the reasoning is left to the humans while the storage and retrieval of information is a major responsibility of the computer system.

Until recently, the conceptual frameworks to develop knowledge intensive systems in both perspectives have been mostly disaggregated. The further understanding of the processes behind the knowledge creation, sharing, reuse and maintenance has made evident the need to integrate these schools of thought. With this new approach, the benefits of managing knowledge have been proved. On the other hand, a trade off between the use of informal and formal knowledge models is advocated by both the KE (Shadbolt and Milton 1999) and the KM research community, (Holsapple 2005; Tsui 2005).

The realisation of this vision is being embraced not only by the scientists on these areas but also by the community of software users and vendors. A remarkable example delivering impact to the society is the global IT standardisation bodies such as the WWW Consortium (W3C) or The Object Management Group (OMG). Within these organisations, the notion of standardisation as the transfer of innovations is becoming reversed. As a consequence, concepts like the Semantic Web standards, whose origins can be traced back to research on KE, have become the driver for leading edge innovations across other research areas.

A significant breakthrough proposed by these communities is the foundation for the semantic interoperability between IT systems across domains of application. The concept of semantic interoperability is associated to the exchange of information at the so called knowledge level. This requires the existence of a formalised and common knowledge model (usually referred as an "ontology" or a "metamodel"), describing concepts towards which two systems are aligned. While in the past the ability to create computable knowledge models has existed, the required commonality has not been achieved until certain degree of maturity has been reached by semantic modelling standards.

1.2 Industrial motivation

In this work, the concept of semantic interoperability is explored in the engineering design research context. A similar disconnection between the schools of thought behind knowledge formalisation and resource management is perceived in the domain. This includes research on AI in design, engineering knowledge management or enterprise systems implementation. At the IT side, the correspondence for knowledge creation and use are the CAD/CAM/CAE technologies. Following the same model, KBE is the technology for knowledge elicitation and representation whereas PDM and PLM are the technological support for resource management.

While the use of 3D CAD data is a relatively mature reality in engineering practice, the systematic management of engineering knowledge is still an emerging concept. KBE has been used as a knowledge modelling framework in aerospace and automotive industries for more than 20 years now. The technology is being gradually transferred into less complex businesses. However, much of the best practices in aerospace and automotive industries remain secret behind corporate barriers.

One of the success factors of KBE can be found in its ability to execute task models resulting from the capture and encoding of engineering knowledge. This is opposite to just building a reference knowledge model like a Wiki (human understandable) or an ontology, (mostly machine interpretable). The latter can be useful for documenting engineering tasks. However, it is just "informative" rather than executable as it is a task model built using KBE technology. In contrast, a disadvantage of KBE task models is that they remain tied up to a software platform and only accessible to those that can interpret the vendor's KBE language syntax and structure.

It has been observed that once the capability for creating KBE models is built, the next step in the maturity of the technology focus on the capitalisation of engineering knowledge. This refers to the effective return of the investments made to create KBE capabilities. The implementation of KBE involves high costs not only due to the training of engineers or the purchase of software. In addition, the effective application of the technology has expensive overheads associated to the knowledge acquisition activities and the disruptions to engineering work practices. This leads to the formulation of two research questions regarding the return of the investments spent on KBE implementation:

- How KBE models can be unlocked from software vendor representations so the knowledge can be more accessible and retained in the long term?
- How KBE models can be stored as enterprise resources enabling their sharing, reuse and the management of their lifecycle?

The need to unlock engineering knowledge representations becomes evident when two proprietary KBE models need to be exchanged between systems. This interoperability issue is illustrated in Figure 1-3 where two different CAD systems with built-in KBE functionalities are used. Both product models have been "knowledge-enriched" so they can execute the generation of the same engineering data. The two KBE models hold the same knowledge about the entities that define the engineering problem and the set of engineering rules that govern the data generation. This example points out that some semantic equivalency exists between the metamodels used to abstract a domain problem in both systems. However, using current data exchange standards, it is only possible to transfer an instance of the design (one state of the design), and not the knowledge embodied to generate it.

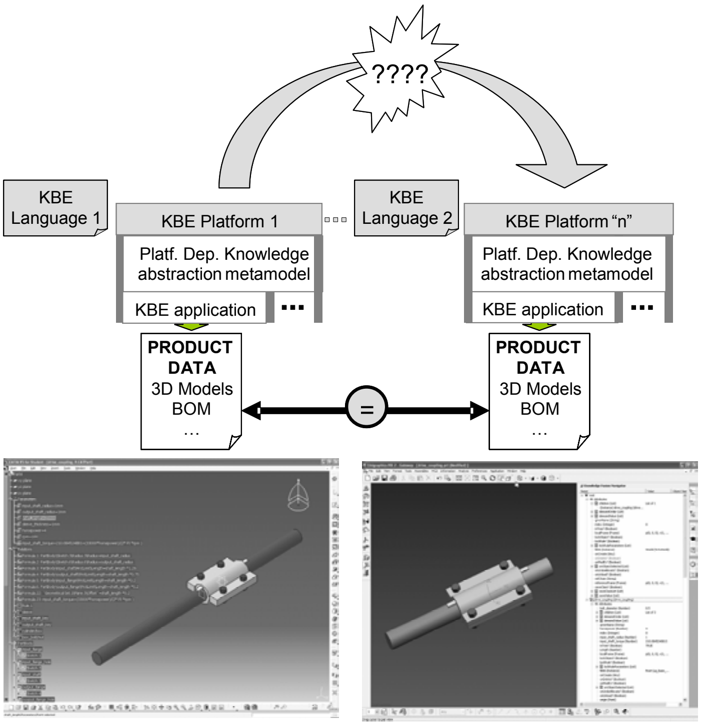


Figure 1-3. A need to unlock KBE codes from proprietary representations.

The response to these challenges has practical implications on the long term retention of engineering knowledge. A recent example is in the community of KBE users that has been affected by the displacement from the market of *ICAD*, one of the leading software products. This disruption has forced KBE teams to migrate their implementations into other systems. Although some users have chosen the transfer of their models into similar KBE products like the commercial tool *GDL*, the transfer involves high costs. The fact that *ICAD* still exists as a legacy system evidences the difficulties to unlock and retain the knowledge in the long term.

1.3 Scope of the research

A design-centred perspective is used to define the boundaries of this research. In this work "engineering design knowledge" refers to the one that is captured, represented and reused using KBE. This view positions the technology in a supporting role for a range of operations executed by designers.

Once the engineering design knowledge has been encapsulated within a KBE application and it has been delivered as a design tool, it becomes an enterprise knowledge asset. However, there exist limitations to reuse pieces of the knowledge that has been encoded into applications. A critical issue behind this is the difficulties in visualising and understanding the task that an application executes and the engineering knowledge applied to do so. A response to this issue is to annotate an enterprise knowledge resource using a particular template that facilitates its understanding. The work reported in this thesis investigates how to create such annotation schema so KBE applications become more transparent and consequently, the knowledge that they contain can be better managed as an enterprise knowledge resource.

Given this starting point, the research pays attention to the model of knowledge processing described above and puts it in the context of this research (figure 1-4). The diagram shows the major research areas explored in the research concerned with the knowledge processing model in the context of engineering design. As it is illustrated, the focus of the research is at the interface between Knowledge Engineering and Enterprise Engineering.

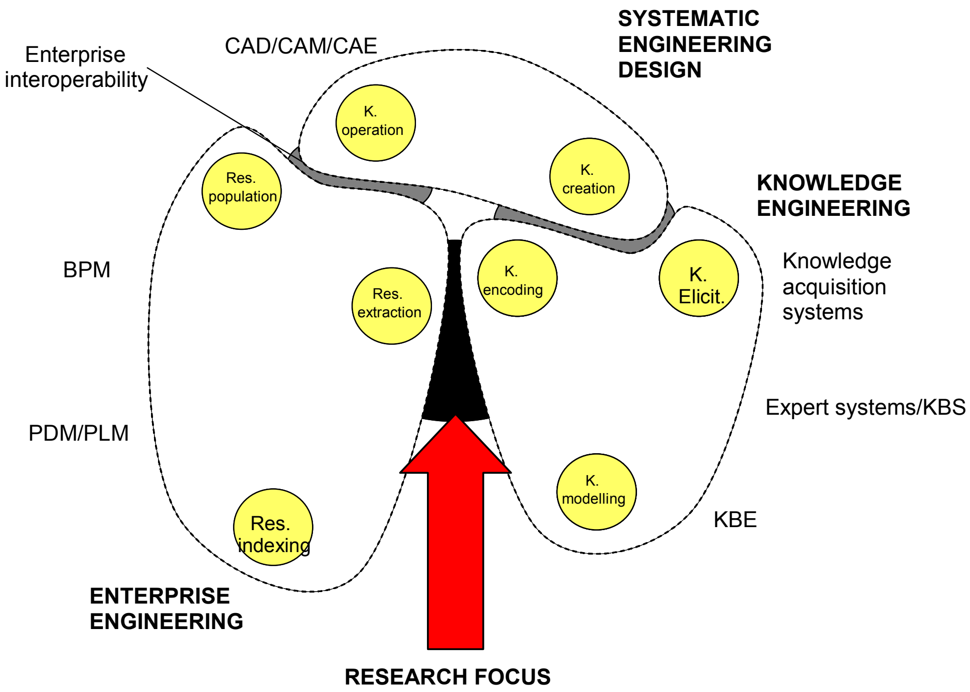


Figure 1-4. Research scope.

1.4 Research objective

At the starting point of the research, the aim was to gain an understanding on how KBE models can be reused more effectively. As the research progresses, the development of the understanding refines the outcome of the research as a metamodel to describe KBE resources. This introduces the notion of KBE applications as Executable KBE Models (XKMs) that become Enterprise Knowledge Resources (EKRs) once they are systematically annotated using a consistent information model that describes them to a larger community than just the code developers. The final aim of the research is enunciated as follows:

"To transform executable KBE models into enterprise resources through a metamodel that can describe them"

The term "metamodel" refers to an information model that contains the necessary abstract entities to describe a set of concepts within a particular domain. A metamodel can be seen as an empty annotation template holding the rules to create instances of domain knowledge concepts for which it has been designed. On the other hand, it is a domain specific language based on an upper level metamodel that can be used to model knowledge from any domain. Some features of the upper level metamodel such as the ability to add constraints affect the accuracy of the domain concepts models that can be expressed by a domain specific language. The use of the upper level language ensures that the way to describe a concept, its information attributes and the way it relates to other concepts within the metamodel follows a consistent approach. Despite the precision in which a metamodel expresses the concepts of a domain, its quality is mostly assessed by its acceptance across a community of users. For instance a very precise metamodel that very few target users understand and use cannot qualify as a good quality model.

The assessment of the research outcome is related to the quality of the metamodel resulting from it. A set of specific objectives that the metamodel has to fulfil to make sure that it fits the purpose of the research aim are listed as follows:

- The metamodel has to respond to the needs of KBE practitioners.
- The information model has to be built using state of the art metamodelling techniques.
- The metamodel has to provide a solution to increase the transparency to the knowledge encoded within KBE applications.
- The metamodel has to be validated by relevant experts in the KBE area

1.5 Research approach

The work reported here applies the concept of semantic interoperability to the KBE development domain. The concept of Model Driven Engineering (MDE) is used as an interoperability conceptual framework to achieve the research objectives. MDE represents a step forward on the thinking behind the development of software systems. At the core of MDE, special modelling languages are used to capture the semantics of the domain in which software systems operate. Then, data transformations are used to transform instances of the semantic model into platform specific representations such as program code or data models.

Building metamodels to describe domain specific concepts is a fundamental step for supporting interoperability between information systems. The research adopts this approach as a mechanism to annotate KBE applications. Annotated codes have a structured representation within an enterprise data repository. Consequently, they can be more effectively identified, retrieved and reused.

The potential of adopting a MDE strategy within the scope of the research becomes apparent through the observations made on an industrial KBE implementation project. Further support for the approach is gathered through the interaction with the community of key researchers, users and vendors sharing interests on the management of KBE resources.

1.6 Research methodology

The research methodology is designed by paying attention to the delivery of an information model as the main research outcome. While the modelling task to create the metamodel is a key activity of the work, the research carried out prior this stage and the validation that follows the modelling are fundamental steps to ensure that the outcome contributes to knowledge and also fits its purpose. This distinction marks three well defined stages in the research:

- Research problem definition.
- Idea generation and metamodel creation.
- Metamodel validation.

In the problem definition stage (Figure 1-5), the objectives of the research are qualified with a review of the literature that is relevant to understand the research gap. At this initial stage, the literature gives foundations on key research areas such engineering design and knowledge management. Special attention is paid to get a deep understanding on KBE research work covering technology directions and implementation case studies.

The idea generation and metamodel creation stage takes approximately half of the efforts spent in this research, (Figure 1-5). The work starts once the problem definition is narrowed down with the exposure of the researcher to an industrial case study. The case study analysis is carried out in the context of a research project to investigate the feasibility of using KBE in the wind tunnel models design and manufacturing domain. The interest of the industrial collaborators, ARA (Aircraft Research Association Ltd., UK) and Airbus UK in KBE comes from the realisation that many of the design activities in the domain involve repetitive and slightly variant tasks. The work proved the feasibility of using KBE to improve the wind tunnel models design process, (Bermell-Garcia 2001). The idea generation explores the use of Reusable Knowledge Components in KBE implementation and it is very much inspired by a further literature review on Knowledge Engineering together with the analysis of the industrial case study. The activity develops the understanding on the importance of reusing KBE efforts and to realise the advantages of managing KBE resources in a systematic manner.

At this point, a project aimed to develop an international standard for the exchange of knowledge between KBE systems influences the thinking on the research gap to be tackled. A non explored route to improve the use of KBE is the enforcement of reuse by looking at applications as enterprise resources that could be indexed using metadata. In this stage, the research acquires a sense of industrial relevance through the technical leader role of the researcher in the standardisation effort. An exposure of the work to leading KBE technology users and vendors facilitates the gathering of data on the practitioner’s view on the transformation of KBE codes into resources stored using PLM data repositories technology.

All the previous pieces of work together build up the learning that guides the research to the design and implementation of a metamodel specifically aimed to transform KBE codes into EKRs. Special attention at this stage is paid to the use of state of the art interoperability concepts. The metamodel development and implementation is an iterative process that requires intensive modelling and testing to achieve a design that fulfils the objectives of the research.

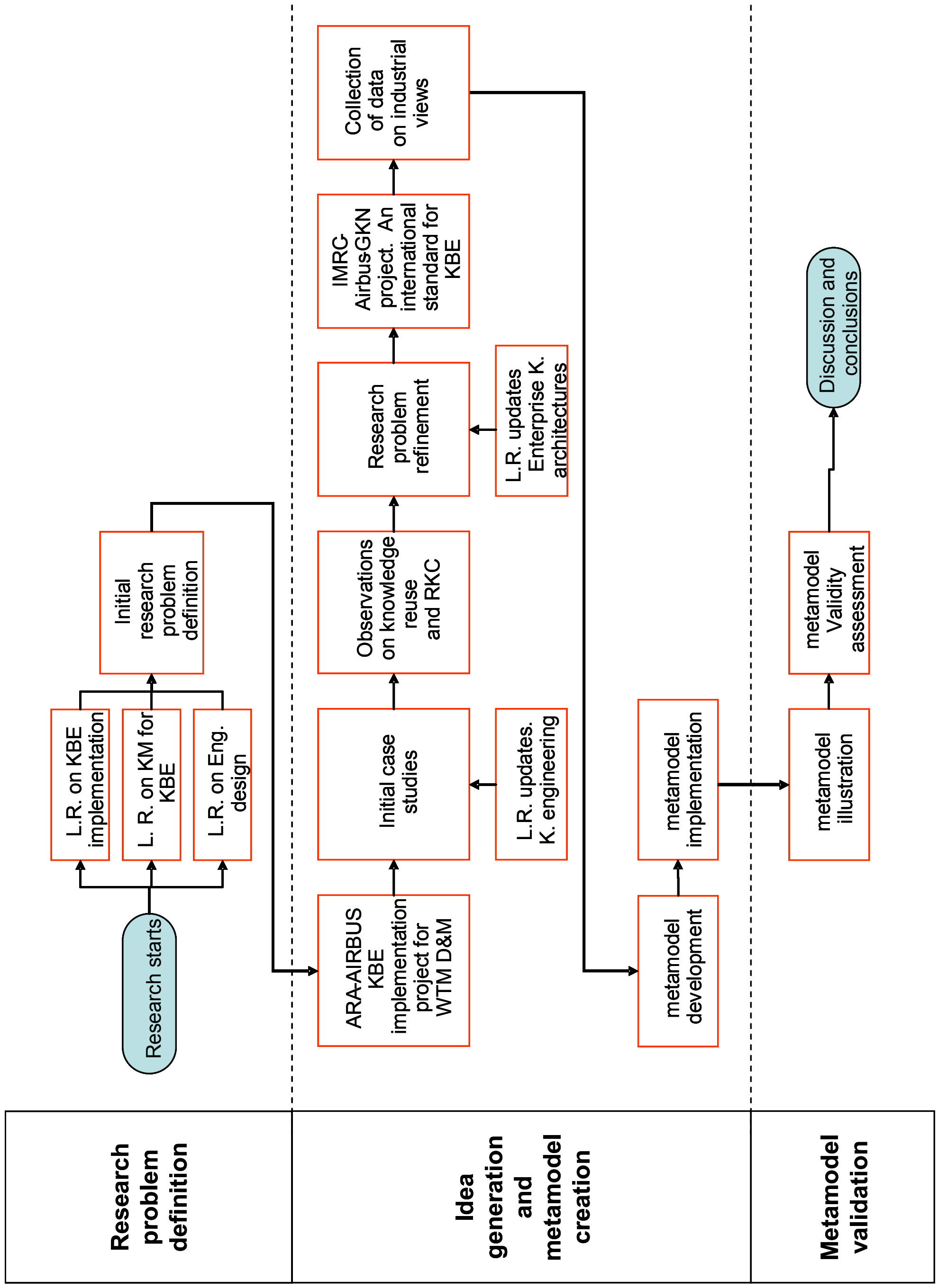


Figure 1-5. Research methodology

In the metamodel validation stage (Figure 1-5), a set of illustration cases are developed. They are instances of the metamodel that can be shared to the validation team. The validation of the metamodel requires the participation of qualified experts. The choice of the validation method though interviews is forced by the circumstance of having a small amount of these qualified experts in the world. Although KBE is becoming a more widespread technology in engineering practice, most of the KBE technical leadership remains behind the corporate barriers of a handful of organisations that co-develop the technology both at the user and vendor side. This group includes large aerospace and automotive manufacturers, consultancy firms and engineering software vendors. A total of three validation sessions have been carried out with up to 8 participants from the target group of KBE experts. The choice of the validation team shows a realistic sample of the world KBE expertise since 5 representatives from one of the two global leading CAD/KBE software vendors is represented. Similarly, the KBE manager from one of the two largest aerospace firms that are intensive users of KBE is part of the team. Finally, other key sectors are represented. The representative from a global consultancy firm with an extended track record on KBE is part of the validation meeting carried on within the aerospace firm. Finally, the automotive sector is represented in the validation through the head of KBE from a large automotive steel supplier that uses intensively the technology since the early 1990s.

1.7 Contribution to knowledge

The outcome of this research is a metamodel that can be used to annotate KBE codes. Ultimately, such metamodel gives the possibility to have a blueprint of a KBE application within enterprise data repositories. In these systems, data items are indexed for searching using metadata that gives information about its context (who created it, when, etc.) and about its content. A novel contribution of the research is to fill the gap for a metadata model that can be used to index the content of KBE applications. With the current status of the technology, KBE applications are stored within enterprise data repositories as undifferentiated data items. Then, the only metadata that can be associated to them refers to their context. The immediate benefits for the community of KBE users from annotating their applications with the metamodel and storing them in enterprise data repositories like PDM systems are faster and more accurate retrieval of existing applications by searching through their content rather than only their context information.

The research adds to the existing knowledge a theoretical basis for a new capability to index the content of KBE codes. This point is behind the research claim seeing the metamodel as an instrument to transform KBE codes into EKRs. From the technical point of view, the developed metamodel increases the visibility to the content of KBE applications annotated using it. An innovative characteristic of its design is the use of two sub-models. Their purpose is to help potential users of the code to understand what is the structure of the encoded XKMs and also how do they operate.

Finally, the results of the research are also the foundations to enable the management of knowledge encapsulated within KBE toolsets by using PLM technology. This represents a mode of KBE/PLM integration and it is certainly raising expectations across the community of users and developers of both technologies. Within the scientific community, the role of knowledge models to support engineering design operations is the focus of intensive research. While most of this research has been traditionally focusing separately on the two schools of thought mentioned in 1.1, there is a movement to unify the thinking. The KBE/PLM integration concept is the industrial interpretation of this, and research initiatives on engineering knowledge management such as (KIM, 2007) are attempting to realise the unification. This research represents a small advance to the current status of that research field.

1.8 Thesis structure

This thesis is divided into eight chapters. The chapters are arranged following the chronological sequence of the research. A brief description of the contents of each chapter is provided here:

- Chapter 1 gives an overview of the research and guides the reader through a brief description of the thinking leading to the contribution to knowledge.
- Chapter 2 reviews the published research work that is relevant to the research. The literature review covers the published work on the support for the creation, use and further management of engineering design knowledge. It also analyses the research work on enterprise knowledge architectures
- Chapter 3 gives an account of a practical scenario for the transformation of KBE applications into enterprise resources. An industrial implementation case study is used to explore the reuse of KBE components.
- Chapter 4 conveys the practitioner's view on the functionalities and use cases for the management of KBE applications as enterprise resources. Due to the chronological sequence, this chapter re-evaluates the findings of chapter 3.
- Chapter 5 summarises the design requirements for the metamodel developed in the research.
- Chapter 6 describes in detail the metamodel to transform XKMs as EKRs
- Chapter 7 gives an illustration of the metamodel and reports on the validation activities carried out with practitioners to validate the metamodel.
- Chapter 8 discusses the research findings and draws conclusions on the research.

Chapter 2

LITERATURE REVIEW

2.1 Introduction to the literature review

This chapter presents the state of the art on published research that is relevant for the understanding of engineering knowledge models and their transformation into enterprise resources. The structure of the review is designed around the concept of engineering design knowledge and the operations that create, formalise and retain it. Special attention is paid to the computer based systems supporting these activities in engineering design.

The fundamental building blocks of this research are the general engineering design theory/methodology and the computer-based systems to manage engineering information and knowledge. The natural starting point of this research is the literature addressing the understanding and improvement of engineering design practice. The knowledge that is further elicited, transformed and converted into an enterprise resource is in the first instance created and used at the design function of an engineering organisation. According to the research scope, an investigation on the state of the art focuses the following main topics:

- **Engineering design knowledge creation and use.** Covers systematic approaches to support the creation of engineering design knowledge.
- **Engineering knowledge management**. Focuses on the development and application of KE to support engineering design work.
- **Enterprise knowledge architectures.** Reports on the state of the art regarding the strategies to store and manage information and knowledge as resources in enterprise data repositories.

The parameters influencing the structure and content of this literature review are described in Table 2-1. The three functional areas are decomposed into the major operations to realise them. A wider view of the areas reviewed is completed by:

- Both the methodological and human capabilities that organisations need to put in place to support each functional area.
- The key computer-based technologies commercially available to respond on each functional area.

Table 2-1. Decomposition of the coverage areas in the literature review

Area	***Sub areas***	***Capabilities required***		***Key computer-based technologies***
		Methodological	**Human**	
Engineering knowledge creation and use	- Knowledge creation - Knowledge usage	Systematic engineering design methods and tools	Engineering problem solving experts	Computer aided design and engineering
Engineering knowledge elicitation and representation	- Knowledge elicitation - Knowledge modelling - Knowledge encoding	Knowledge acquisition and representation	Knowledge engineers and software developers	Knowledge management and knowledge-based engineering systems
Enterprise knowledge architectures	- Resource extraction - Resource annotation - Resource population	Systematic data storage, access and change management	Project managers and information systems architects.	Product Data Management and Product Lifecycle Management systems

The structure in this literature review is related to the evolution of computer-based support for engineering design. Although intensive research has been carried out at the three areas, the third one seems to be an emerging topic in engineering design support systems.

A possible distinction between the first and the rest of the functional areas covered here is deeply rooted in the philosophy driving industrial systems. The first of them emerges from the Industrial Engineering view of the world. The driver is the efficiency of productive processes imposed in the industrial era. Archetypical examples of this are the standardisation of the parts in *Colt* guns in the XIX century or the specialisation of work envisioned by Henry Ford in the production line of the T model. However, in the second and the third areas a philosophical notion of sustainability has been attached to that of industrial efficiency. In the current post-industrial age it has been realised that the timescales of industrial efficiency and competitive advantage in the market are longer than a lifetime. The sustainability of engineering organisations highly depends on the careful retention and adaptation of their knowledge (and consequently their data) in an increasingly changing world.

Efforts are taking place to realise the integration of these three views in the benefit of engineering design practice. However, it can be recognised that they represent three different schools of thought whose origins can be traced back to engineering design, Computer Science/AI and the emergent field of Enterprise Engineering. This particular work and many others across the research communities in the three areas are putting the efforts and creating the necessary impact so their convergence is transferred into the designer's desktop computer.

2.2 Engineering design knowledge creation and use

In the context of this thesis, engineering design is main body of research concerned with the creation and use of engineering knowledge. Coyne et al. (1990) describes engineering design as a skilful activity (rather than opportunistic) that has to do with the representation of an engineering system in a (design) abstract space. In this definition, "engineering system" is made up of physical artefacts. This implicitly means that among other conceptual distinctions, an act of design delivers the representation of artificial physical objects.

This distinction facilitates the understanding of what is meant by design in engineering. However there are many other species of "design" that do not deliver a physical artefact representation. This distinction is a source of controversy across different communities and thus domain-independent definitions of design are pursued by researchers. For instance, the work from Reymen et al. (2006) makes the distinction between design "in general" and other domains such as architecture, software engineering and mechanical engineering.

Table 2-2. Topics and foundations in design process research, adapted from (Langen 2002).

Topics in engineering design research	***Applied disciplines in engineering design research***
Models of design problem spaces Models of design processes Design representations, (artefacts, environments, design problems, design knowledge) Design methods Techniques for reasoning in design Design support systems and automated design systems Design themes such as requirements engineering, DFx, conflict management in design, design strategies, design rationale, design creativity or learning in design.	Decision theory Mathematics Logic Information processing theory Cognitive psychology Software engineering Artificial intelligence

A more relevant perception of engineering design for this research goes beyond the understanding of design as a cognitive activity. Its focus then is on the improvement of design practices in an increasingly complex world. A wide spectrum of the current research areas paying attention to this is well covered and summarised in the book "Engineering Design Improvement", (Eckert and Clarkson 2005). In the introductory chapter, named as "the reality of design", the authors identify the thinking on engineering design research as the identification of "patterns of designing". Identifying patterns has the role of handling the complexity of design processes across engineering domains. This is opposite to the attempt of creating universal theories and models of design that work in any domain. The book starts with this premise and identifies areas of research approaching different types of patterns.

Table 2-3. Research in engineering design, adapted from (Blessing et al. 1998).

Research area	***Research method***	***Focus of the research***
Engineering design as a cognitive activity	Observation and analysis of design activities.	Theories, models and studies on cognitive issues mainly related to design, (major design theories, empirical studies about design, etc.). EXAMPLES: General Design Theory (Yoshikawa 1981), Axiomatic Design (Suh 2001), Theory of Creative Problem Solving (TRIZ) (Altshuller 1996), Theory of Technical Systems (Hubka and Eder 1988), Systematic Design (Pahl and Beitz 1996).
Engineering design methodologies	Assumption and experience.	Generic methodologies for improving the performance of the design process. EXAMPLES: Total Design (Pugh 1991), Value Analysis (Miles 1972), Failure Mode Engineering Analysis (FMEA) (Stamantis 1995), Quality Function Deployment (Revelle et al. 1998).
Tools to support engineering design activity	Observation and analysis of design activities.	Generic or specific tools to support designers in their activity (This makes special focus on computational support for engineering design work). EXAMPLES: Computer Aided Design (CAD), Computer-Aided Manufacturing (CAM), Computer-Aided Engineering (CAE), Knowledge-Based Engineering (KBE), TRIZ tools, Product Data Management (PDM), Product Lifecycle Engineering.

Although engineering design has its own identity as a research community, it combines a wide scope of disciplines. The research from Langen (2002), identifies the major topics on the study of design processes and its foundations (Table 2-2).

The outcomes of design research usually come in the form of three main types of contributions:

- Design theories.
- Design methods.
- Design support systems.

Such classification is usually acknowledged by the community of engineering design researchers. For instance, Blessing et al. (1998), gives a similar decomposition of the research in the field. Table 2-3 briefly characterises these three types of foci in engineering design research and provide some examples for each.

2.2.1 Theories and models of design

Design theories are sometimes models rather than theories itself, as they provide a conceptualisation of only a part of a universe of discourse rather than the whole (design patterns). Nevertheless, they provide strong foundations to understand design activities from a domain independent point of view.

A useful classification of design models is the one provided in (Wynn and Clarkson 2005). A fundamental distinction is made between abstract, procedural and analytic models. The authors argue that the abstract models of design are of little use to explain design processes in detail and have limited applications. This appreciation coincides with other researchers in the field, (Smithers 1996). Examples of these abstract models are the well known Analysis-Synthesis-Evaluation (ASE) model (Jones 1970), and Darke's model of the problem solving process in architecture (Darke 1979).

Other more sophisticated abstract models of design have emerged at the research interface between AI and engineering design. An example is the Function-Behaviour-Structure model (FBS). The FBS model is widely used as an approach to describe design processes, (Umeda et al. 1990; Umeda et al. 1996; Lin and Zhang 2004). It is also common to see the model in the literature reporting on empirical design experiments with designers to analyse particular design episodes, (Gero and McNeill 1998; Mulet et al. 2002). In one of its multiple forms, a link between the FBS and the ASE models is usually found in the literature as illustrated in Figure 2-1 (A). However, more sophisticated versions of the model exist, (Figure 2-1 B).

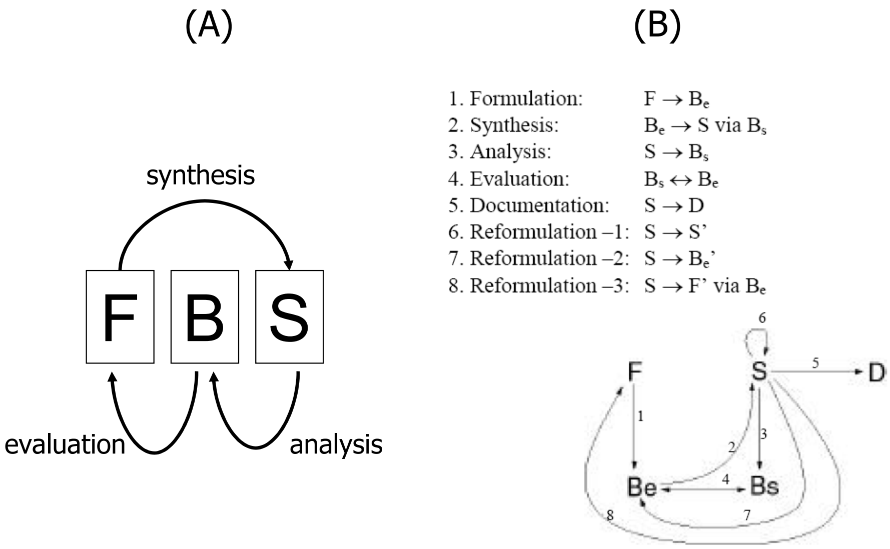


Figure 2-1. The FBS model. (A) A simple FBS model using the A-S-E model. (B) a more sophisticated FBS model, from (Gero and Kannengiesser 2002).

Special research efforts have been spent in understanding and modelling the synthesis phase of design. The synthesis process is usually presented in the literature as the mapping between the required functionality of a product and its form (Roy et al. 2001; Ueda 2001). Studying the synthesis process has gained relevance in the last years as an instrument to develop systems guiding and even automating the creative generation of design solutions, (Kryssanov et al. 2001). A review of synthesis research can be found in the book edited by Chakrabarti, (Chakrabarti 2002). Apart from covering the definition, approaches and tools, the book also brings together the authors of well known engineering design theories and models and put their work under the perspective of synthesis. This includes influential researchers such as Gerhard Pahl, Vladimir Hubka, Ernst Eder or Karl T. Ulrich.

The modelling of synthesis is a central topic in the research carried out by a group of Japanese researchers including H. Yoshikawa, H. Takeda, T. Tomiyama, M. Yoshioka and others. Their research is strongly based on mathematical models of design. In the large amount of literature published by these authors, the logical reasoning in design is analysed. A remarkable outcome is the study of the role of cognitive processes such as deduction, circumscription and especially abduction as key abstract processes in synthesis (Takeda 1994; Lin and Wang 2001; Takeda et al. 2003).

Aligned with this way of modelling design, in 1981 M. Yoshikawa presented his General Design Theory, (GDT), (Yoshikawa 1981). This work is a unique design model that is completely based on mathematical foundations. At the core of GDT, a set of axioms for design are logically proved from the existence of general assumptions about the nature of objects. Although the theory is intended for describing design, its ultimate goal is to prescribe the development of CAD systems. However, the GDT has been criticised in (Reich 1995) on its limited scope of application and its restrictive theoretical assumptions.

Many of these theories and models have been validated through experiments with designers. It is usual to find in the literature these types of studies focusing on certain cognitive or social phenomena happening in the design process (i.e. the generation of solutions, the impact of internet-based collaboration in design, etc.). See (Cross et al. 1996), for a compilation of this type of studies.

In reference to the concept of "design patterns" previously introduced, some of the abstract design models formalise the understanding on particular aspects of design. For example, the theory of co-evolution uses this type of research to demonstrate and formalise design as a dynamic process in which solutions and problems are generated together (Maher and Poon 1996; Parmee and Bonham 2000; Dorst and Cross 2001; Maher 2003).

2.2.2 Design methods

A large proportion of engineering design research deals with the development of infrastructure (methods and tools) oriented to make the design process more efficient in industrial situations. It is common in the literature to separate the abstract models of design covered in section 2.2.1 from the procedural models that prescribe design processes, (Finger and Dixon 1989; Wynn and Clarkson 2005). The latter ones are based on industrial best practice and their role is to guide the designer through a set of stages.

Table 2-4. Abstract and procedural models of design.

	ABSTRACT DESIGN MODELS	PROCEDURAL DESIGN MODELS	
		DESIGN ORIENTED METHODOLOGIES	PROJECT ORIENTED METHODOLOGIES
Usage context	Understand design as an intelligent problem solving activity.	Guide the design process as an engineering activity made up of stages aimed to create a product	Guide the design process as a business process within a manufacturing environment
Literature sources	(Jones 1970) (Darke 1979)	(Hubka 1982) (Pahl and Beitz 1996) (French 1999)	(Pugh 1991) (Baxter 1995) (Ertas and Jones 1996) (Ullman 2003) (Hales and Gooch 2004) (Ulrich and Eppinger 2004)
Outcome of the design process	Principles of solution for the design of an artefact	The engineering description of an industrial product	A designed and industrially developed product
Scope of the model	Describing the reasoning in a design process	An individual engineering problem solving process	A collaborative problem solving process
Other features in the models		A set of available supporting methods	A set of aspect-based methods to integrate disciplines such as cost estimation
			An increased relevance of manufacturing constraints handling
			Management of the influences of the design process a project
			Management of the processes involved in product development.

The procedural models of design have significantly influenced the thinking of engineers since they are basic engineering design textbooks in many universities and colleges around the world. One of the most popular is the systematic design methodology, (Pahl and Beitz 1996). However, other reference methods like (Pugh 1991; Ullman 2003; Ulrich and Eppinger 2004) are also widely used. Table 2-4 gives a comparison between abstract and procedural models of engineering design. A further classification of the procedural design models is given in regards to whether their focus is mostly on technical design or on project management.

In general, these models are based on the formalisation of years of engineering design practice rather than on mathematic models. An exception to this is the Axiomatic

Design Theory (AD), in which the grounds are both design practice experience and mathematic modelling (Suh 2001). Axiomatic Design together with the Dependency Structure Matrix (DSM) method (Steward 1981), can be positioned between the procedural and analytic models of design. The use of both approaches facilitates the handling of the complexity of the design process by analysing the coupling between product components and their functions. An interesting application of coupling analyses is the identification of modularity in complex products, (Whitfield et al. 2002).

Apart from complete methodologies for engineering design, a number of "smaller" methods exists that can be used across the different stages of design process. These methods are systematic approaches to carry out specific design activities. Many of these methods are described as supporting methods in (Cross 1989; Pahl and Beitz 1996). However, many variations of the methods exist for particular situations. Table 2-5 shows examples of these methods in reference to their common use in the design process.

Table 2-5. Design methodologies

Conceptual Design Methods	Embodiment Design Methods
- Functional Analysis - Brainstorming - TRIZ - Analysis of Interconnected Decision Areas (AIDA)	- Quality Function Deployment (QFD) - Failure Modes Engineering Analysis (FMEA) - Value Engineering (VE) - Failure Tree Analysis (FTA)

The classification in Table 2-5 is not absolute. A current research trend is to integrate creative methods not only at early stages but across all the design process. In addition, the use of modern CAD simulation technologies facilitates the use of some of these methods before having detailed designs or prototypes. In addition, experimental observations of the design process have revealed the divergent-convergent nature of design activities (Liu et al. 2003). According to this, some methods are intended to generate solutions (divergent) while others are used to select and discard solutions (convergent).

2.2.3 Evolution of computer-supported design practice

The third element as the outcome of engineering design research is design support systems. Their review is focused on the evolution of computer based technology in reference to the context of engineering design practice.

The perception of engineering design practice as the means to deliver product/service systems rather than just artefact descriptions has evolved along the development of engineering oriented IT systems. The current vision of Product Lifecycle Management (PLM) has become real through several generations of CAD tools, including early geometric modelling, solid modelling and Product Data Management (PDM). This evolution has seen the increasing support for computer mediated design coordination on top of engineering problem solving technologies that support the analysis, synthesis and evaluation of product solutions. The combination of different trends in engineering design research and practice has contributed to this progressive contextualisation of the product engineering function as part of a larger socio-technical system. Paying attention to this evolution, four generations of engineering design research can be distinguished and mapped to key computer support technologies (Figure 2-2).

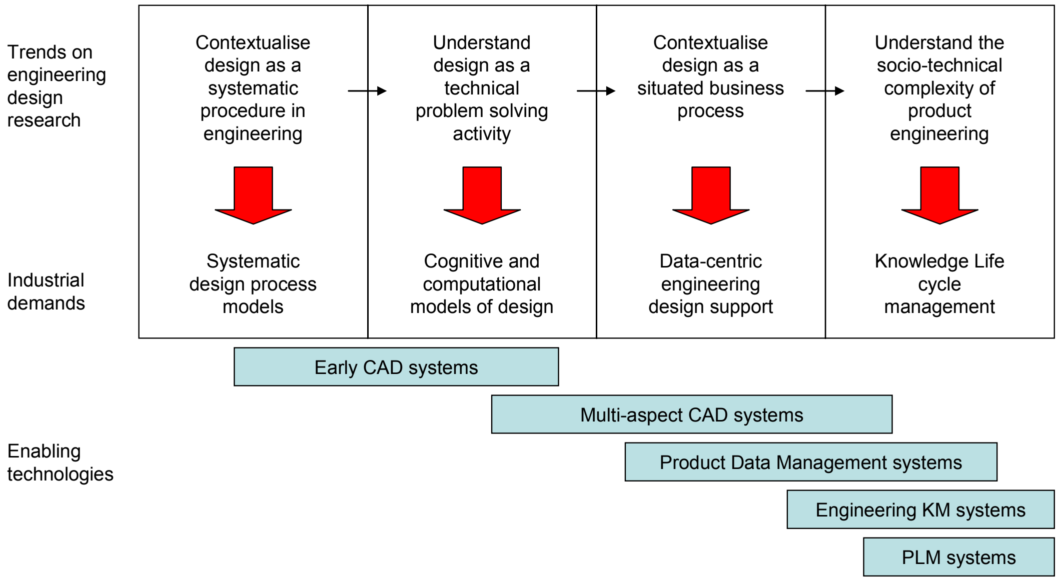


Figure 2-2. Evolution of engineering design practice.

2.2.3.1 Systematisation of industrial design

Engineering designers require guidelines to systematically carry out their activities across different projects. A consolidation of the German systematic design school of thought is the work from (Pahl and Beitz 1996) and the resulting VDI 2221 design process guide, (VDI 1987).

By the time computers were starting to be introduced in engineering problem solving, industrial design work was mostly carried out on drawing boards. It has been argued that the systematic approaches are embedded in the design culture of engineers. However, some authors argue that the impact of CAD technology and the need to respond to industrial circumstances makes it difficult to apply them with the same level of formality as they are taught in universities and colleges, (Dankworth et al. 2004).

2.2.3.2 Formalisation of engineering design for computer systems

The emergence of CAD raises the question of formalising design as an intelligent activity to be supported by computers. Simon's work (Simon 1969), apart from being a seminal reference in Artificial Intelligence (AI) has also driven much of the thinking in the research for computational support in engineering design. Simon's description of design as an ill-defined problem remains as a widely accepted reality about design processes. Similarly, the decomposition of complex systems into semi-independent components is advocated in Simon's work. This also remains as a core concept in influential design literature sources such as the Theory of Technical Systems (Hubka and Eder 1988) and Axiomatic Design (Suh 2001).

The AI in Design research community has been a key player in the realisation of current computer tools for knowledge aided design. In a retrospective editorial for the Advanced Engineering Informatics research journal, Sriram describes the last years of AI in engineering research as the application of expert systems and knowledge based systems technology in engineering design toolsets, (Sriram 2006). In fact, Knowledge Based Engineering and other design technologies aiming to achieve intelligent support for the design process are founded in this body of research.

2.2.3.3 Data-centric engineering design

The further contextualisation of engineering design as a multidisciplinary business process delivering products to the market is consolidated in the literature through Pugh's Total Design, (Pugh 1991). Evidence on the importance of work coordination and information exchange in engineering design is provided by (Hales and Gooch 2004) and also corroborated by (Crabtree et al. 1997). These studies reveal that this part of the design work takes some 50% of the engineering effort. In these empirical studies, the remaining effort is associated to those engineering problem solving activities covered by systematic design guidelines.

These circumstances raise the need of managing engineering data, especially in large scale engineering programmes. The Concurrent Engineering (CE) paradigm is a response to this issue that consider the use of computer systems in design, (Handfield 1994). CE leverages the elimination of barriers across the different players involved in product engineering by centralising product data repositories for shared access. Then the design process is sped up by concurrent rather than sequential execution.

The practical implementation of CE has driven a significant amount of research on the coordination of engineering work using IT systems. A key research initiative in this direction is the DICE project (Distributed and Integrated Environment for Computer-Aided Engineering) started by the MIT in the late 80s, (Sriram et al. 1992; Sriram and Logcher 1993; Sriram 2002). A key innovation of the DICE system is to give an infrastructure for designers form different disciplines to work together. This includes the checking for conflicts between those disciplines and the recording of the use of engineering data.

Research in these areas has been transferred to commercial software in the form of PDM systems. An essential contribution of CE and PDM systems is the centralisation of engineering data and the management of its changes. A key characteristic of these systems is the ability to relate data entities to the structure of a product, (Fan 2000).

The importance of managing data in the development of products has influenced the evolution of early CAD systems through a number of generations of the technology from 2D drafting systems to parametric and feature-based systems. A modern CAD system uses these advances to offer a design solution that allows the modelling of product data from many engineering viewpoints (Figure 2-3).

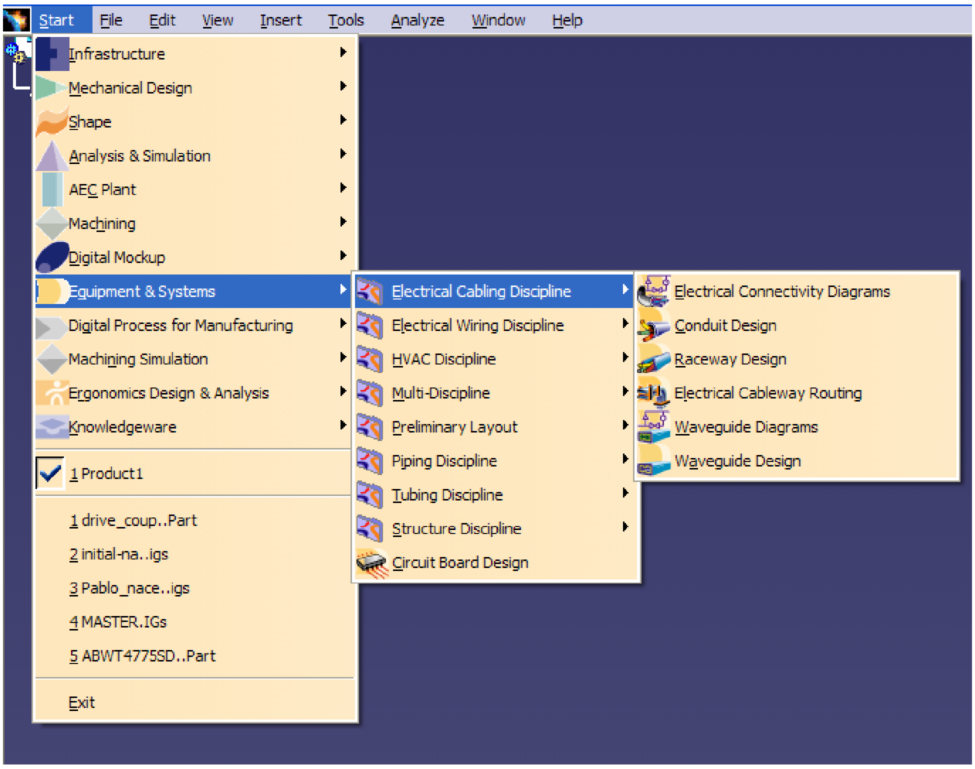


Figure 2-3. A modern multi-disciplinary CAD system.

Having engineers displaced from drawing boards and creating digital models of products has improved the efficiency of design work. This improvement is very much related to the better way of exchanging design data enabled by CAD technology. Referring to the concepts in section 2.2.1, CAD is a major advance to speed up analysis and evaluation design tasks while synthesis requires more complex cognitive qualities such as creativity.

A side effect of the emergence of CAD is an explosion of digital information that has to be exchanged across teams often using different systems. In 1984, the International Standards Organisation (ISO), launched the ISO 10303 initiative for the exchange of product data that is commonly known as The Standard for Product Data Exchange (usually known as STEP), (Owen 1997). Before STEP the major CAD data exchange standard was the Initial Graphics Exchange Specification (IGES). Apart from the exchange of geometry, the intention of STEP is to create neutral data models that are of relevance for different domains, such as automotive or electronics. The resulting data models also cover the needs at different stages of product development such as design, planning and others. The strategy used by STEP is a two stage translation in which a neutral file is written by one system. The file is the translated by another system into its native representation, (Pratt 2005).

2.2.3.4 Socio technical complexity in engineering design

Modern engineering design practice is highly influenced by the socio-technical context in which it happens. The research from Lu and Li (2006), investigates engineering work as a socially mediated technical activity. Under this viewpoint, engineering work is not seen as absolute mechanistic process that can be easily prescribed. Technical decisions are human dependent, socially sensitive, culturally related and location specific. Confirming this view, the research from Hales and Gooch (2004) identified several mismatches between observed design processes and the systematic approach described by Pahl and Beitz, (Table 2-6).

Table 2-6. Mismatch between the systematic design process and an observed design process, adapted from (Hales and Gooch 2004)

<table>
<tr><th colspan="2">Classification of observed design activities</th><th>Specific activities identified</th></tr>
<tr><td>General activities</td><td>Design team activities happening in all phases of the Pahl and Beitz design process but not covered on it</td><td>- plan activities
- create verbal or written reports/reviews
- estimate costs
- retrieve information
- make social contact
- help others</td></tr>
<tr><td>Working techniques</td><td rowspan="3">Remaining activities that do not belong to generic phases of the design process. (They could not be characterised as part of the design-related techniques suggested by Pahl and Beitz)</td><td>- Making lists
- Cost estimating
- Calculating
- Scheduling
- Filing engineering forms</td></tr>
<tr><td>Communicating techniques</td><td>- Questioning people
- Presenting viewpoints
- Negotiating agreements
- Reviewing and reporting</td></tr>
<tr><td>Motivating techniques</td><td>- Becoming involved
- Injecting enthusiasm
- Adding humour
- Team building</td></tr>
</table>

This means that in addition to the technical challenges, soft organisational constraints affect the performance of the design process as described by O'Donell and Duffy (2005). Other authors have also studied the difficulties in managing large scale design projects in which this socio-technical complexity appears, (Hobday 1998; Eckert and Clarkson 2003). In these situations deterministic design models tend to fail and complexity is handled by finding the so-called patterns of designing as described by Eckert and Clarkson (2005).

The research community has proposed frameworks like the Design Structure Matrix to manage this complexity, (Steward 1981; Eppinger et al. 1990; Kusiak and Wang 1993; Sharman and Yassine 2004). However, engineering projects go though a series of iterations not only to execute the design work but to consolidate agreements on product configurations, selection of suppliers and other non-purely technical decisions. Human factors seem to play an important role in these iterations as it has been reported by Siemieniuch and Sinclair (2006). This would explain the research results identifying that engineering organisations are progressively paying more attention to soft skills of their engineering designers in addition to hard engineering abilities (Hong et al. 2005; Robinson et al. 2005). These skills include: "personal attributes", "project management skills", "clarity of project targets" and "shared knowledge about customers".

Responding to these issues, PDM technology is being scaled up into a broader approach for data management and team coordination known as Product Lifecycle Management. The technology is aimed to become an enterprise framework for the coordination, communication and exchange of engineering data across distributed teams working collaboratively at different stages of the product lifecycle, (Saaksvouri and Immonen 2002; Stark 2005; Grieves 2006). Observing the activities listed in Table 2-6, it can be seen that apart from the motivating techniques, the rest of the activities can be supported by PDM and PLM systems connecting design teams.

PDM and PLM are becoming critical design technologies for some enterprises to operate despite of the geographical dispersion of engineering teams working collaboratively in different projects. The question still remains on how the large amounts of engineering information stored in these repositories will be retained and capitalised as intellectual property assets. According to the research from McMahon et al. (2005), an important issue is related to the shape of digital models resulting from the design process. This work acknowledges that a future research agenda for the representation of engineering models shall address the following issues:

- Semantic enrichment of engineering models such as CAD files, specification documents and others.
- Support the capture of engineering decisions, as well as the information sources triggering them.

Under this perspective, a potential future scenario consists in using PLM systems to manage the knowledge contained within data items and keeping the record of the decisions leading to them. The concept of "item" is a generic solution to deal with situations in which many types of digital files are managed within a data repository. The notion of item in PLM is commonly acknowledged as an undifferentiated managed object that has generic metadata such as owner, identifier, creation date and others. The typical granularity level of data items in PLM is that of digital files. According to Eriksson, Shahar et al. (1995) this is a coarse level of data granularity and it has caused the perception of some collaborative engineering solutions as "glorified file managers". The same report advocates for a further realisation of the PLM vision through the management of data on a finer level of granularity than at the file level. Current PLM installations include built-in metamodels designed to cover a wide scope of engineering functionalities including item annotation and storage, change management and coordination of distributed engineering teams. Besides the particular "out of the box" functionalities of each system, customised metamodels can be authored by users to respond their specific needs.

In the research agenda for the underlying technologies for enterprise systems like PLM or ERP (Engineering Resource Planning) these metamodels will be built upon advanced semantic modelling approaches, (Jardim-Goncalves et al. 2006). This can be seen as an evolution in which the research in knowledge representation techniques has been progressively transferred to software development practices. The ultimate target in this progression is the achievement of semantic interoperability for 21st century's enterprise information and knowledge management systems.

2.3 Engineering knowledge management

Up to now, the review has presented the evolution of the practice and tools aimed to handle the complexity of today's engineering design operations. Considering the current technology possibilities to process large amount of engineering knowledge, the opportunity to capitalise on the intellectual property of engineering enterprises becomes evident. Both the elicitation and representation of knowledge require additional efforts that are usually perceived as overheads. This added cost to engineering operations has always existed and associated with the documentation processes. Nevertheless, the emergence of computing technologies has, among other changes, increased the speed on knowledge retrieval and the efficiency on its reuse. In a similar way as the use of CAD has brought the need of addressing data exchange, the management of knowledge brings the need to formalise knowledge. While accepting that there is a cost, research covered in this section shows that evidence exists on the long term benefits of managing knowledge.

The research work on the engineering and management of knowledge covers its elicitation, representation and its further maintenance. These operations have deep implications in the semantic enrichment of engineering models and in the recording of engineering decisions. The adaptation of this research field within the engineering design domain is reviewed in this section of the literature review.

2.3.1 Engineering knowledge elicitation

With the development of theoretical AI, the idea of having machines with certain degree of intelligence gained prominence. The so-called "knowledge level" term, coined by Newell, refers to the conceptual layer on an intelligent computer system that does not depend on its specific implementation and that describes its problem solving behaviour and the knowledge to sustain it, (Newell 1982). This concept can be considered as a trigger for research in the KE and AI area. Similarly, much of the thinking behind Knowledge Management research is related to the knowledge level idea. Examples of this are the work from Nonaka & Takeguchi and Davenport & Prusak, considered as seminal work on the understanding of how knowledge is created and managed in organisations, (Nonaka and Takeguchi 1995; Davenport and Prusak 1998). In these influential contributions, the creation of knowledge is associated to the idea of transforming it from its tacit state into an explicit form, (Figure 2-4).

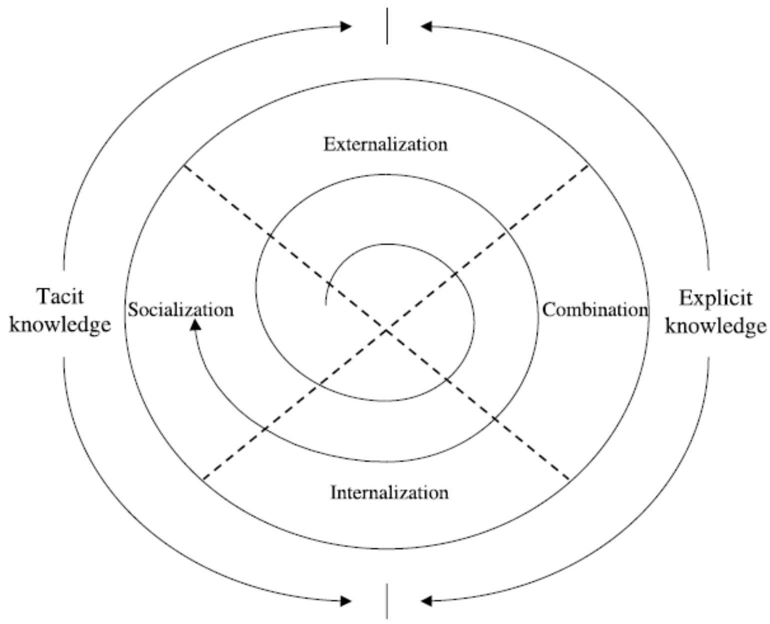


Figure 2-4. The knowledge creation process, from (Nonaka et al. 2000).

It is common to find in the Knowledge Management literature definitions of knowledge in respect to information and data. Examples are the definition of data as symbols in a numerical form and the definition of information as data within a context, (Benyon 1990). A useful example in the engineering design context is provided by (Ahmed et al. 1999). According to the authors a computer file containing numbers is data. When the data is loaded into a computer programme and it displays the distribution of stress in a part, it becomes information since it can be interpreted not only as "colourful picture". In the same example, the information becomes knowledge when it triggers a decision (i.e. "increase the thickness") in order to solve a problem (i.e. "improve the mechanical performance of the component").

In engineering teams, data, information and knowledge exist on a wide variety of formats. These are stored in a variety of containers including the minds of workers, their CAD models drawings, standards, memos, e-mails, etc. Due to the high amount of decisions to be quickly made, engineering design is widely acknowledged as a knowledge intensive task. However, the building of explicit engineering knowledge bases supporting design work is not an easy task due the diversity of the different types of knowledge needed. In fact, it can be argued that within an engineering team what is data for one person can be knowledge or information for others and so on. This makes it especially difficult to create a process to transform knowledge from its tacit to its explicit form.

2.3.2 Engineering knowledge representation

In this section, the formalisation of knowledge is studied. Specific techniques have been developed in the KE domain to make formalisation explicit for computers as well as for humans. The implementation of formal knowledge models is the basis for the Expert System and Knowledge Based System technology. The modelling of knowledge responds to the need of having explicit representations of a domain (static knowledge about cars, diseases, etc.). On the other hand it is necessary to model the reasoning process to solve a problem using static concepts that describe the domain (procedural knowledge). Several formalisms exist to declare knowledge. A simple classification is given as follows:

- **Frame based formalisms**. Use the concept of directed graphs to represent concepts on the nodes and relationships such as "is-a" on the arrows.
- **Production systems**. Use the concept of "if-then" rules to model procedural knowledge.

Most modern knowledge representation languages use a mixed approach between these to establish formalisms. In general, these languages can be classified as *vocabularies* when their structure has the shape of taxonomies using simple inheritance. On the other hand, object based representations use the notion of frames or classes as containers of instances that can be related with other frames via relationships. Using this construct, knowledge models can be represented as graphs rather than just as taxonomies. More formalised approaches to model knowledge use mathematical logics to enrich the meaning of these relationships. In general the use of these highly formal languages allows the implementation of advanced computational reasoning techniques. A common pitfall of these languages is their mathematical complexity. An emergent way of combining logic languages and frames is the use of *Description Logic* (DL)*.* DL is a subset of First Order Logic that is particularly suitable for frame representations. DL has become popular with its implementation on the Ontology Web Language (OWL) specified by the W3C. OWL models support the use of reasoning operations like consistency checks and classification.

Beyond the specific techniques for knowledge representation, research efforts in KE provide methodological support for building such systems in any domain. Using these approaches, the selection of the knowledge modelling strategies is defined in the methodology. According to (Studer et al. 1998), CommonKADS (Schreiber et al. 1994), MIKE (Angele et al. 1998) and *PROTÉGÉ* (Eriksson et al. 1994) are reference frameworks to model knowledge.

2.3.2.1 Knowledge Engineering

KE is an emerging discipline derived from the field of AI. KE focuses in the formalisation of knowledge in computer systems so it can be processed to solve domain tasks (Bench-Capon 1990). First attempts to create knowledge-based systems came up from the AI community in the form of expert systems (ES) which had encoded knowledge in the form of IF-THEN rules to perform particular tasks. However, it was demonstrated that ES's had several weaknesses such as the difficulty on maintaining rule bases and consequently their "ad-hoc" character. The emerging KE community often uses the term Knowledge Based System to describe the new way of developing systems to support out knowledge-intensive tasks. The work from Efstathiou (1990) highlights that a KBS is not a well-defined creature. However, the author establishes that a KBS is likely to possess some of all of the following characteristics:

- One or more knowledge bases able to accommodate different kinds of knowledge.

- More than one inference mechanism apart from the simplest one composed by IF-THEN structures.
- More than one way of representing knowledge in addition to rules.
- A model of the domain incorporating not only knowledge representation formats but other knowledge sources such as text-books or common-sense.
- Combination of bases containing "deep" knowledge from the experts with knowledge such as geometry or a model of a plant and its processes.
- Capabilities to manipulate acquire and maintain the stored knowledge as a tool to manage it.
- May be used to derive knowledge not known before by the experts using specific methods to derive and make conclusions from the knowledge stored.

A KE review article from Studer et al. (1998), identifies two major elements that characterise the state of the art on building KBS:

- The representation of knowledge is approached as a modelling exercise. This is distinct from the early ES approach consisting in the transfer of knowledge from experts to the system. In this perception, knowledge models are approximations to the reality and as such the modelling process is cyclic and the subject to refinements.
- Significant emphasis is put on the separation between the domain knowledge as a formal theory of the domain and the problem solving methods (PSMs) modelling the reasoning to carry out a task, (Eriksson et al. 1995; Benjamins and Fensel 1998). The former is a static model expressing the concepts in the domain as well as their relationships and constraints. In building these models the notion of computer based ontologies has become widely used. According to Gruber's (1993) definition: *an ontology is a formal, explicit specification of a shared conceptualisation*. On the other hand, PSMs represent procedural knowledge structures specifying the inference actions and the sequence followed for solving a given task.

The concepts of task, domain knowledge and PSMs are central to the current understanding of KBS. The research on the formalisation of knowledge has lead to the development of frameworks and methodologies to create KBS. The notion of KBS is closely related to the building of IT systems implementing them. Considering KBS as the underlying technology for KM, KE authors claim that their systems are only part of a KM strategy, (Wielinga et al. 1997; Shadbolt and Milton 1999). However, the research from Holsapple (2005) and Maier (2005), suggest that the use of Information Technology systems and particularly the formal representation of knowledge using computer interpretable models is an essential ingredient on KM initiatives.

A salient framework for the building of KBS is the CommonKADS methodology, (Schreiber et al. 1994; Schreiber et al. 1999). In reference to the concepts of task, inferences (PSM) and domain knowledge, the approach in CommonKADS builds upon the previous research on KADS, (Schreiber et al. 1993). Figure 2-5 shows an example in which the three elements are assembled together and abstracting the knowledge to address a particular task in a medical application. Using these elements, CommonKADS provides the infrastructure to create reusable and configurable components. The example of the figure reuses the diagnosis task template to address the particular domain problem.

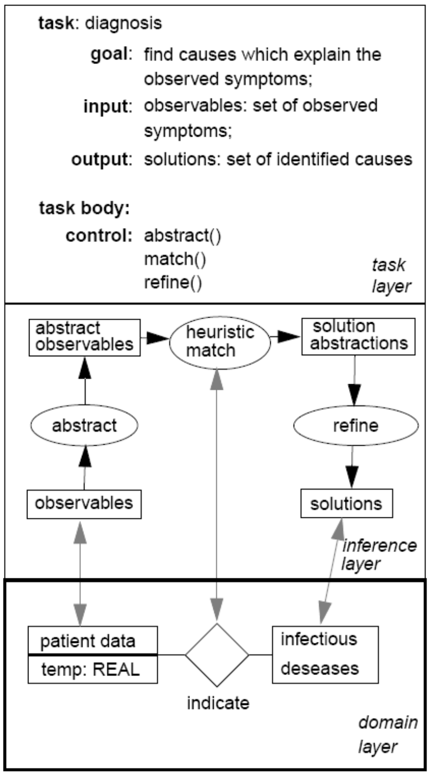


Figure 2-5. An example of task, inference and domain knowledge. From (Studer et al. 1998).

The possibility of building KBS in the engineering design domain has been investigated by many researchers. However, it is hard to distinguish if the systems resulting from this research can be classified as ES or KBS according to the parameters described in 2.3.2.1. The AI in design community has been a key player in this area. In this type of work, design systems use advanced AI techniques such as constraint satisfaction algorithms, multi-agent systems, case-based reasoning or machine learning. Some examples of these systems are listed Table 2-7.

This compilation is a sample from many systems that have been created as research prototypes. The impact of the research on engineering practice would be higher if these systems can be run on mainstream CAD systems. In general, these systems are built using object oriented programming languages and KBE technology could have been used in many of them.

Table 2-7. 10 ES/KBS systems.

System	*Usage domain*	System details
(Duffy et al. 1996) NODES	Example on a pump system	Taxonomies of concepts linked by numerical relationships
(Sanchez et al. 1997) IRA (intelligent reasoning assistant)	Design for manufacturing, metal machining intensive	Rule-based written in C++
(Yeun and Yang 1997) CORE	Ship design	Object-based knowledge representation NS
(Chao et al. 1998) NewSun	Case study on offshore petrochemical plant	Multi agent system using domain ontologies and an Object Request Broker
(Gao et al. 1998) DEJAVU	Not specified. Case study with a laptop computer hinge design	Case Based Reasoning oriented to the reuse of design plans. Lisp (using CLOS)
(Lee and Lee 1999) BASCON IV	Ship design	Case based reasoning with a learning algorithm
(Herveaux and Mille 1999) ACCELERE	Closed cell rubber products	object oriented knowledge representation with Case based reasoning based on queries NS
(Fenves et al. 2000) SEED-config	Structural design in civil engineering	Uses a semiformal abstraction of the structural design as node trees to be manipulated by users. The system is implemented using ET++ an object oriented framework built on top of C++
(Chen 2001)	Ceramic kiln design	Object Oriented representation
(Kitamura et al. 2002)	Generic but an example of a power plant is provided	Qualitative reasoning in combination with an artefact function ontology and explicit relationships with product behaviours Allegro Common Lisp

2.3.2.2 Knowledge modelling approaches in engineering design

Apart from modelling engineering design knowledge using the models described in 2.2.1 and 2.2.2 other formalisms have been developed at a higher level of abstraction. A basic strategy for an engineering enterprise to transform tacit engineering knowledge into an explicit representation is to focus on physical products (Yoshioka et al. 2004; Kitamura 2006). Product knowledge can be made explicit by extracting knowledge from experts and indexing it using predefined templates to describe their characteristics. Transforming this tacit knowledge into explicit is useful as a strategy to build product data repositories such as the one developed by US National Institute of Standards and Technology (NIST), and reported in Szykman and Sriram (2006). The actual repository can be accessed online at the Design Engineering Lab website in the University of Missouri-Rolla, (UMR 2007). It contains information on 102 products and 4624 artefacts. The knowledge captured about them includes functional models, failure modes, manufacturing processes and others. A screenshot of the repository is shown in Figure 2-6.

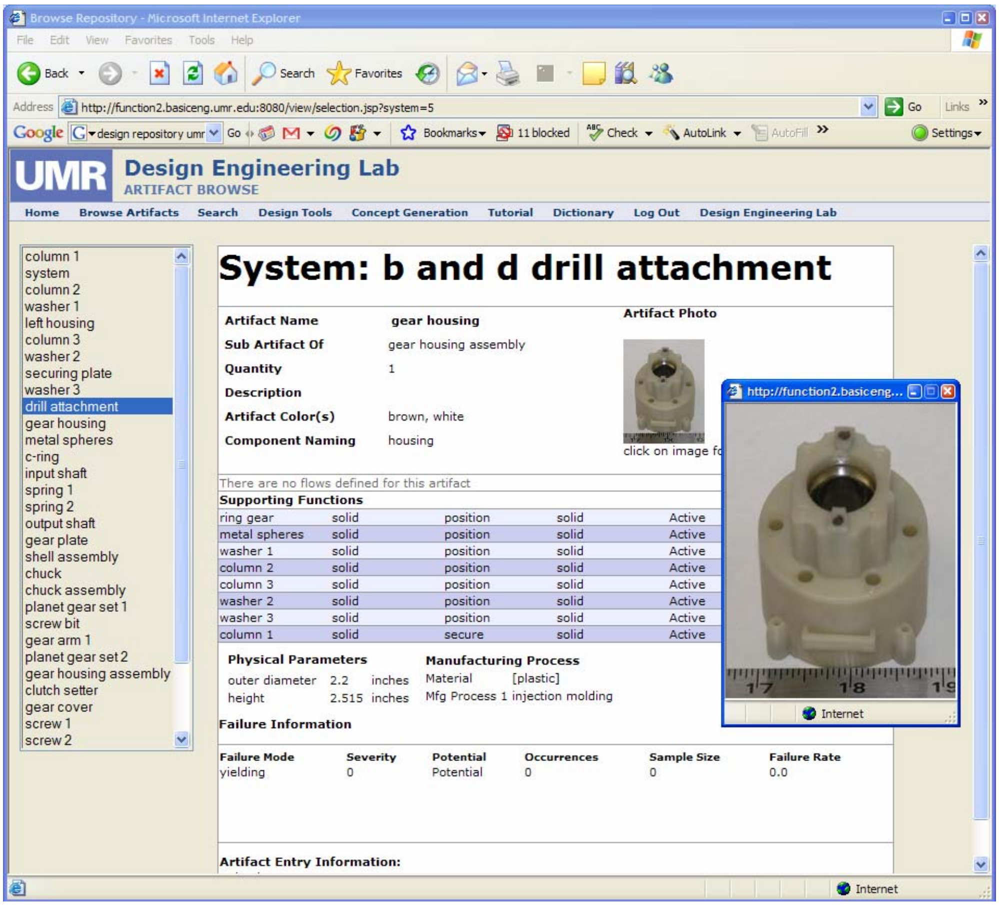


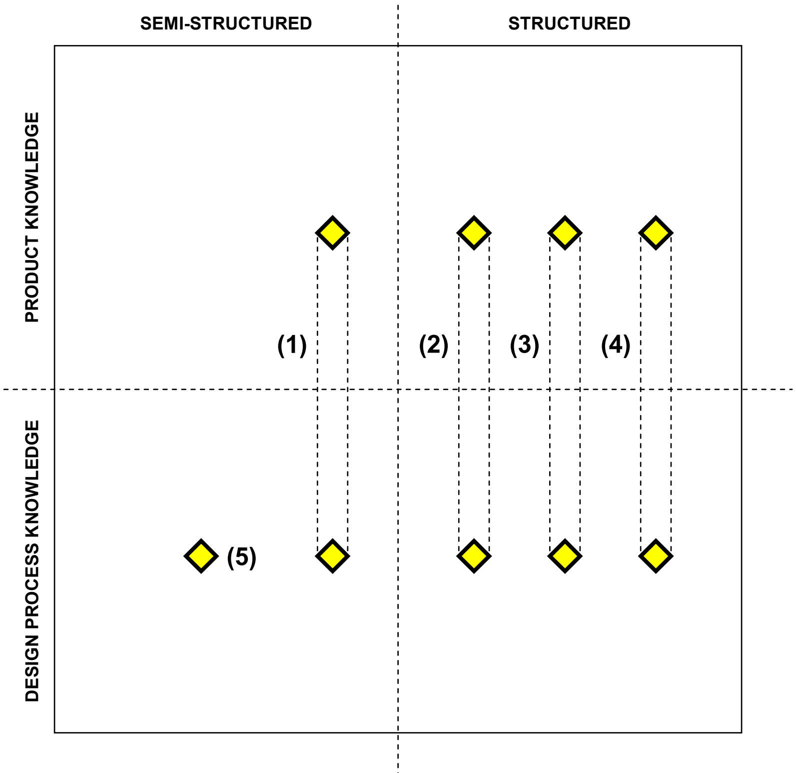
Figure 2-6. Design repository at the Design Engineering Lab, University of Missouri-Rolla, (UMR 2007).

Representing engineering knowledge using a product-component approach allows keeping a record of the design solutions that responded to certain functionality or requirements. However, as it is described by Whitney (1996), mechanical systems are functionally coupled. The distinction highlights that functions in a mechanical products does not correspond to a physical entity on a 1 to 1 relation. This is in contrast to what happens for instance in electronic circuits, where entities in the functional model (a circuit schema), tends to correspond with a single electronic component. Consequently, tracing the information that triggers design decisions makes knowledge elicitation a difficult task due to the amount of interactions between physical entities which carry out multiple functions and are related to other functions.

This raises the issue that a knowledge model about the implicit properties of products covers only a part of the total knowledge that delivers a product to the market. The research from (Li et al. 1999) investigates the types of design knowledge through a study of available literature and a study carried out through intensive interviews to European aerospace designers. The identified types of knowledge fall into the following categories:

- Design process
- Customer requirements
- Design definition
- Practical considerations
- Physical design concepts and principles

Some authors argue that the modelling of both product and design process knowledge models leads to more complete representation (Klein 2000). In this direction, the research from (Sim and Duffy 2003) analyses a number of design process models with the aim to create a unified knowledge model. A number of design knowledge models exist covering these aspects of the design knowledge. Some examples of these models are classified in Figure 2-7.



(1) MOKA informal model, (Stokes 2001)
(2) MOKA formal model, (Stokes 2001)
(3) Core Product Model and Open Assembly Model, (Sudarsan et al. 2005)
(4) The Pluggable Metamodel Mechanism, (Yoshioka et al. 2001)
(5) Design Rationale Editor, (Bracewell et al. 2004)

Figure 2-7. Design knowledge models.

A promising area of research to represent design process knowledge investigates the use "design rationale" models, (Buckingham-Sum 1996). According to (Gruber and Russell (1992), *"Design rationale is an explanation of why something is designed as it is"*. The concept has been the subject of intensive research. A number of systems have been developed including gIBIS (Conklin and Begeman 1990), PHI (McCall et al. 1990), DESPERADO (Ormerod et al. 1999) and PROSUS (Blessing 1994). A recently developed system is the Design Rationale Editor (DRed), (Bracewell et al. 2004). According to the authors, the system has been used on several engineering programmes at *ROLLS-ROYCE* (Bracewell and Wallace 2007). A screenshot of the system is shown in Figure 2-8.

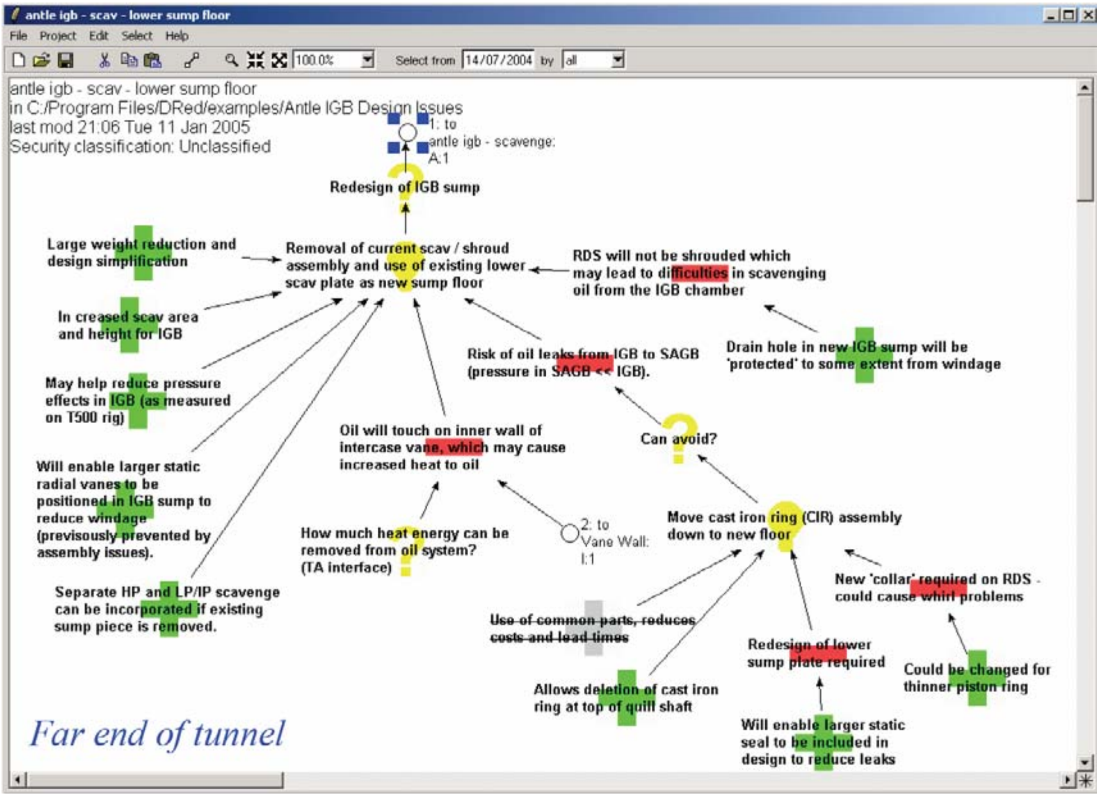


Figure 2-8. The DRed system, from (Bracewell and Wallace 2007).

The knowledge about the engineering design process strongly influence design decisions. Representing the rationale to carry out a design task is an emergent approach that also can support the capture of tacit knowledge. A significant amount of knowledge not directly linked with design technicalities influences the operation of engineering organisations.

2.3.3 Knowledge-Based Engineering systems

KBE technology allows the encoding of engineering data generation processes using specialised languages to explicitly declare the instantiation of software objects on CAD systems. Two elements are enabled through KBE technology: generative modelling and integrated modelling. The concept of generative modelling is at the heart of a KBE model. A generic model of a product can be built and new instantiations of the product can be generated from the generic model nearly instantaneously. Engineering rules can be integrated into the product model easily to model the creation of finite element meshes, process plans, manufacturing features, or cost information. The concept of integrated modelling means that the product model can be built with a predictable structure and in a modular fashion with the support of object-oriented programming. Figure 2-9 illustrates the concept of generative and integrated modelling.

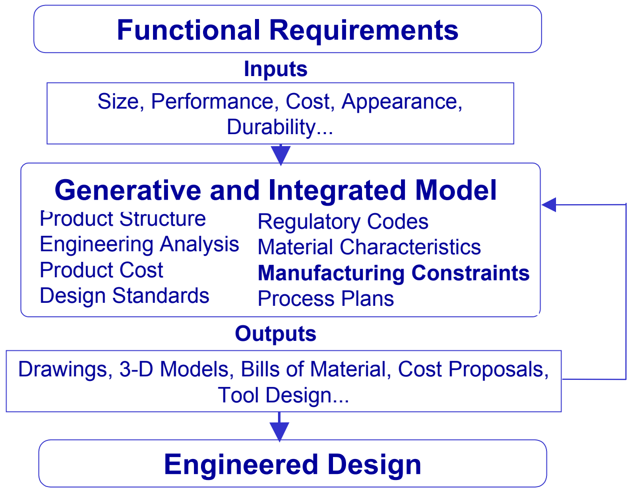


Figure 2-9. Generative and Integrated Modelling, from Cooper et al. (1999).

Using KBE, engineers can build task models leading to the creation of a wide range of engineering data elements (geometry, bills of material, etc.). KBE encompasses the technology for creating KBS together with the tools used in engineering work in the form of CAD technology. From this perspective, KBE reduces the gap between the capabilities to build intelligent systems for engineering work while keeping the interoperability with CAD systems.

The technology relies on the integration of an object-oriented programming environment and a geometric modeller. The technology has been intensively used by large aerospace and automotive companies to automate repetitive and slightly variant engineering design tasks, thus providing significant results in design time reduction (Chapman and Pinfold 1999; Cooper et al. 1999; Fan et al. 1999; Bermell-García and Fan 2002; Kulon et al. 2006).

The "Knowledge-Based" part of the acronym is not a marketing embellishment but a descriptive indication that these systems include a domain knowledge modelling infrastructure and an inference engine. The upper level knowledge model available "out of the box" in KBE tools is an abstract representation of the entities available on a CAD modeller together with a complete set of functions to define engineering rules, mathematical expressions, and many others. In practical terms, this means that a KBE developer can create a domain-specific model of an engineering process using concepts like "parts", "attributes" and manipulate CAD-specific functions such as "3D-distance", "surface-area". With this initial domain layer the scalability of the systems enables the building of more complex domain models defined through the combination of CAD entities and definitions relevant in the particular engineering context.

The application of KBE requires a new way of thinking in engineering design. By building KBE tools, knowledge about design processes is modelled and retained for further reuse. However, this new way to approach engineering design requires additional capabilities on engineering teams. On one hand, knowledge capture and modelling abilities are important to build tools that are fit for purpose and to document the knowledge that exists within them. Awareness on knowledge engineering and management techniques is also important to gain the benefits of the technology in the long term.

2.3.3.1 Commercial KBE tools

In the early 90s KBE technology was mainly implemented in large organisations like aerospace and automotive enterprises. Today, medium size engineering firms are increasingly taking on KBE technology, (Str.Direction 2005). Although it is not expected that a majority of these organisations will step into KBE, it is forecasted that the KBE market will increase in a similar rate as the CAD market, (CimDATA 2005). Table 2-8 highlights some differences between KBE users at large and medium sized organisations.

Table 2-8. Differences between large and medium size KBE users.

	Large firms	**Medium size firms**
Existing CAD technology	High end CAD tools (i.e. *CATIA v5, Unigraphics, ProEngineer*).	Mainly users of mid range CAD tools (i.e*. Solidworks, Inventor, Autocad*).
Users KBE strategy	Moving from standalone KBE systems (i.e. *ICAD*) to CAD integrated systems (*CATIA, Unigraphics KF).*	Little usage of KBE technology, Awareness on its potential.
KBE vendors delivery strategy	Few high volume contracts.	Many small contracts.
Value per KBE license	Low value per license	High value per license
Potential user needs in respect to the KBE system	Replace/supplement current KBE systems.	Introduce KBE as an added value for CAD.

According to Cyon (2003), the readiness to add value to design processes through KBE is correlated to the maturity of the organisation to manage product information using IT systems. As medium size firms mature in this direction, it is expected that the medium size KBE market will grow in the next few years. For a particular product (*StoneRule*) integrated with *Solidworks*, a mid range CAD tool, CimDATA (2005) estimates that 80% of its installations in the following years will be in medium sized design teams.

The evolution of the technology throughout 90s saw the emergence of new KBE system providers gaining acceptance next to *ICAD*, the leading tool in the market (i.e. *Intent!, AML, KNEXT*). These new systems achieved market differentiation from *ICAD* mainly by integrating their systems to CAD platforms and also by providing more user friendly ways for developing KBE applications. In the late 90s CAD vendors at the high end of the market (*CATIA* and *Unigraphics*) acknowledged these features as a way to introduce KBE in their products. Resulting from such evolution two types of commercially available KBE systems can be identified:

- **Standalone KBE systems.** These systems are independent tools that supplement CAD technology in the capture and representation of knowledge for engineering processes. Their KBE languages allow the representation of complex engineering procedures using advanced language abstractions including diverse type of conditionals and iterations. Standalone KBE systems support diverse levels of interoperability with CAD systems. This ranges from data exchange through STEP or other information formats to a closer integration via the Application Programming Interface (API) of the target CAD system. Examples of these systems are: *KNEXT, ICAD, Design ++ and AML*.
- **KBE workbenches in CAD platforms.** This type of KBE systems are an extension of a mainstream CAD suite. Typically they allow users to interactively enrich the CAD models by adding engineering constraints and rules. Normally they include a KBE language so engineering procedures can be encoded. Although these languages are evolving, they are usually perceived as less powerful than those implemented on standalone KBE systems. In exchange, they operate on the objects available on the CAD platform. The closer level of integration reduces the risk of data loses in data translations from external KBE systems. Examples of these systems are *CATIA Knowledgeware, UGS Knowledge Fusion* and *SolidWorks DriveWorks*.

Common agreement on when these two types of KBE are best option seems not to be reached. In general, standalone and code-based systems are more suitable for large applications due to the scalability of the models developed using their object oriented modelling approaches. Some practitioners remark that a major difference is that KBE workbenches require the addition of geometry in order to add knowledge to the model. In contrary code-based KBE can add the knowledge without adding the geometry.

2.3.4 The management of knowledge within KBE models

As described before, the implementation of KBE technology allows the automation of engineering design task models. In addition to this, the technology retains engineering knowledge within a model that it is not only informative but also executable.

Once the knowledge is represented within a KBE model, the next question is about how it can be managed. This refers to the reuse, sharing and maintenance of the task models built using KBE. An approach to manage the knowledge encoded with KBS is the one described in the CommonKADS methodology (see section 2.3.2.1). The management of the knowledge is described by the methodology as a process consisting on the following stages, (Figure 2-10):

- Identify existent knowledge
- Plan what knowledge will be needed in the future
- Acquire or develop the needed knowledge
- Distribute the knowledge to where it is needed
- Foster the application of knowledge in the business processes of the organisation
- Control the quality of knowledge and maintain it
- Dispose off knowledge when it is no longer needed

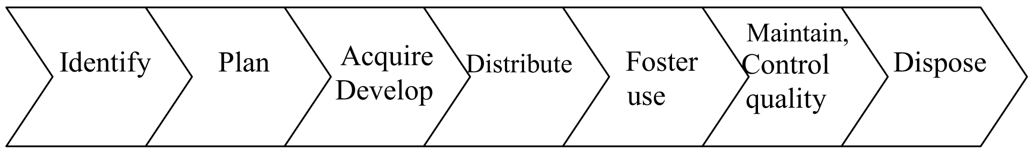


Figure 2-10. The KM process in CommonKADS, from (Schreiber et al. 1999)

Regarding to the management of the knowledge embedded within KBE models some gaps exist at the current state of the technology. An important issue in this direction is on how to make accessible the knowledge that KBE applications have encoded inside. The research reported on Fan et al. (2002) shows that the capabilities to manage knowledge contained in KBE tools is significantly enhanced by making understandable the knowledge to non KBE development experts.

Although KBE provides the infrastructure to build KBS for engineering design work, the technology has similar weaknesses to the ones on expert systems technology described in section 2.3.2.1.

2.3.4.1 Codification and personalisation aspects of KBE

The work from McMahon (2004), makes a distinction between codification and personalisation approaches to manage engineering design knowledge. This distinction refers to the role of KBS systems as the information technologies enabling knowledge management.

KBE is often presented as a codification KM instrument, (Bates et al. 1997; Chapman and Pinfold 1999; Lovett et al. 2000; Kulon et al. 2006). In fact, "out of the box" KBE software tools can be used as just codification KM instruments. However, much of the value of the technology can be found on its use as a personalisation KM instrument. Achieving this requires methodological support and organisational endorsement rather than just software tool implementation. The implementation of KBE encourages the following beneficial KM practices:

- **Reflexive analysis of engineering activities.** KBE projects usually start with the identification of a routine or variant engineering task suitable to be automated. Identifying a business case for KBE in itself brings continuous improvement to engineering practice. Furthermore, deploying KBE has other beneficial side effects like standardising terminologies, clarifying procedures and identifying engineering decisions.

- **Identification of multidisciplinary knowledge areas needed to solve engineering problems.** KBE implementations usually integrate engineering rules from different knowledge domains. Their elicitation enforces an interdisciplinary exchange of information, knowledge sharing and the establishment of collaboration networks.
- **Documentation of engineering best practices.** Either by using formal KBE codes or more informal descriptions, the knowledge about engineering procedures is explicitly retained in a way that otherwise would remain tacit.
- **Making more efficient work that is not fully supported by software systems.** Software development usually involves high costs not only associated with coding activities but also in knowledge capture and requirement definition. KBE gives a cost-effective computation solution for engineering jobs in which automation involving CAD simulation is needed and software development is expensive.

2.3.4.2 The MOKA methodology for KM in KBE

A unique approach to realise both the codification and personalisation KM capabilities of KBE is MOKA, (Stokes 2001). MOKA is a European Commission supported research project. The main partners in the project were Airbus, PSA Citroen and Knowledge Technologies International, the software vendor owning *ICAD*. Using MOKA, major aerospace and automotive companies have deployed KBE as an enterprise best practice rather than just as a solution for automating certain engineering tasks. In addition to KBE codification tools, MOKA´s methodological support includes procedures to interview experts, ontological schemas to organise the knowledge and tools for representing and publishing the knowledge across the organisation. A six steps process is suggested by the methodology from the identification of a potential task to be automated using KBE. The end result of the process is an application that is distributed and maintained to keep it up to date, (Figure 2-11).

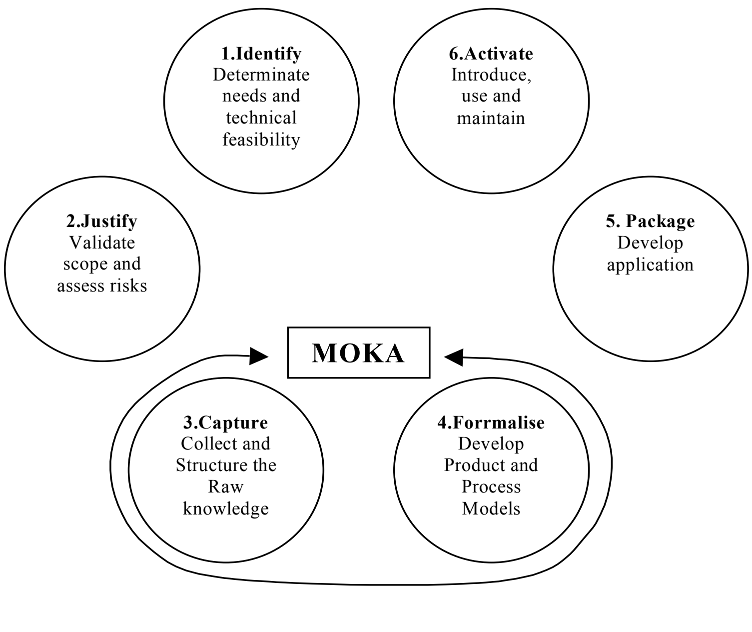


Figure 2-11. Overall MOKA methodology

The MOKA approach could be significantly improved by using PDM and PLM technologies to store and manage the knowledge. However, it can be argued that these technologies were not mature enough at the time of the project. After the EU funded period, industrial partners have found it necessary to develop extensions to the MOKA supporting tools to enable the management of changes in knowledge repositories. This drives the possibility that many of those knowledge management operations could be carried out under the PLM scope of applications.

2.4 Enterprise knowledge architectures

The learning objective of this part of the literature review is to understand the possible routes to store knowledge as a resource in enterprise data repositories. The two key areas reviewed are: interoperability research and Model Driven Engineering. The first one gives a general understanding on what are the existing approaches to handle situations such as the one described in the industrial motivation of the research (section 1.2). The second area investigates the foundations of the semantic interoperability concept and concentrates on the Model Driven Engineering framework (MDE). MDE is a major technological trend to support the semantic interoperability during the development of software systems. An important feature of MDE is the use of metamodels that model domain knowledge concepts that connect to software codes. The potential of this approach is to exploit the concept of metamodelling to describe knowledge about KBE applications that are later encoded using the programming language of a particular vendor solution.

Before covering these two concepts, the notion of enterprise knowledge architectures is introduced here. According to Maier et al. (2005) an enterprise knowledge infrastructure (EKI) is defined as follows:

> *An enterprise knowledge infrastructure is (1) a comprehensive ICT platform (2) for collaboration and knowledge sharing (3) with advanced knowledge services built in that are (4) contextualised, integrated on the basis of a shared ontology and (5) personalised for participants networked in communities (6) that fosters the implementation of KM instruments (7) in support of knowledge processes (8) targeted at increasing productivity of knowledge work.*

The author describes the architecture of an EKI as the underlying technologies realising the concept. This includes the computer infrastructures, the integration services, the knowledge services and the access services. Using enterprise knowledge architectures (EKA), knowledge is created in a variety of formats from semi-structured to structured models such as ontologies. The realisation of this is through the definition of "metadata" to annotate the knowledge and populate it on the EKA. According to the manual edited by the UK's Digital Curation Centre, in the context of keeping information records, metadata is defined as follows:

> *Structured or semi-structured information which enables the creation, management and use of records through time and within and cross*

domains in which they are created. Record keeping metadata can be used to identify, authenticate and contextualise records: and the people, processes and systems that create, manage and maintain and use them.

The definition of metadata models is a key concept to support not only the modelling of knowledge within EKIs but also the interoperability between systems that generate it.

2.4.1 Interoperability research

The delivery of common and influential models for the interoperability between IT systems is being supported by the development of semantic modelling standards. The W3C and the OMG are key global bodies of standardisation working towards achieving semantic interoperability between IT systems. Two types of semantic modelling standards are found in both communities:

- Generic modelling instruments. They are independent from the domain of application. Their target is to provide computational representations to capture the semantics of virtually any situation. Examples of this are the knowledge modelling languages associated to the W3 Consortium. This includes the Resource Description Framework (RDF), the OWL and all their extensions. Some of the modelling instruments under the OMG can be included in this category. Although their traditional scope has been in the software engineering domain, the technology behind the OMG has evolved to support generic information modelling. For instance, the Meta Object Facility (MOF) is a higher level model from which the semantic of domain specific languages like the Unified Modelling Language (UML) can be built.
- Domain-specific modelling instruments. They have emerged to meet the need to transfer generic modelling approaches into specific domains. Although the modelling instruments owned by the W3C are domain independent, they are becoming widely used to build semantic models in many domains. In the case of the OMG, Domain Task Forces deliver domain specific standards aligned with generic modelling instruments across several sectors such as telecommunications, robotics, manufacturing and others. In this model of standardisation the process is mainly driven by the industrial needs to support the interoperability between systems.

The availability of these standards and modelling frameworks catalyse research around the concepts of interoperability. In Europe, the INTEROP Network of Excellence aims to integrate the research on software systems architecture and platforms, enterprise modelling and ontology engineering to deliver interoperable enterprise systems and software systems (INTEROP 2007). This effort is closely related with the ATHENA integrated project (ATHENA 2007). The overall objective of the project is: "Contributing to enabling enterprises to seamlessly interoperate with others". The scientific target is to deliver an infrastructure for system interoperability. Special attention is paid to the exchange of semantics at three levels: business layer, knowledge layer and information and communications technology layer. The enabling disciplines to support the vision are: enterprise modelling, ontology engineering, business process modelling and information systems architecture. ATHENA covers implementation scenarios on collaborative product development and product data management in virtual networked enterprises in the automotive and aerospace domains respectively. In the United Kingdom, the EPSRC Grand Challenge on Information and Knowledge Management Through-Life led by the University of Bath is a large research effort to deliver systematic methods and tools to handle and preserve engineering design information and knowledge, (KIM 2007). Similarly, NIST has launched a Manufacturing Interoperability Programme. The aim is to leverage global manufacturing systems interoperability through the use of semantic modelling standards together with standard engineering data models such as STEP (NIST 2007). In these efforts, the reuse of data models based on ISO 10303 (STEP) standards is a common pattern. The data models in STEP are becoming aligned with semantic interoperability initiatives. An example is the participation of the team responsible for the ISO 10303-233 application protocol for systems engineering in the development of SysML, a standard supporting the semantic interoperability in the field of systems engineering (Rachuri et al. 2005). In the PLM domain, the STEP Application Protocol 214 for automotive product data is being aligned with OMG's Model Driven Architecture (MDA) in an effort to create a standard on PLM software services (OMG 2005).

2.4.2 Model Driven Engineering

The need to support interoperability has driven the development of MDE as a paradigm to support the development of software systems. MDE is a generic term to describe a new way of creating software systems that allows its business semantics to be separated from code implementations, (Schmidt 2006). The MDE concept has its origins on the software engineering domain and in particular on the research to support systems interoperability.

Although the concepts behind MDE are under development, the approach is being progressively adopted as a software engineering best practice. A number of MDE-related software development frameworks are being developed. This include concepts like Generic Modelling Environments (Ledczi et al. 2001) and Language Oriented Programming, (Dimitrev 2004). Among them, the most influential is the OMG's MDA development framework (Mellor et al. 2004). In the current status of MDE, the technology is changing the software development process up to the point that C++ or Java code can be automatically generated from abstract domain models.

According to Schmidt (2006), MDE attempts to overcome the limitations of third generation programming languages that are still closer to expressing machine processing rather than to the modelling of problem solving processes. Such distinction has been around for a long time now and it is part of the rationale on major research initiatives in Knowledge Based Systems, (Studer et al. 1998). MDE is the continuation of the effort to raise the level of abstraction from machine code to procedural programming languages to object oriented code compilation. Two elements distinguish the MDE approach from the traditional software engineering practice:

- The development of domain-specific modelling languages. These models capture the semantics of a domain language through an abstract syntax defining the entities in the domain as well as their relationships and constraints. The purpose of developing specifically tailored languages is to express the business functionality of the resulting software systems.

- The use of code generation and transformation operations. The abstract syntax can be mapped to a concrete syntax that includes the set of machine readable symbols used in particular implementation platforms to represent information. Apart from the common case of mapping high-level domain models to programming languages, the approach can be used to generate data using predefined schemas such as XML Document Type Definitions (DTDs) or XML Schemas.

The approach has significant implications to the retention of knowledge in the long term and to support the change management of software systems. The application of MDE principles is perceived as an opportunity to support the management of knowledge encoded in KBE systems. Although the technology is gaining acceptance in engineering operations, some authors are questioning its maturity as an IT practice (Poenisch and Clark 2006).

2.5 Concluding remarks

A review on the current research trends to process create, manage and store knowledge has been presented in this chapter. Special attention has been paid to the support of engineering design activities through knowledge processing frameworks. Two main conclusions for the research reported here are extracted:

- KBE technology is the application of knowledge engineering principles and tools to engineering design work. A key factor of the success of KBE is its ability to retain knowledge while building a usable toolset for CAD design tasks. However, the technology requires design engineers to become programming experts to encode applications.
- Knowledge management frameworks are a response to retain engineering knowledge in the long term. Their strength is on the readability of the information that a knowledge base like the design repository described in 2.3.2.2 can offer. However, they usually behave as library of documents that may become difficult to manage.

A significant research effort to align these two views of knowledge processing for engineering design is the MOKA methodology. Its main weakness is on the difficulty to formalise the knowledge between the level of abstraction found in the KBE code and the informal model resulting the knowledge capture (steps 4 and 3 respectively in Figure 2-11). In the formalisation stage, MOKA uses a technically robust and domain independent design knowledge model. To represent design knowledge, it uses concepts like the FBS framework described in 2.2.1. However, in practice the model is not intuitive and consequently becomes difficult to apply.

This highlights a research gap in the management of knowledge resources in engineering design. The KBE approach of executing knowledge models is not connected to a knowledge management approach to reuse, share and maintain them. The possible route to fill the gap is by using enterprise data repositories like PDM and PLM. These systems manage information resources that can be annotated for further identification and reuse through metadata attached to them. At the current state of the technology, these metadata models are not highly sophisticated. On the other hand, specialisations of these models need to be developed to annotate a wide range of possible resources that can be stored in PDM and PLM databases. A question to respond is what will be the shape of the metamodel that annotates and indexes the content of KBE resources.

To respond this question, the review section on enterprise knowledge architectures investigates the foundations on the concept of metadata models. It is found in the literature that the interoperability between information systems and the concept of Model Driven Engineering are key element to develop such metadata models. Based on this, the research takes the challenge to build a metamodel to annotate KBE codes as enterprise resources. The state of the art on metamodelling techniques allows the definition of a common language to describe KBE resources. While the literature investigation gives the foundations and the tools to build the metamodel, the rest of the thesis reports and discusses how its specific design is carried out.

Chapter 3

STRUCTURING KBE CODE FOR REUSE

3.1 Introduction

In this chapter, an initial approach to the transformation of KBE codes into EKRs resources is explored. A KBE code reuse case study is analysed in the context of wind tunnel models design and manufacturing. The traditional way of developing KBE is followed so the knowledge of the designers is transformed from its tacit to its explicit format and finally into code. A code structuring strategy based on reusable components is adopted in the case study. It is observed that the implementation project achieves time reductions and design process improvements. Furthermore, the reusable component strategy widens the potential of using the KBE toolsets and their building blocks across projects in the domain. The implications of these observations for the transformation of KBE codes into EKRs are discussed.

3.2 KBE implementation case study

In this research collaboration project the author is commissioned to build a set of KBE applications to investigate the feasibility of using KBE in the aerodynamics wind tunnel model design and manufacture domain. Aircraft Research Association Ltd. and the Aerodynamics department at AIRBUS UK, design, manufacture and test wind tunnel models. These are scaled down versions of aircraft components which are tested in a range of wind tunnel facilities. Although computational fluid dynamics (CFD) simulation is used extensively for the aerodynamic testing during the development of aircrafts, using a physical model in a wind tunnel is still an essential step to validate the design. The external shape of the wind tunnel model has to conform to the full size aircraft design. The internal structure of the model has to accommodate the instrumentation and the attachments for subcomponents while maintaining a similar structural behaviour of the full size aircraft. A typical wind tunnel test requires the collection of pressure data from a pre-determined pattern of points on the surface of the model. Using the terminology in the domain, these points are the location of 'pressure tapping' holes machined in the surface of the component. A network of tubes of 1mm of diameter runs inside the model to connect each pressure tapping to the pressure measuring instruments outside the tunnel, (Figure 3-1).

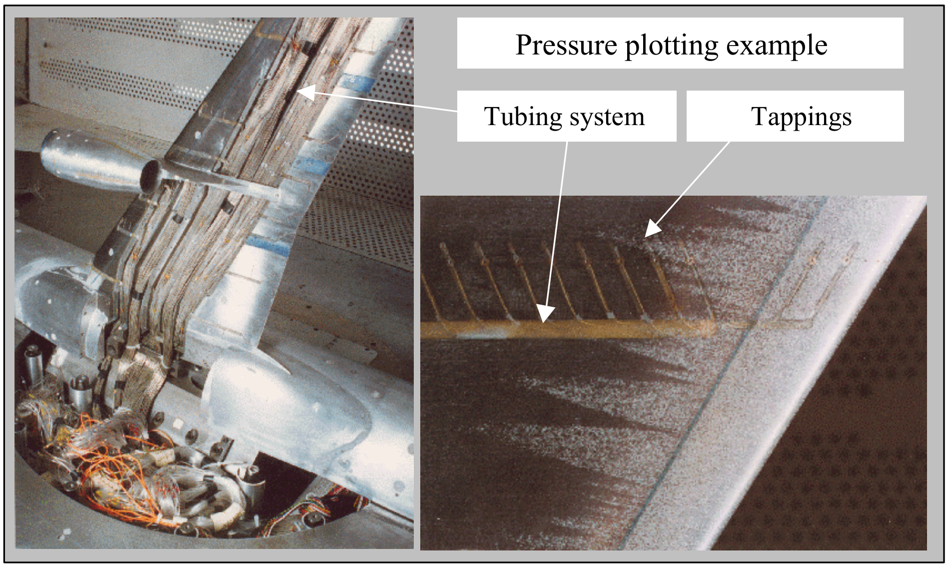


Figure 3-1 Pressure tappings and tubing system in a typical wind tunnel model component.

Introduction to KBE technology was provided to the industrial partners at the beginning of the project. This step helps to identify a suitable case study for the implementation of the technology.

An analysis of the process to design wind tunnel models is carried out, (Figure 3-2). A bottleneck in the design process exists at the detail design of the models, where a large amount of pressure measuring stations need to be positioned (red area on the process model). In this part of the process, the geometric features for the Computer-Aided Manufacturing (CAM) system are created in order to calculate the tool paths for the machining of the components.

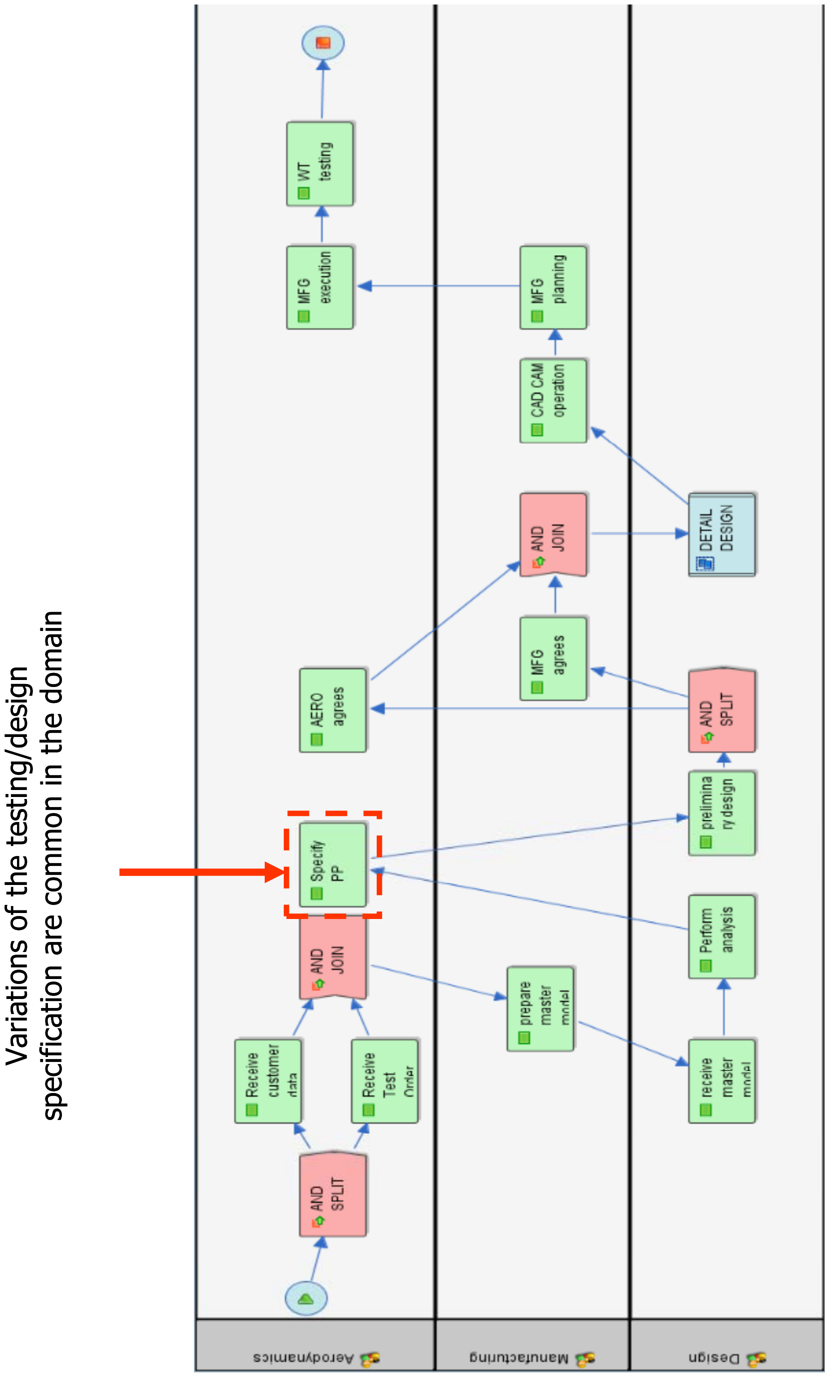


Figure 3-2. Wind tunnel model design and manufacturing process.

It was found that it is common in projects to have late changes in the specification of the tapping locations. The quick response to changes is identified as a major opportunity for using KBE. Using existing practices, the design engineers spend an average of 1 week/person of CAD operation depending on the complexity of the models. Changes in the specification cause delays that are amplified when they propagate to the workshop causing disruptions in the allocation of machines and other tooling issues.

3.3 Knowledge elicitation and representation

Two case studies are selected as representative of the type of designs jobs from which the use of KBE can give significant advantages. They are the design of an isolated nacelle component and an aircraft wing.

A series of knowledge capture meetings were arranged with design and manufacturing experts at the collaborating organisations. Information from the designer was collected using a drawing annotation method during the interviews. The method allows the researcher to gather both the concepts and methods to execute the design. It also avoids the need to ask engineers to fill forms and gives them more freedom to express their ideas.

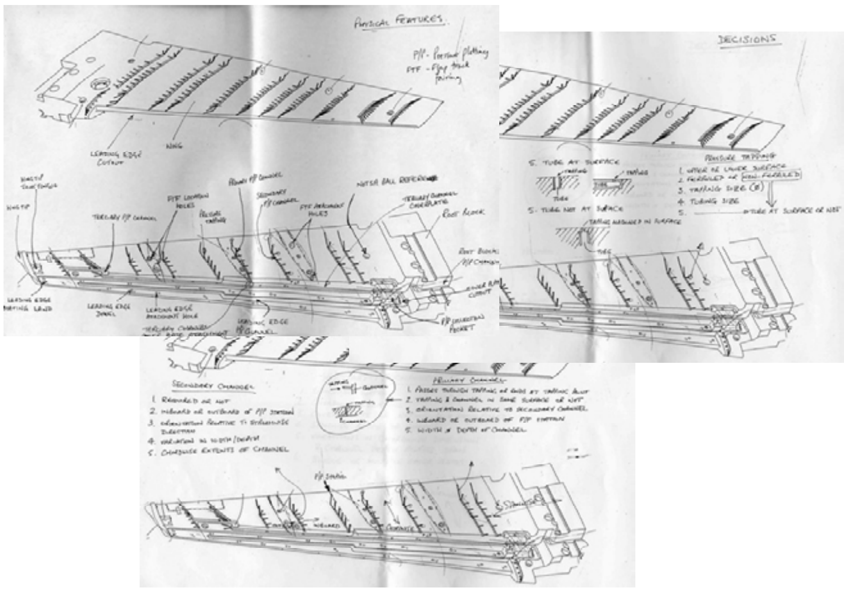


Figure 3-3. Examples of the drawings annotated during the knowledge capture interviews.

The KBE implementation project follows the procedure to transform the engineering knowledge from its tacit form into an explicit representation. Following this approach, the tacit knowledge is abstracted into an informal model. Further structuring of the knowledge uses an abstraction layer that allows the decomposition of KBE codes into reusable components, (Figure 3-4).

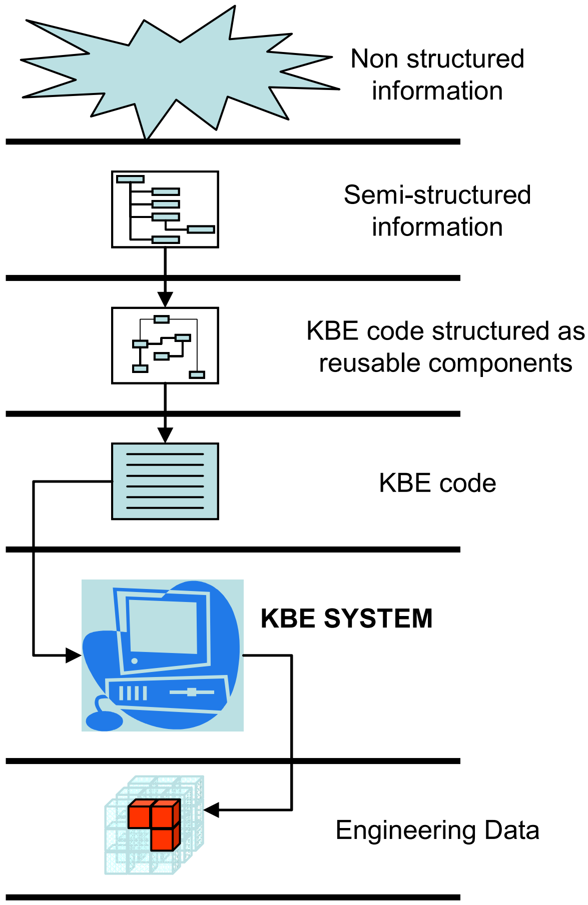


Figure 3-4. Transformation of the knowledge from tacit to explicit.

An informal schema is used structure the data collected in the knowledge acquisition interviews. The designers find difficulties on using the structure prescribed by the MOKA methodology, (Stokes 2001). This consists of a series of templates known as ICARE forms (Illustrations, Constraints, Activities, Rules, and Entities). In order to prevent the loss of knowledge caused by this situation a different informal model was agreed with the designers. The classification of information consists on the following entities:

- **Physical features**. Expresses the terminology used in the domain associated to physical elements in the wind tunnel models as well as their functionality.
- **Design tasks**. Expresses the procedural operations executed in the design of wind tunnel components.
- **Design decisions**. Expresses the engineering rules that apply in the design of wind tunnel components.
- **Consistency checks**. Expresses the constraints associated to the design and the possible checks to prevent failure modes.

Examples of the data collected from the designers are illustrated in Figure 3-5.

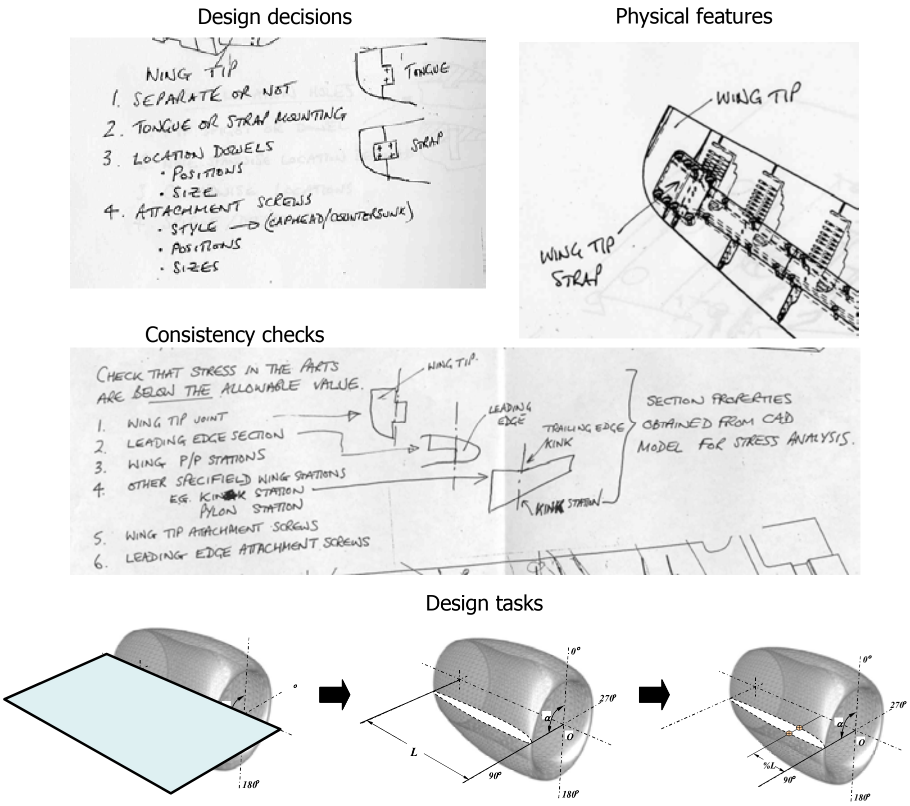


Figure 3-5. Excerpts from the knowledge capture.

A formalisation of the knowledge captured in the semi formal model is carried out by abstracting the KBE codes as reusable components. The KBE toolset used in this project was *ICAD*, (KTI 2007). The software provides support for encoding engineering knowledge using an object oriented modelling approach. *ICAD* uses an object oriented programming language built on top of a LISP implementation called *IDL (ICAD Design Language*). *IDL* is also non procedural, demand-driven and order independent language. However, the language uses a domain dependent abstraction that allows users to program "parts" by accessing the entities of a CAD geometric modeller. A screenshot of one of the applications is shown in Figure 3-6.

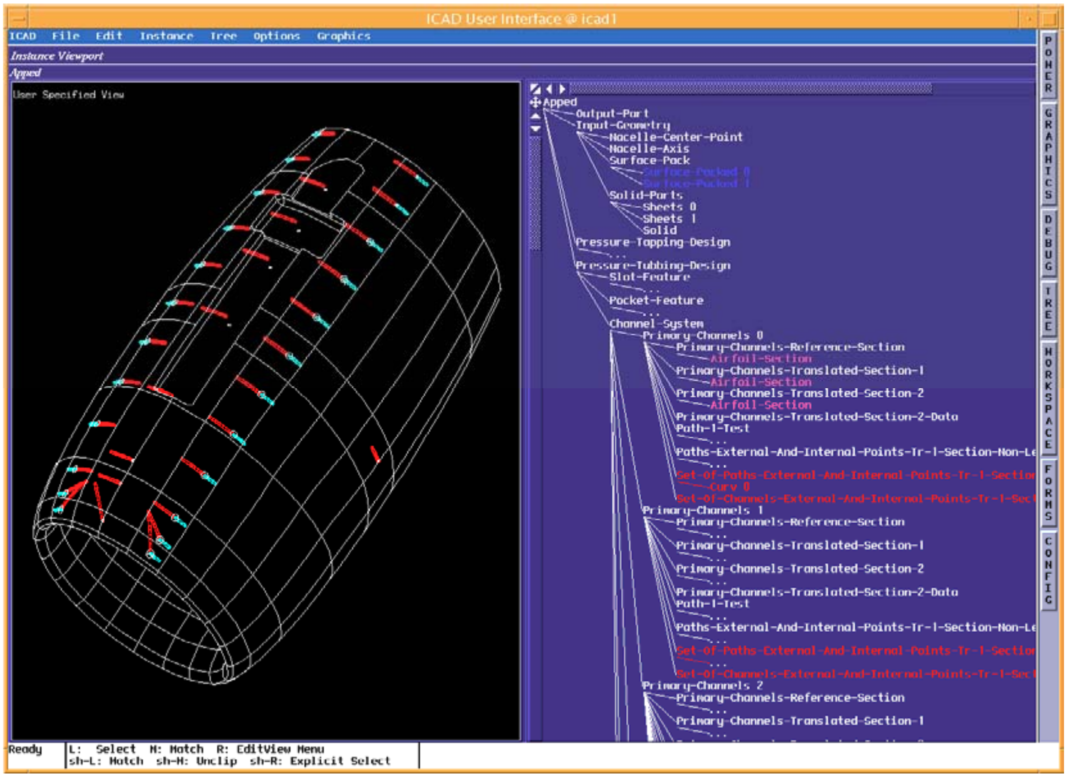


Figure 3-6 Screenshot of the KBE application

3.4 KBE component structuring for reuse

In the general software engineering domain, a debate exists on the promises of the Object Oriented paradigm (OO), to scale up systems based on code reuse. Two types of software reuse are usually described in the literature:

- **Black box reuse** occurs when pieces of code are reused across applications without the need of any modification. In this case, it is essential for potential users to know where the code is located and what it its functionality. On the other hand, the understanding of the code is not necessary.
- **White box reuse** requires a more complex approach since it requires the code to be understood in order to adapt it to a particular situation.

According to the survey research carried out by Fichman and Kemerer (1997), object orientation has not played a major role in code reuse. The research also suggests that although OO technology is consistent and well developed, other socio-technical factors influence the limitations preventing reusability. This includes the difficulties for organisations to spread out the learning on the fundamental concepts behind OO or the immaturity of the technology resulting in a lack of supporting tools. A more in-deep research study on these factors can be found on Rine and Sonnerman (1998). The research from Etzkorn and Davis (1996) argues that the eventual reuse of software components needs to be considered from the beginning of the coding process. The authors also highlight that the understanding of the overall functionality of software components is critical for their successful reuse. Other authors in the field coincide on the importance of code comprehension to support the reuse of software, (Prieto-Diaz and Freeman 1987; Mili et al. 1995; Etzkorn et al. 2001). It can be perceived that the black-box reuse it is far from being fully realised. Recommendations point out to the documentation and understanding of code since white box reuse is a more common case. In this direction, the work from Lattanzy and Henry (1998) proposes organisational structures in which black box reuse is encouraged and white box reuse is commissioned to a specialised teams that may re-structure the code to make it more reusable. The reusability issues described above are very likely to be amplified when the software development refers to that in KBE. The reason is that this type of coding is carried out by engineers rather than computer scientists.

KBE software objects hold an abstraction of how a particular engineering problem is solved. This includes detailed information on the operations required to instantiate a range of CAD entities available in the system. Given the engineering purpose of KBE, modularity of the code for reuse can be associated to modularity of the design process. The notion of reusable KBE components is introduced here as a strategy to decompose applications into self-contained units of code that can be reused. The remaining question is: what is the criterion for grouping code entities that promotes reuse? The research from Ahmed and Wallace (2005) suggests that indexing design knowledge (i.e. reports) according to the issues in which it is useful and its role in the design process encourages its reuse. The concept is extrapolated to the grouping of KBE components as groups of KBE software objects. Following this approach the identification of KBE components can be facilitated by considering the engineering task executed and the particular procedures captured from practitioners.

3.4.1 Case study implementation

The case study in this part of the research analyses two applications in the wind tunnel domain. The objective is to explore the possibility of reusing code from one to another. It is realised during the research that this largely depend on the way the knowledge and the KBE software objects are decomposed within the code. A special consideration in this decomposition is to make it intuitive by associating reusable components to steps taken in the design process. Notice that this may not be the solution that makes the running of the code more efficient in pure software engineering terms.

According to the analysis of the problem illustrated in Figure 3-2, 5 design issues are identified as the task that each of the components of the resulting KBE application has to address:

- Introducing the design specifications into the KBE system
- Importing the customer's geometry model
- Allocating the pressure tapping points in the surface of the wind tunnel component
- Modelling the pressure tapping entities
- Extracting the data for further steps of the design process

The data captured from the designers during the knowledge capture interviews is used to elicit the terminologies used in the KBE code, to understand the procedures associated with each issue and the rules that govern the behaviour of the application. Figure 3-7 illustrates the component structure used in the two KBE applications developed.

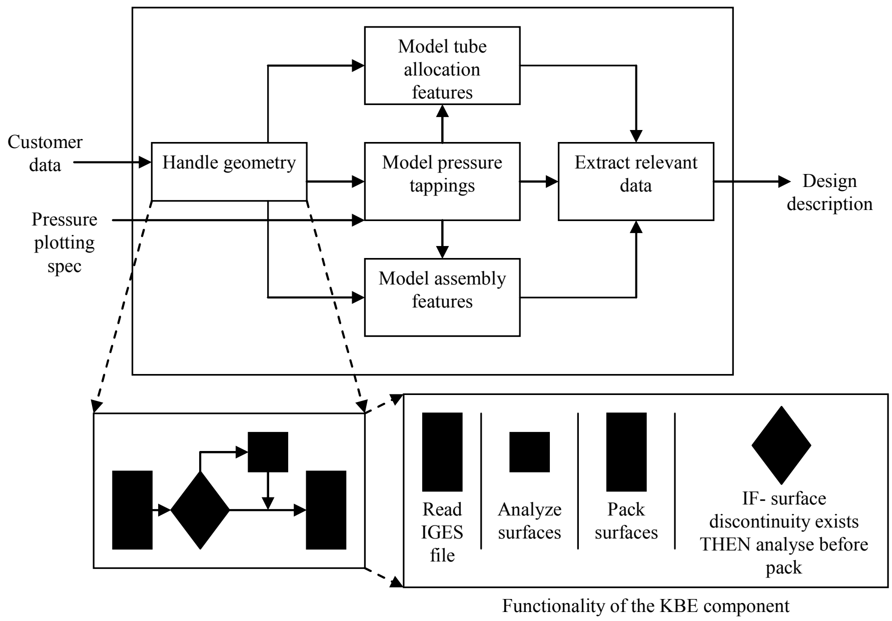


Figure 3-7. Component structure of the applications.

A KBE component contains one or more software objects. This facilitates the modularisation of code and its decomposition into sub-functional units. Altogether, the objects specified within a KBE component are a complete unit of functionality. In *ICAD*, the "mixin" construct is used to link the objects within a component. The construct exists in other KBE systems such as UGS Knowledge Fusion and it expresses multiple inheritance relations between objects. In the KBE component decomposition, it expresses that one object receives knowledge definitions from other objects. The knowledge structuring schema handles Engineering Rules defined in the code as special entities and explicitly represents them to enable their management by people with no IDL skills. This capability is available by the use of a rule level knowledge management system specifically developed for *ICAD*´s KBE applications. Detailed documentation about such system can be found in Fan et al. (2002).

Following this approach, a library of KBE components is created from the first KBE application developed. Then, the development of a new application is facilitated by the assembly of existing KBE components. For this purpose, the encoded software objects are created with commitment to a protocol that explicitly describes the inputs and outputs of every component in the KBE application. The specification of the problem solving model by engineering experts has to be therefore complemented with an analysis of the requirements in terms inputs and outputs of the software components that will be instantiated. The KBE component decomposition facilitated the reuse of components from the nacelle to the wing design applications covered in the case study, (Figure 3-8).

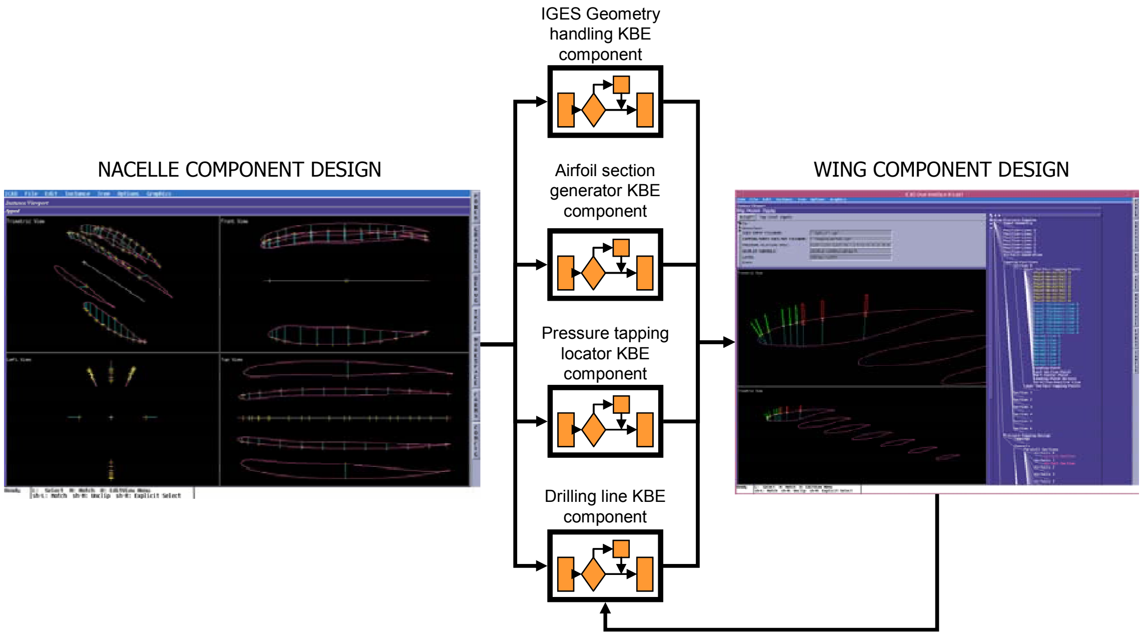


Figure 3-8. KBE components reuse across applications.

Three modes of reusing the KBE code at the component level were identified. Their description using examples from the applications are listed as follows:

- **The KBE component is reused from one application to another as they are (black box reuse)**. An example is the Geometry handling component. In the nacelle application, intense effort was dedicated to build the KBE objects that prepare the geometry received from the wind tunnel test customers as an IGES file. The component had to be designed in a way that cleans non relevant entities and analyses the continuity of more than 200 surface patches before packing them into a simpler surface entity. The scope of reuse of this component is not only the wing component application but any future KBE application requiring a secure method of handling surfaces in the IGES format.
- **The KBE component is reused with modifications (white box reuse)**. An example is the component originally designed to generate airfoil sections. In its initial version, it used an axis around which intersections with the nacelle component are created at the angles described in the pressure tapping design specification. Updates were made in the code so multiple axis can be specified for a linear arrangement of the airfoil sections instead of the radial one used in the nacelle. Apart from this modification in the root object of the component, other objects included on it remained unchanged.
- **The KBE component is replaced due to updates of the knowledge**. A third mode of reuse is identified in the case study. An illustrative example of this case is the component that models the pressure tapping manufacturing features. The original component developed for the nacelle design used manufacturing rules to create line entities that the CAM software can use to generate the machining tool paths. In the re-engineered component a significant amount of modifications allows the selection of a 3-axis or 4-axis milling manufacturing strategy. Depending on this selection the machining paths are either aligned with the Z-axis or normal to

the airfoil section. This is useful for the manufacturing planers to optimise the allocation of machining jobs to the available machines in the workshop since the design is updated almost instantly.

3.5 Observations made from the case study

The implemented KBE applications demonstrated the feasibility of using KBE technology in the particular domain of wind tunnel model design. It was reported by ARA that the design work performed by the application in a session of two hours would take about one person/week of repetitive and slightly variant modelling tasks. In this part of the research the reuse of KBE code fragments is analysed. Different patterns of reuse described in the generic software engineering literature are identified.

At the KBE encoding level, a structuring method based on components was implemented on a reuse and maintenance scenario. Based on the case study, the following guidelines have been developed to facilitate this decomposition:

- A KBE component shall address an issue necessary for the complete execution of the application.
- In structuring applications into components it may be useful to map the overall design process to identify issues that can be efficiently solved using KBE.
- A KBE component shall be able to be run independently in other applications in the case it is applicable.
- A KBE component contains a representation of the detailed procedure by practitioners to address the issue that it covers. This may include CAD modelling procedures, calculations and other data processing operations.

3.6 Implications for KBE resource management

The implications of the research to transform KBE models into enterprise resources are discussed in this section. In reference to the scope of this research they are discussed in respect to the following topics:

- The contextualisation of KBE within engineering design processes.
- The management of engineering design knowledge.
- The use of enterprise knowledge architectures.

3.6.1 Contextualisation of KBE within engineering design processes

It is observed that the analysis of the process leading to wind tunnel designs facilitates identifying the design role of KBE toolsets in the domain. The result from the design process analysis finds a bottleneck that can be approached using KBE. Furthermore, the decomposition makes a relationship between the encoding strategy and the design process. Although, the language used (*IDL*) is non procedural, there is an underlying sense of a design procedure in the code. This view is unveiled when the engineering functionality of the application is analysed and expressed in Figure 3-7 as a way of describing its components. This part of the research gives an insight on the usefulness of decomposing KBE applications for efficient reuse. On the other hand, it is realised that a process view on the code facilitates its comprehension. At this stage of the research, it can be seen that the design process workflow described in Figure 3-2 could have embedded processes like the one in Figure 3-7. However, no formal connection exists to link both representations of the overall design process and the procedure followed by the application to execute the design.

3.6.2 Management of knowledge

Some observations are made on the management of the knowledge embedded in KBE applications structured as components:

- The reuse of code is supported by the decomposition of KBE components. It is observed that considering the reuse of the components from early stages of the KBE development facilitates the roll out of the technology across projects in the domain.
- During the research, different configurations of the components were tested. This is an iterative process until a satisfactory configuration is reached. It was observed that the same functionality for the user can be built within *ICAD* using different decompositions. This is related to the role played by the expertise of the KBE developer to foresee reusability.
- Reuse happens at different levels of granularity including components, objects and also expressions within a particular object.
- The structuring of applications into components and their documentation enhances the knowledge sharing capabilities of KBE applications by enabling non *IDL* trained people to understand the overall functionality of KBE components.
- The decomposition into components as a strategy for KBE development facilitates the re-engineering of KBE codes using an adaptive process.
- It can be seen that a change management for KBE components is necessary so existing application can gain the benefits from enhancements on the components.

3.6.3 Enterprise knowledge architectures

The concept of reusable knowledge components is associated to the ability to create libraries form which these components can be retrieved and reused. The idea of has been subject of intensive investigation since it was proposed by the US Advanced Research Projects Agency (ARPA) in 1991, (Neches et al. 1991). It is argued by Gomez-Perez and Benjamins (1999) that the concept influences the architecture of modern KBS that separates the domain and inference knowledge as illustrated in section 2.3.2.1. The research from Li et al. (1999) proposes the value of the approach in KBE implementation.

3.7 Concluding remarks

This chapter explores the concept of reusable components in the context of KBE implementation. The analysis of the case study shows that a decomposition of codes into components is a feasible strategy for KBE implementation considering reuse at early stages. In this approach, the understanding of engineering procedures in which KBE plays a significant role is an important element to identify jobs that are more suitable for reuse.

This initial research phase leads to the notion of transforming XKMs into EKRs. An EKR is a XKM that becomes explicitly documented facilitate the comprehension of its content. Since a documented XKM can be understood, it becomes more easy to index and store as resource that can be managed. In a research roadmap to achieve this KBE resource management concept, two key points are highlighted:

- An initial approach is the documentation of XKMs as it was done in the case study reported here. A specifically designed approach for this is not available so KBE engineers have used their own particular methods. The notation used in section 3.4.1 is the particular example used in this research.
- A further step into the systematic documentation of XKM as enterprise resources consist on developing a more formal approach to describe KBE resources. A notation is useful to document KBE applications. However, a more formal data model is necessary to support the discovery and retrieval of KBE resources within enterprise repositories. Such model shall capture the semantics of the engineering functionality of the application as well as its component structure.

Chapter 4

INDUSTRIAL VIEWS ON THE TRANSFORMATION OF XKMs INTO EKRs

4.1 Introduction

Chapter 3 introduces the concept of managing XKMs as resources that can be adapted and reused through the notion of components. From this insight, the idea of managing KBE applications as annotated resources has been exposed to the community of researchers, users and vendors. The main vehicle for this is the participation during the research on a standardisation activity for KBE technology.

Through a time span of 8 months, the research involves the participation in an international standardisation effort to support the interoperability between KBE software systems held at the Object Management Group. In this activity the researcher is responsible to encompass the multiple views on KBE from the international consortium in the OMG with his own KBE experience. In the context of this research, this step exposes the concept of XKMs as enterprise resources to a community of researchers, technology users and software vendors. The major outcomes for the research are:

- 5 requirements that an abstract syntax to describe XKMs has to satisfy.
- A ranked set of business functionalities that the data model for XKMs as enterprise resources has to fulfil.
- 2 use cases where the data model for XKMs as EKRs has to be applicable in.

4.2 Collecting the industrial views

The OMG has been playing a proactive role in establishing standards to achieve software interoperability in a variety of strategic application domains. Domain Task Forces (DTFs) cover areas in Business Modelling & Integration, C4I, Finance, Government, Healthcare, Life Sciences Research, Manufacturing Technology & Industrial Systems (MANTIS), Robotics, Software-Based Communications and Space. DTFs are composed by representatives from industry, academia and government agencies. OMG membership costs are transformed into business advantage by influencing and having privileged access to emerging software standards and technologies.

The work to create the standard follows a procedure in which its requirements have to be prepared and approved by the OMG. The activity leads to the preparation of a request for proposal (RFP) on "KBE services for PLM", (Appendix A). The author is responsible to edit the technical content of the RFP and to harmonise the views of the different players involved in the activity. The RFP went to the rigorous approval procedure of the OMG's Architecture Board who evaluates the correctness of the requirements as well as their industry impact.

The standardisation process has attracted industrial interest as a strategy to capitalise on the efforts invested in KBE and to coordinate its deployment across engineering programmes. Up to 15 participants represent organisations with some interests on KBE. This includes representatives from *NIST*, *NASA*, *Airbus*, *Dassault Systems* and others. The participation of these agents is either direct (as OMG members), and indirect (as external contributors). The initial work carried out during the interaction with the OMG consortium is the set of 5 KBE functionalities that an abstract syntax for XKMs has to describe. From the modelling point of view, an "abstract syntax" describes the type of constructs that compose a XKM. This is a typical target on interoperability efforts. An abstract syntax describes at the semantic level the constructs that a particular concrete syntax can represent. On the other hand, a concrete syntax is formed by the specific symbols used by a platform specific model to represent the same information. A simple example of this is the UML as an abstract syntax of the C++ programming language.

For the community of researchers, KBE practitioners and software vendors involved in the standardisation activity, the concept of transforming XKMs into EKRs is interpreted as the integration between KBE and PLM systems. Responding to this, the scope of the requirements is extended to the semantic interoperability between constructs at the KBE abstract syntax and other abstract models describing PLM functionalities. Although specific requirements for the later are not specified, the RFP suggests the approach of treating XKMs as "items". In this view, basic PLM operations such as change management can refer to any of the 5 functionalities solicited in the RFP.

4.2.1 Research background on KBE/PLM integration

The engineering community accepts the progressive introduction of PDM and PLM technologies as a major strategy in highly distributed product engineering operations. The vision, the concepts and the generic roadmaps to transfer the PLM vision into particular industrial situations can be found in various literature sources, (Saaksvouri and Immonen 2002; Stark 2005; Grieves 2006). Similarly, the perception of the technology as a "success formula" in increasingly complex product-service systems and global markets is being suggested outside the software vendor circles (Str.Direction 2005). These appreciations together with the influential agendas of software vendors are positioning PLM as the container for the intellectual capital of engineering organisations. However, on a wider research context, hesitation exists on the capabilities of PLM to sustain the digital data storage for long product lifecycles (McMahon et al. 2005).

The integration of KBE within product lifecycle systems is early discussed as a need for future engineering support tools by Penoyer et al. (2000). The research from Subrahmanian et al. (2005) suggests that a possible path to realise the PLM concept as a strategy for knowledge capitalisation is by leveraging the integration between existing standards related to PLM. This includes not only product engineering data schemas but also other standards for information modelling and formal knowledge representation. Similarly, a KBE/PLM integration roadmap has been suggested by Prostep-iViP association on a study on product engineering strategic areas as subjects of attention up to the year 2010. According this work, a combination of different standards on information and data modelling like STEP, UML, XML and others shall contribute to realise the integration, (Table 4-1).

Table 4-1. KBE/PLM integration roadmap, from (Lukas et al. 2005).

Timeline	***Targets to be achieved***
By 2007	Implementation of KBE applications with the support of CAD systems.
By 2008	Knowledge integration among CAD tools and management systems in PLM environments. Standardisation of the knowledge representation with the use of standards in information modelling (STEP, UML, XML, etc.).
By 2009	Implementation of a framework for integrated product development in a KBE environment.
By 2010	Integration of the KBE framework with a PLM environment.

At the bottom line of these initiatives semantic modelling standards will play a significant role. Examples of standardised modelling frameworks are the Semantic Web for e-business and web based systems supported by the W3 Consortium, (Daconta et al. 2003) and the MDA for interoperability between IT systems, owned by the OMG, (Mellor et al. 2004).

4.2.2 Survey objectives and design

A survey strategy is used in this part of the research to gather the views of major industrial players regarding the transformation of XKMs into EKRs. An important feature of any metamodel to annotate information resources is to have a level of acceptance among its potential users. For instance, a highly expressive metamodel written using the most advanced modelling techniques can be unfit for purpose due to the lack of acceptance of the users. An example of this is the MOKA formal model mentioned before in the thesis. The learning objectives are fixed as follows:

"To develop and validate the basic requirements for a data model that expresses the functionality of XKMs"

"To understand the needs of key KBE users and vendors on the transformation of XKMs into EKRs."

In order to achieve this objective, a survey is designed to collect and analyse data from KBE experts. The use of interviews and other qualitative research methods as a mean to elicit the needs for future support systems is a common practice in engineering design research, (Li et al. 2000a, Lowe et al. 2004). The survey research is designed as a two stages process. A detailed description of the activities carried out at each stage is described as follows:

In this first stage of the survey data is collected using focused group meetings at the OMG technical meetings. Non structured interviews are carried out with KBE/PLM technologists outside of the OMG. The details on the participants involved at this stage are shown in Table 4-2.

Table 4-2. Participants on the first stage of the survey.

Participants	***Data collection***	***Research Outcomes***
Aerospace (6) Automotive (1) Software vendors (4) Government agencies (2) Academia (2)	KBE info day 11 presentations focused on KBE standardisation collected	Opportunities to launch a KBE services standardisation effort identified.
	2 OMG technical meetings	Scope of the standard adjusted to "KBE services for PLM"
	3 Off-line interviews with KBE/PLM practitioners	Edition of the RFP document
	1 OMG technical meeting	KBE services for PLM RFP approved by the OMG's Architecture Board. Two letters of intent received.

In these activities, the definition of an abstract syntax for KBE and the integration of this model as the way to describe EKRs guides the discussion. The first outcome of the research is the set of 5 requirements for describing the functionality of KBE as specified in the RFP. On the other hand, the analysis of the data collected helps to narrow down a set of 10 business functionalities and 2 potential use cases for the integration of KBE and PLM technologies. The elicitation of this information is the basis for the second stage of the survey.

Table 4-3. Participants on the second stage of the survey.

	Organisation type	Organisation size	Position in the organisation	Role in respect to KBE			*Role in respect to PLM*			
				D (1)	**U** (2)	**S** (3)	**IR** (4)	**A** (5)	**U** (6)	**D** (7)
Participant 1	Consultancy/ Software vendor	Between 1000 and 2000 employees	R&D director	X		X				X
Participant 2	OEM aerospace	More than 2000 employees	Senior aerospace engineer	X	X	X	X	X	X	
Participant 3	OEM aerospace	More than 2000 employees	KBE product line manager	X		X	X			
Participant 4	OEM aerospace	More than 2000 employees	Associate Technical Fellow	X					X	
Participant 5	Consultancy	More than 2000 employees	Engineering automation deputy manager	X					X	
Participant 6	OEM aerospace	More than 2000 employees	Knowledge engineering team leader			X	X			
Participant 7	Research org.	Between 1000 and 2000 employees	Lecturer and aerospace engineering course director	X	X		X	X	X	

(1) Developer of KBE applications; (2) User of KBE applications; (3) Provider of software support for both KBE users and developers; (4) Part of the team responsible for implementing PLM in the organisation; (5) Administrator of a PLM solution in the organisation; (6) User of the PLM solution in the organisation; (7) Part of a PLM software development team.

In the second stage of the survey data is gathered through interviews guided by a structured questionnaire, (see Appendix B). The aim of this study is to rank the importance given to the business functions and the use cases elicited in the previous stage of the survey. The seven practitioners taking part of the study are either at the user or the vendor side, (Table 4-3). All of them share the following features:

- They have responsibilities closely related to KBE and PLM implementation. In particular, all the interviewees hold leading positions in their organisations related to KBE technology. As an exception, one of the participants recently retired from its position after more than 20 years of KBE development activity in a large aerospace Original Equipment Manufacturing (OEM) organisation.
- They have extensive experience on the deployment of KBE technology and exposure to KM and PLM practice. All the participants have been users of the first KBE system in the market (*ICAD*) and have seen the evolution of the technology since then. All of them have more than 10 years experience in KBE.
- They belong to engineering organisations large enough to have a corporate strategy for KBE implementation and PLM interoperability. This includes one member of an academic institution. She has been in charge of KBE strategies in several research programmes in the aerospace domain. All the participants declared in the study that the integration of KBE and PLM is part of their vision of future product realisation technologies.

A final outcome of the study is a ranked set of business functionalities and use cases that the interviewed participants expect to be fulfilled from the KBE/PLM integration. The criteria for ranking them is based on the relevance that participants assign to each of them according to its alignment to the short and long term KBE/PLM integration strategies. Values from 1 to 5 are assigned to each of the business functions in order to weight their importance so 1 and 5 represent the minimum and the maximum relevance respectively.

4.2.3 Survey results

4.2.3.1 Requirements of an abstract syntax for XKMs

KBE-enabled modelling tools use a domain-specific language particularly expressive for the specification of data generation processes using a CAD engine. The set of operations that a KBE system is capable to represent include the definition of engineering rules, domain-specific parameters and other constructs. While this represents an abstract syntax for describing KBE functionalities with certain level of commonality across systems, a concrete syntax is tied up to the specific KBE language available in the particular system language. The research identifies a set of five basic entities that can be used as a high-level language for expressing the functionality of XKMs. They are listed here:

- *(1) The assembly of CAD data instantiation objects to model the target engineering problem solving task as well as the clarification of how these software artefacts interact,* (Figure 4-1).
- *(2) The assignment of domain-specific terminologies to the internal attributes of the assembled CAD data instantiation objects,* (Figure 4-2).

- *(3) The creation of data attributes with special significance in the domain-specific problem to be addressed by the KBE application,* (Figure 4-3)*.*
- *(4) The definition of relationships between the attributes explicitly declared in the application,* (Figure 4-4).
- *(5) The definition of engineering rules capturing engineering decisions,* (Figure 4-5).

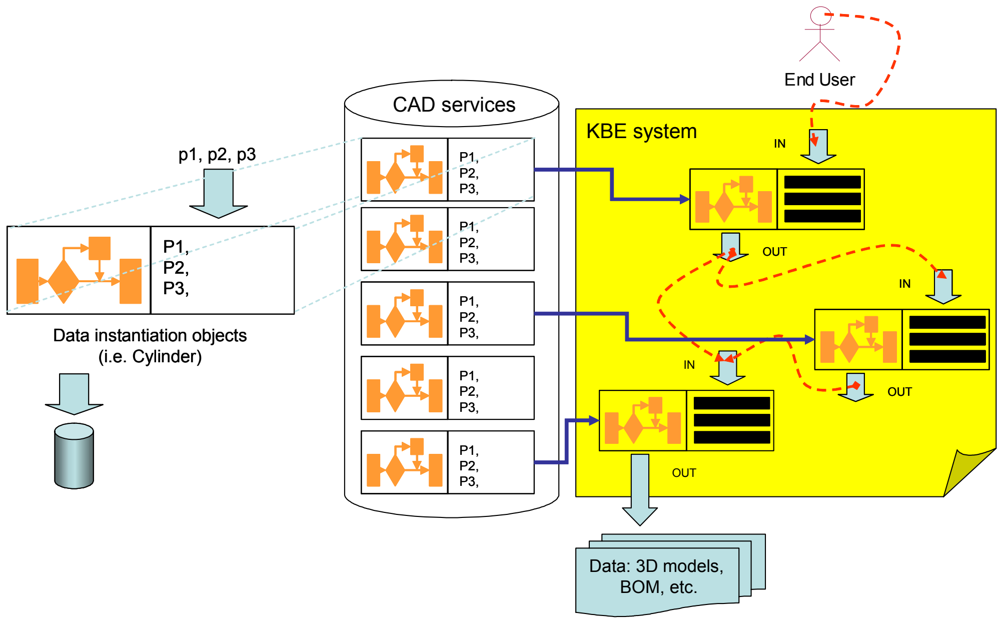


Figure 4-1. Assembly of CAD data instantiation objects.

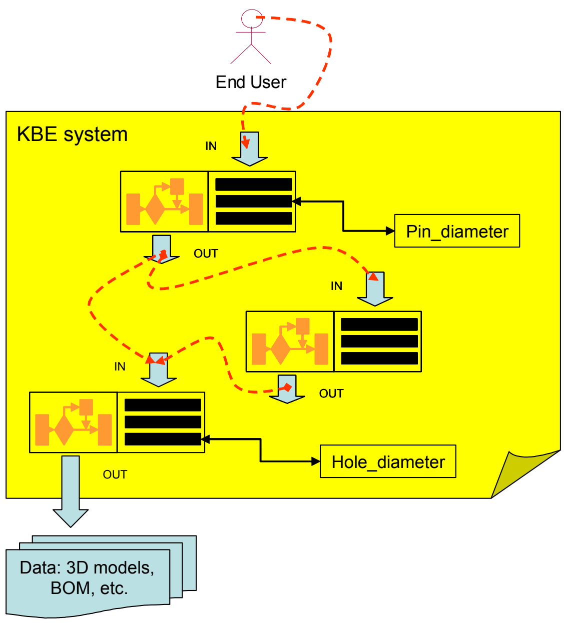


Figure 4-2. Assignation of domain specific terminologies

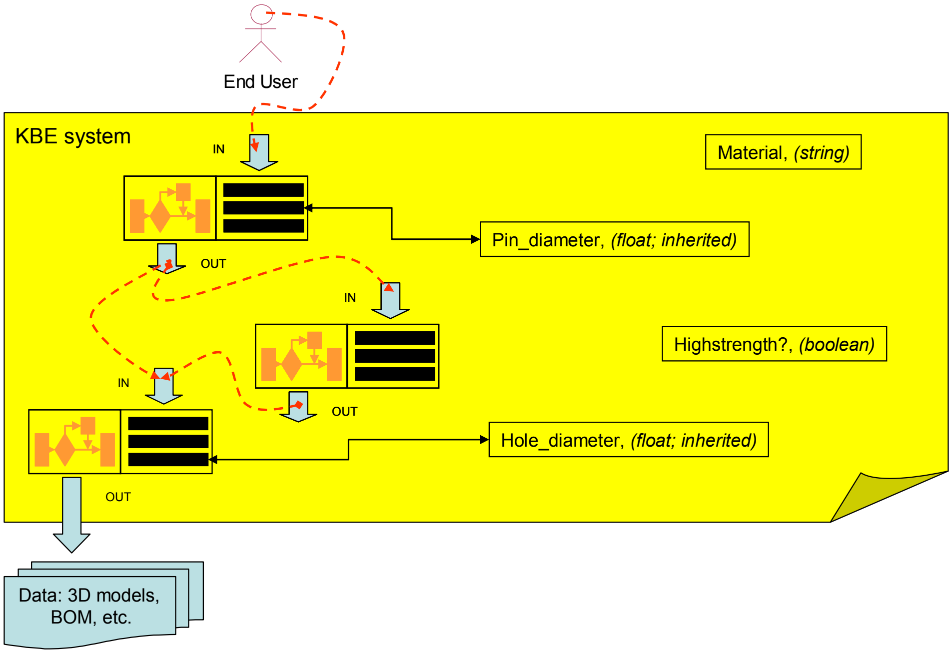


Figure 4-3. Creation of domain-specific data attributes.

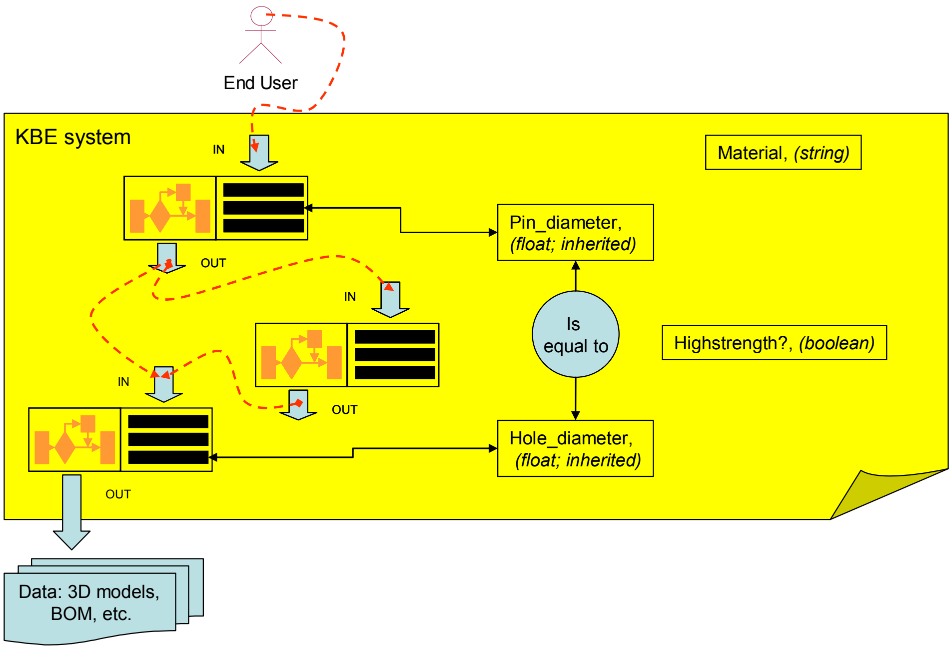


Figure 4-4. Definition of relationships between explicit attributes.

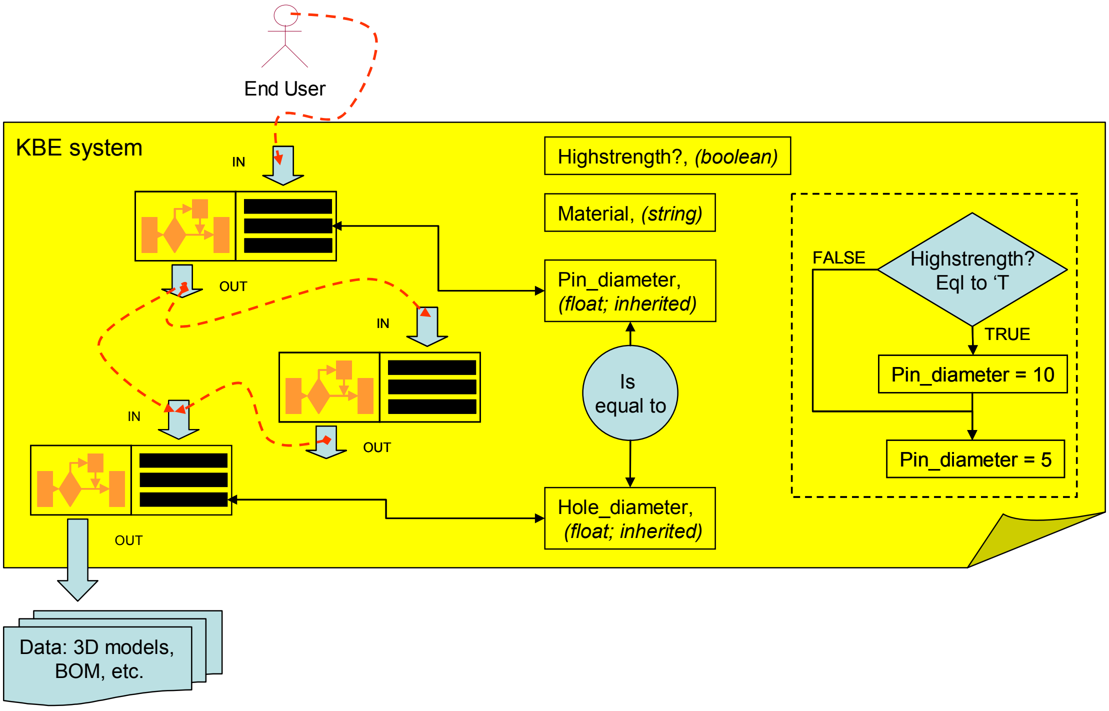


Figure 4-5. Definition of engineering rules.

4.2.3.2 Ranked set of business functionalities

In the second stage of the survey, the results are a set of ranked business functionalities and use cases expressing the practitioners' needs for integrated KBE in PLM. The quantitative value of the ranking results is limited due to the small data sample. However, a qualitative analysis of the data considering the background of the participants and the value of their inputs provides useful insights to achieve the learning objective of the research. Given the common pattern of small KBE teams in large organisations it is difficult to know accurately the total amount of KBE team leaders in industry and consequently estimate the size of a relevant sample. However, the participant's selection attempts to mimic the distribution of KBE experts across the engineering community. On one hand, most of the users of KBE technology are concentrated on large OEM organisations (4 representatives in the study). The second most common type of KBE users are in firms providing consultancy services. The study includes two representatives from this group: one form a large international engineering consultancy firm; and another one from a leading PLM/KBE software vendor. The last participant represents the academic/research community.

Table 4-4 compiles the elicited business functions ranked by the average importance assigned by the participants. An example of application for each business function is also provided. In general, there is consensus on the high importance of the business functions presented and on their relevance distribution.

Table 4-4. Ranked set of business functionalities resulting from the survey.

Assigned importance ranking		***Business functions to be supported by the KBE/PLM integration***	Examples of application
1	**4.57**	The modularity and easier development of KBE applications	KBE applications can be more easily created by assembling existing documented components
2	**4.43**	The increase of efficiency in maintaining and updating KBE applications	KBE applications can be more efficiently adapted to changes in the knowledge
3	**4.43**	The use of formal knowledge representation methods for both KBE and PLM	KBE systems and PLM solutions enable the deployment of formal conceptual models and advanced inference/reasoning mechanisms
4	**4.14**	The increase of transparency of KBE application functionalities and data processing	Information processing in KBE applications can be better visualised by non KBE experts
5	**4**	The interoperability between KBE systems	KBE application from KBE system "A" can be used in KBE system "B"
6	**4**	The increase of the reuse of existing KBE applications across domains and projects	KBE applications are more easily retrieved and reengineered to be usable in more situations
7	**4**	The management of in intellectual property stored in PLM	Engineering knowledge stored in PLM repositories is used as an input for KBE applications and vice-versa
8	**4**	The engineering change management of KBE applications through PLM	The change requests for KBE applications can be supported by the engineering change management functionalities in PLM
9	**3.71**	The management of service oriented KBE infrastructure	KBE applications can be deployed as services across the network to be discovered and reused
10	**3.29**	The KBE generation of data through semantic web services	KBE applications are deployed as semantic web services that user discover and access in order to generate engineering data

The high importance assigned to the modularity and easiness to develop XKMs (1st business function) confirms the evolution of KBE technology in respect to the Knowledge Engineering trends discussed in section 2.3.2.1. As KBE becomes a mainstream practice users demand more user friendly modelling functions so non-specialised engineers can benefit from the technology. In particular, aerospace interviewees advocate for making the technology more modular and reducing the entry skills for gaining its advantages. However, they acknowledge that frequently they operate complex XKMs involving hundreds of software objects and thousands of code lines. The development of this kind of KBE software services are likely to be commissioned to specialised teams across the organisation using code-based KBE systems like in *ICAD* or *AML*.

The second most appreciated business function matches the identified challenge to manage KBE services within a PLM environment. It can be noticed that the coordination of KBE development work is more appreciated than the KBE interoperability challenge (5th business function). 5 out of the 7 interviewed experts consider the use of PLM to coordinate KBE work as "highly relevant" and 3 of them see the problem as part of their short term strategy. Aligned to this view, the research from Siemieniuch and Sinclair (1999) recognise that in competitive environments knowledge has a lifecycle that includes its creation, propagation and retirement across the organisation. A representative from a major PLM and KBE software vendor summarises these ideas as follows:

> *"Definitely, exposing the components of a KBE solution in PLM has the same power as exposing the component artefacts of an engineering design in PLM. You can search and re-use at a much finer level of granularity, and you can approach the problems of versioning, maturity, release management and configuration management methodically and in a unified manner. Note that mature users of KBE now realize that the second-tier problem with KBE is solution management, configuration and reuse."*

The transparency of KBE is appreciated by the participants as a socio-technical barrier for the effective deployment of KBE (4th business function). On one hand, making more transparent the functionality of XKMs reduces the fears to take up KBE as it is no longer perceived as a "black art". On the other hand, model transparency is also correlated with the ability to manage KBE deployment work. The knowledge embedded in XKMs can hardly be validated if it is not visible enough for users. This issue is pointed out on the following quotation from a participant:

> *"Transparency is critical for the success of KBE within the traditional enterprises. If it is perceived as a "club" or only for "elite" engineers, it will not succeed. It must become "democratized". But transparency, as well as interoperability, will require the development of strong and relevant standards."*

The concern on formal knowledge representation (3rd business function) expresses the willingness of KBE users to exploit fundamental technological jumps like formal knowledge representation. This is also emphasised by the presence of semantic web services and service oriented architectures as business functions (9th and 10th business functions). It is also remarkable that the KBE/PLM integration raises expectations on traditional KM best practices. Knowledge reuse, sharing and maintenance are acknowledged by KBE users in the 6th, the 7th and the 8th business functions respectively. Such business functions seem to be associated to the analogy made on the use of PLM technology to distribute, manage and store product data. These perceptions can be summarised with the following question: why not use PLM to manage the lifecycle of engineering knowledge in a similar way as it is done with engineering data "items"?

4.2.3.3 Selected use cases

A part of the structured interviews investigates the possible scenarios in which the transformation of XKMs into EKRs can be beneficial for current practice. 5 use cases developed through the interaction with researchers and practitioners and are presented in the questionnaire and discussed during the structured interviews. Two use cases are appreciated as the most important for the practitioners:

- KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects, (Figure 4-6).
- This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services, (Figure 4-7).

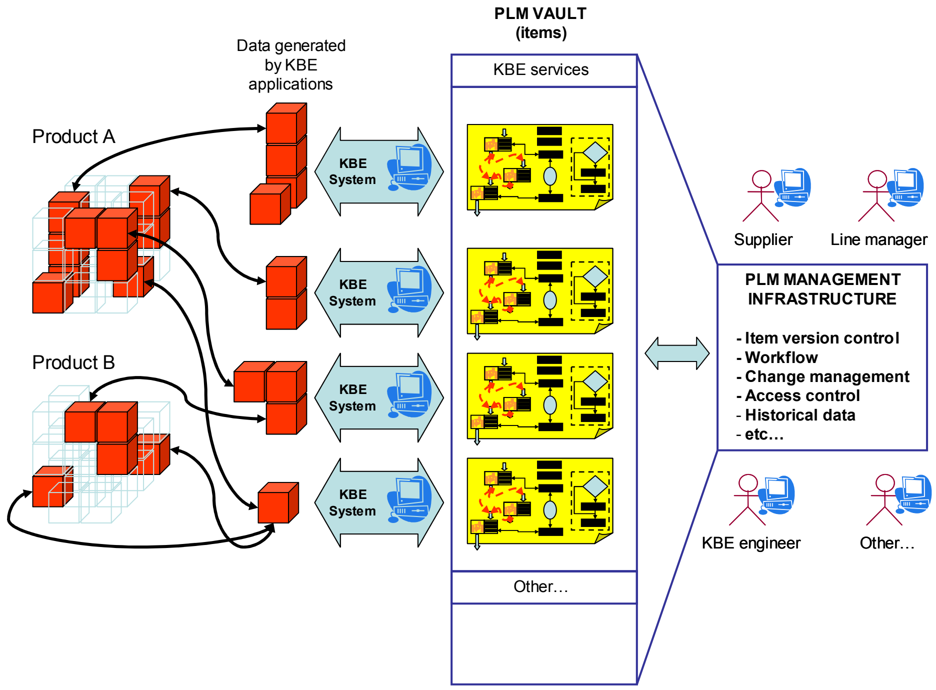


Figure 4-6. Use case: standardised KBE services as PLM items to support reusability across engineering projects.

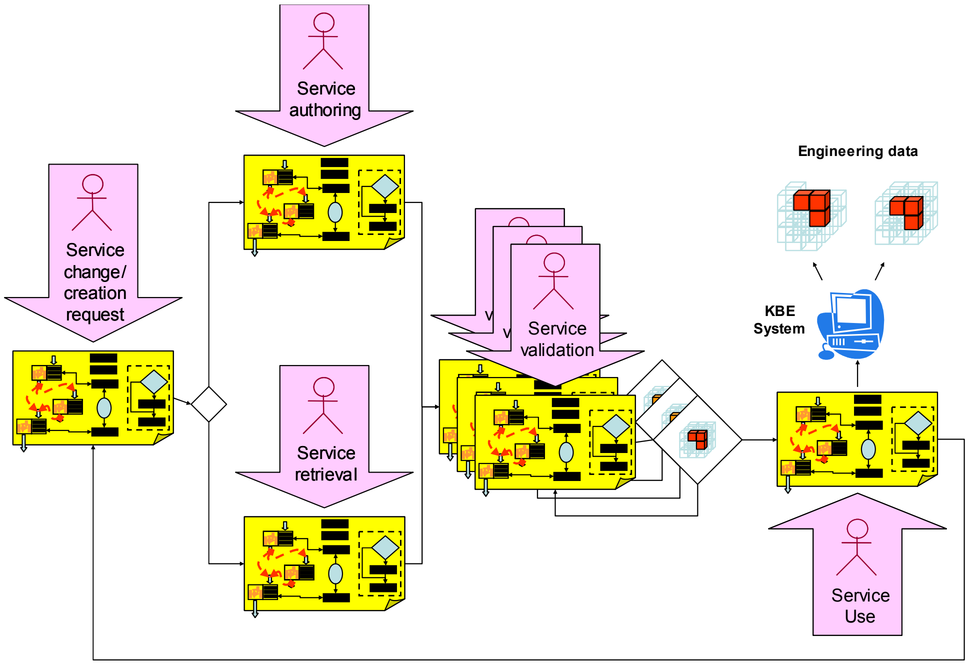


Figure 4-7. Use case: lifecycle management of KBE resources including change, authoring, retrieval, validation and implementation.

4.3 Concluding remarks

This section summarises the findings on the transformation of XKMs into EKRs. The conclusions from the XKM reuse case study are contrasted with the results of the survey research collecting the industrial views. Table 4-5 summarises the main outcomes from the survey research as described in 4.2.3. Each of these aspects is reviewed in respect to the observations made on the case study. This part of the research influences the design of the metamodel by adding the voice of qualified KBE technologists.

The target in the case study was to understand how to reuse of the knowledge within KBE applications. In contrast, the role of the survey is to refine the thinking with the aim of identifying desirable features for the specific design of the metamodel. Table 4-5 illustrates the influences on the thinking brought by the survey results reported in Chapter 4 in respect to the observations made in the case study in Chapter 3.

Table 4-5. Summary of the findings of the survey in respect to the case study.

	Case study implementation perspective	**Industrial perspective**
An abstract syntax for KBE models	Only a part of the abstract syntax is considered in the decomposition of the models into components. This part refers to the structure of a XKM.	An abstract syntax of the elements that can be found in a XKM represents a common set of entities that are shared from one component to another. The OMG interest on such model is the support the interoperability between XKMs created in different systems.
Modularity of KBE models	Modularisation plays a major role on the further reuse of code. Special attention has to be paid in the choice of components so they respond to potential issues in the domain.	Modularity is understood as the capability to store independent elements that can be reused across XKMs.
Lifecycle management of KBE models	As the component are further reused, retired and substituted, the changes need to be traced down to other applications. The replacement of the drilling line component illustrates the need to lifecycle management.	This aspect critical for KBE architects so they can maintain the models in the long term. Supporting the management of the lifecycle of EKR is appreciated as a measure to capitalise the efforts spent in KBE development.
Transparency of KBE models	The decomposition into KBE components increases the visibility of the overall purpose of applications. However, the details on how the application executes the task remain difficult to trace out.	The comprehension of the tasks executed in KBE is highly correlated with the reuse of models. For both users and vendors this aspect is critical in KBE development.
Formal modelling within KBE models	The formal modelling of the knowledge is not fully supported by KBE technology. XKMs retain part of the knowledge by declaring the terminology of domain concepts and "how" they can be computed by the software.	Formal modelling is perceived by practitioners as a best practice as long as it gives value to XKMs. However, practitioners have doubts on the overhead costs to build formal models such as ontologies.
Use case 1.	The systematic storage of KBE components is stated as an issue on the case study.	PLM is perceived as the enterprise system to systematically store XKMs as resources and facilitating their discovery, retrieval.
Use case2.	The encoding of KBE using the component decomposition is an iterative process. The management of components through their development and deployment.	Another opportunity to use PLM in conjunction with KBE is to manage the lifecycle of XKMs.

Chapter 5

REQUIREMENTS FOR A METAMODEL TO ANNOTATE XKMs

5.1 Introduction

This chapter summarises the learning from the previous phases of the research. The outcome is a set of features that should characterise the design of the metamodel developed in the research. The resulting features of the design are grouped according the three areas defined in the research scope:

- The contextualisation of XKMs within engineering processes
- The management of the knowledge contained in XKMs
- The use of enterprise knowledge architectures

The analysis of the case study in Chapter 3 shows that black-box reuse is a best practice in the development of object-oriented systems in general. However, white-box reuse through adaptations is a common case in KBE development. This makes evident a human-factors issue behind KBE development. The first appreciation of this issue in the research is gained by the difficulties to use the MOKA models by engineers that have not been trained in the methodology. Further understanding of this emerge by considering that KBE implementations result from the use of knowledge modelling and software engineering techniques by users that most likely have mechanical engineering backgrounds. Considering this, a compromise solution is to look at KBE models as procedures formalised through coding. This approach allows connecting XKMs to wider engineering processes by considering the former as sub-processes of the latter.

Once a XKM is seen as a formalised procedure within a larger engineering process, the next issue is to manage the knowledge that is embedded on it. The body of knowledge that is embedded within KBE codes mainly exists in the form of expressions and IF-

THEN statements. Potential users of those formalised procedures need to have a view on what rules are used on each step. The support to this requires an increased transparency to the code. Considering this perspective, any strategy that increases the access to the rules is a strategy to make the knowledge within KBE applications more manageable.

To realise the process view in combination with transparent access to the knowledge requires new ways of looking at KBE development. In this research, the strategy focuses on developing a systematic annotation approach for KBE codes. This allows users to perceive applications as resources that can be discovered, adapted and reused. This approach facilitates the building of practical KBE skills through component adaptations on situations where black-box reuse is not always possible.

The use of enterprise knowledge architectures is the enabling capability to manage resources within data repositories. Using a descriptive metamodel is a fundamental step to support the use of enterprise data repositories to store XKMs.

5.2 Contextualisation of XKMs within engineering processes

The definition of KBE models as EKRs has to provide strategies to contextualise their use within larger engineering processes containing many other non executable activities. A KBE model produces multiple possible solutions resulting from the execution of its internal model of the engineering task. The contextualisation of KBE resources within engineering practices can be realised through their description as process models. A KBE application is ultimately a task model described by using a programming language that can be interpreted by a computer. Describing KBE models as processes makes them easier to understand to engineers than a bespoke description based on software objects and object oriented modelling concepts. A consistent process view of an XKM has the following advantages:

- It facilitates the understanding on how an application works and consequently increases the chances to adapt it and reuse it in the domain. The case study presented in chapter 3 is an example of an engineering process (the nacelle design) that has been extended through KBE model adaptation to a similar process in the domain (the wing design).
- It supports the progressive formalisation of non-executable design procedures described using process models into executable ones. An example of this is a process model like the one illustrated in Figure 5-1 where a generic design process includes a KBE process, ("KBE rib design"). Such process is executed through a KBE application that exists in the context of a wider engineering process. However, as the expertise in KBE grows, other parts of the process (i.e. "identify int. element") may be formalised into a KBE application and then become an executable sub process.

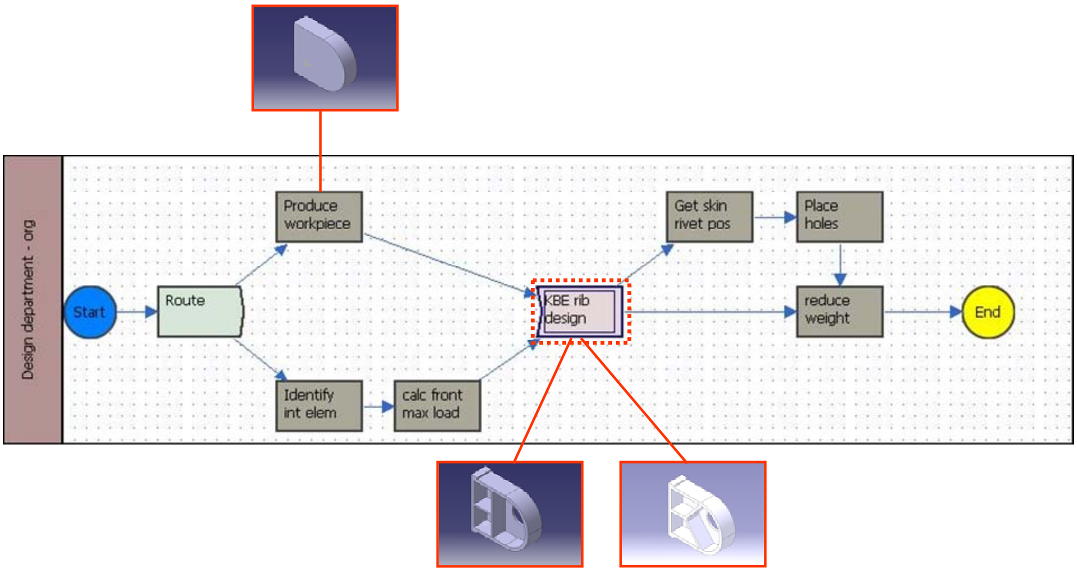


Figure 5-1. A hypothetical workflow model that integrates executable tasks using KBE.

From this viewpoint, the description of an XKM shall support the abstraction of the models as process models. A first requirement for the design of the metamodel is stated as follows:

The metamodel has to provide a strategy to support the integration of XKMs within engineering process models.

5.3 Management of knowledge

In the KBE encoding phase, substantial efforts are spent on defining the architecture of the application in terms of its software objects and their attributes. This includes the planning and arrangement of the object classes and the coding of the specific expressions using the KBE vendor's language. Since recently, KBE is positioned by CAD vendors as another IT tool within the PLM scope of applications. This has made the technology more accessible. However, the implementation of KBE without a knowledge management strategy makes little difference to the way the technology has been implemented in the past.

An attempt to transform XKMs into EKR shall support the management of the knowledge encapsulated on them. The literature acknowledges that knowledge resources have a lifecycle. Similarly, mature KBE practitioners recognise the importance of managing the process of creating, using and maintaining knowledge resources and the associated XKMs. The transparency of EKRs is a critical issue for sharing, reusing and maintaining the knowledge. In most code-based KBE tools, there is no special distinction for code that introduces engineering rules. The research from Fan et al. (2002) shows that the ability to increase the transparency of engineering rules at the *ICAD* KBE code level enhances the capabilities to manage the knowledge embedded in applications. However, the elicitation of engineering rules as a differentiated type of expression is only a partial solution to manage the knowledge embedded in the code. The engineering rules capture the procedural knowledge related with the inferences made by the system. On the other hand, the rationale followed by the KBE application to fulfil a task is more difficult to visualise than the engineering rules. Two aspects contribute to the difficulties to understand encoded XKMs:

- Engineering procedures are embedded in the code via inheritance relationships between software objects.
- Within the boundaries of encapsulated objects, a dependency between expressions exists that is not explicit.

An example of this shown in figure 5-2, where a software object encoded with *ICAD* is associated to a directed graph annotating its operation. The graph facilitates the understanding of a piece of KBE code as a procedure and consequently to contextualise it within a wider process. Furthermore, it allows to associate expressions in the code to particular actions such as "compute angle" or "list surfaces". Managing the knowledge contained in the piece of code of the example implies making transparent how the information is processed by a KBE software object like the one illustrated in the figure. On a first approach to the problem, a metamodel to annotate the code needs to distinguish between the roles played by attribute expressions. Based on this a desired feature of a metamodel to annotate XKMs should:

The metamodel has to support the comprehension of the operation of XKM codes by using:

- **Entities that model the procedure and the rules governing it.**
- **Entities that specify the use of other entities.**
- **Entities that model domain concepts.**

In addition to this, Chapter 3 has shown that grouping different KBE software objects that perform a particular engineering procedure facilitates the comprehension of the application. This is useful to visualise how an application is structured. A requirement for the metamodel supporting this can be enunciated as follows:

The metamodel has to support the comprehension of the structure of XKM codes by using:

- **Entities that describe its component structure.**

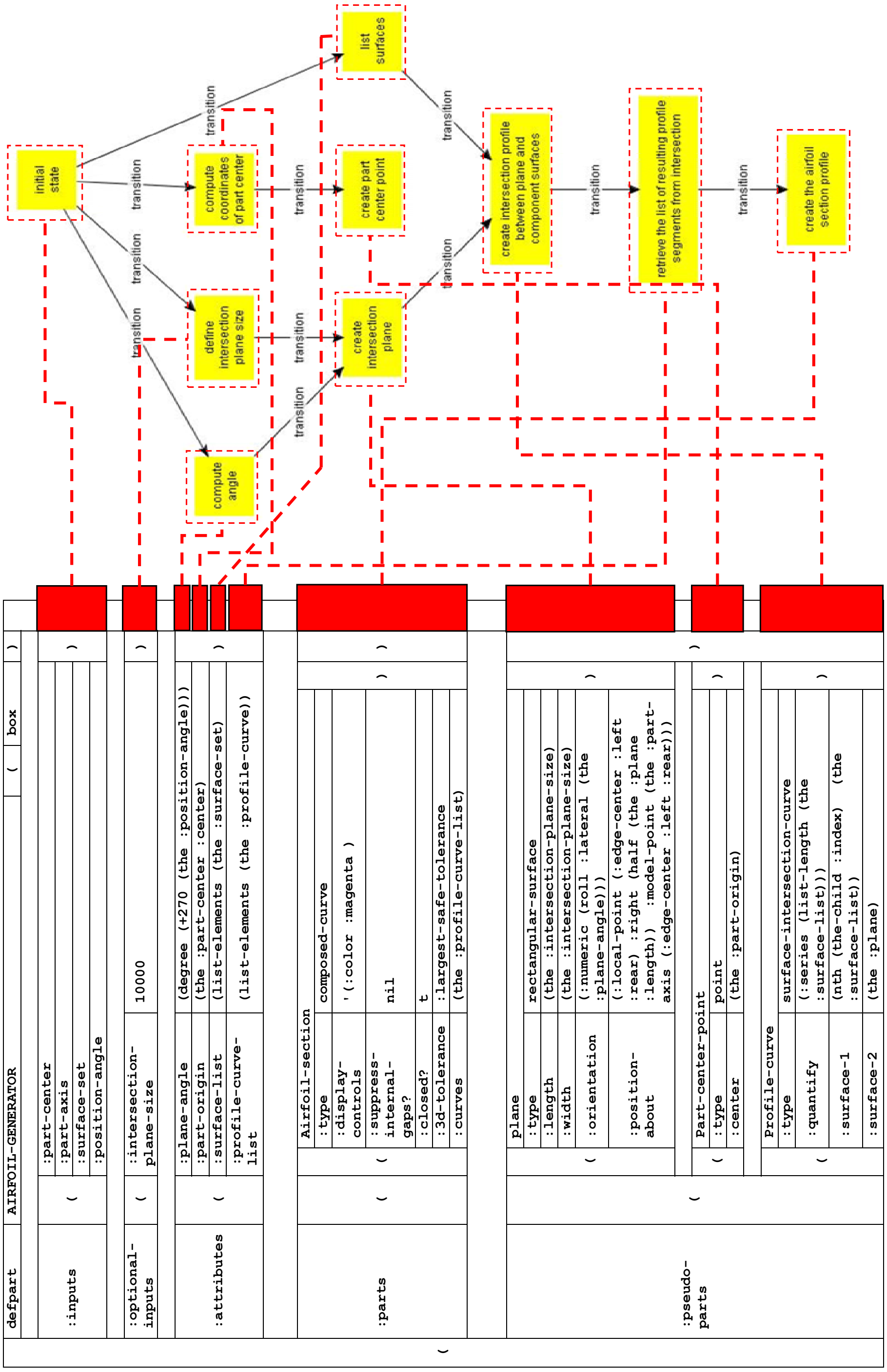
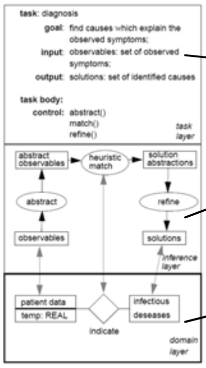


Figure 5-2. Directed graph expressing the functionality of a KBE object.

5.4 Enterprise knowledge architectures

It has been realised through the research that the way in which the knowledge is organised within XKMs affects the management of the knowledge that is embedded on them. An example is the decomposition into components to code reuse as described in chapter 3.

In addition, it has been observed that in the current state of the technology, the use of KBE as a modern KBS technology is not fully realised. The work from Poenisch and Clark (2006) highlights that the concept of separating domain and inference knowledge is not fully realised in KBE technology. In contrast, the literature on KBS acknowledges this separation as a major knowledge structuring breakthrough, (see 2.3.2.1). Figure 5-3 illustrates the comparison between the information held on task models described using the CommonKADS expertise models and their counterparts on a KBE software system.



CommonKADS expertise model	Information on each layer	Information on each layer on a KBE model
Task layer	Metadata about the particular task performed by the knowledge system	A file name An object name
Inference layer	Rationale of task performed by the knowledge system	Object oriented programming code
Domain layer	A description of the domain concepts used by the knowledge system	A terminology used in the domain with low level definitions

Figure 5-3. Comparison of the CommonKADS expertise model and KBE.

The extraction of engineering rules is useful to manage the lifecycle of the knowledge in EKRs. However, the current technology trends of enriching CAD models just with rules and not commonly agreed domain models can have unexpected results. The upload of hundreds of CAD models enriched with engineering rules may result in the same issues to manage them that were detected on early Expert Systems technology. Considering these issues, another desired feature of the metamodel is described as follows:

The metamodel has to provide a strategy to annotate separately the domain knowledge and the task knowledge

5.5 Concluding remarks

Much of the value of KBE comes from the retention of task models that can be executed almost instantly. However, there is an associated risk for KBE models to become islands of automation. The ultimate objective of transforming XKMs into EKRs is to avoid this issue by attaching information to them using a metamodel. Using this approach, the knowledge can be indexed and then easier to retrieve within data repositories like PDM and PLM systems. Instances of the metamodel contain information describing it as a specialised type of data resource that automates engineering tasks. Otherwise, an XKM is just a text file containing code that even if it is stored in an enterprise repository, it has little meaning for non KBE experts.

The previous stages of the research investigate the functional needs of a metamodel to annotate KBE applications as resources. Based on these investigations, a set of specific features to characterise the design of the proposed metamodel are described here. They are presented as requirements for the design in table 5-1.

Table 5-1. Summary of the requirements for the metamodel.

Contextualisation of XKM within engineering practice	**The metamodel has to provide a strategy to support the integration of XKMs within engineering process models.**
Management of the knowledge within XKMs	**Support the comprehension of the operation of XKM codes by using:** **- Entities that model the procedure and the rules governing it.** **- Entities that specify the use of other entities.** **- Entities that model domain concepts.**
Enterprise knowledge architectures	**- Support the comprehension of the structure of XKM codes by using:** **- Entities that describe its component structure.**

Chapter 6

A METAMODEL TO ANNOTATE XKMs AS EKRs

6.1 Introduction

This chapter of the thesis presents the design details of the metamodel developed during the research. The proposed design annotates XKMs with the aim of keeping a blueprint for EKRs populated within enterprise data repositories. A distinctive feature of the resulting metamodel is its positioning as an additional layer in the abstraction process leading to the encoding of XKMs, (Figure 6-1).

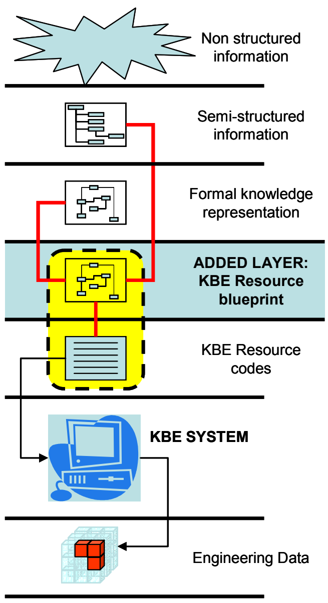


Figure 6-1. An additional layer in the abstraction leading to the encoding of XKMs.

At such level of abstraction the metamodel can be seen as a semantic bridge between the code in XKMs and other structured or semi-structured representations of the knowledge. The physical shape of an EKR consists on a file containing the code of the XKM and an instance of the metamodel as its blueprint within and enterprise repository. Among the possible types of enterprise repositories, PDM and PLM systems are the potential candidates for which the use of the metamodel can be beneficial. The metamodel provides the basis for the systematic storage of XKMs which become EKRs once they are annotated.

6.2 Structure of the metadata to annotate EKRs

This section describes the information that an EKR has to retain as annotated metadata. In general, a XKM contained in a code file corresponds to a single EKR. According to the research on enterprise knowledge infrastructures from Maier et al. (2005), three types of metadata are useful to describe a knowledge resource in distributed enterprise repositories:

- **Context metadata** relates to the creation and/or application of a particular resource.
- **Structure metadata** describes the formal set of associations within or among resources.
- **Content metadata** indicates what a resource contains or is about and it is intrinsic to itself.

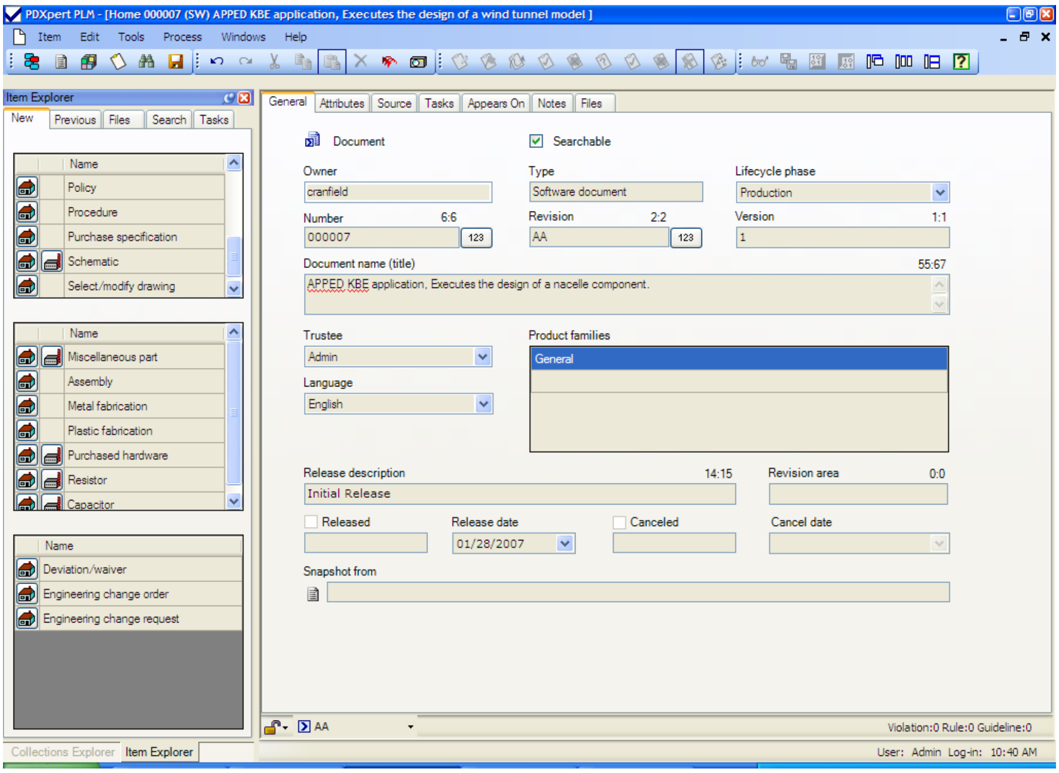


Figure 6-2. The result of uploading a file containing a XKM in a PLM enterprise repository.

Without a metamodel like the one proposed in this research, only context metadata can be attached to the text files containing XKMs to identify them in a data repository, (Figure 6-2). The metamodel developed in this research goes beyond this basic annotation by attaching structure and content metadata to a XKMs. Otherwise detailed information about the XKM can be only obtained by opening and browsing the code.

The metamodel has to annotate knowledge-rich task modes encoded using KBE technology. A response to address this effectively is to align its design with state of the art KBS modelling principles. In particular, the design associates the three types of metadata described above with the three types of knowledge that KBS systems hold according to modern Knowledge Engineering practice, (see 2.3.2.1). The role of the three types of metadata in reference to these types of knowledge is explained in Table 6-1.

Table 6-1. Types of metadata considering the KE perspective.

Context metadata	←	The task layer corresponds to the context metadata. It contains metadata fields that document the creation of undifferentiated data resources. This includes their creation date, ownership, etc. This layer is out of the scope of the developed metamodel since it is common for any other type of enterprise resources not defined as an XKM. Any particular descriptions about a EKR are described within the Inference and the domain layers.	→	**Task layer**
Content metadata	←	The inference layer corresponds to the EKR operation metamodel. Its instances use a data flow representation to facilitate the comprehension of how does an XKM operates. The choice of using of a specific metadata model to annotate the operation of XKMs is influenced to the need to integrate EKRs with engineering workflow processes.	→	**Inference layer**
Structure metadata	←	The domain layer is aligned with the EKR structure metamodel. Its instances provide metadata to describe the internal architecture of a XKM. Its functionality as a domain layer relies in the use of a formal knowledge representation of the knowledge. This representation can be linked to define the terminologies used in XKMs to formal ontologies or other semi-structured domain models.	→	**Domain layer**

6.3 An MDE architecture for the metadata model

The architecture framework to design and build the metamodel uses the MDE approach described in section 2.4.2. In the context of MDE, the metamodel captures the semantics of an engineering task modelled using a KBE software tool independently from its code implementation. This in fact means that it is a platform independent abstraction of the basic entities that can be used to build XKMs. MDE advocates the use of code generation techniques to perform transformations between this neutral representation, (abstract syntax) and the particular set of symbols that compose XKM codes in a particular KBE software system or the metadata blueprint annotating a EKR, (concrete syntax). The ultimate application of these transformations is the automatic generation of code from instances of the metamodel and vice-versa. As it is explained in section 2.4.2, MDE is a generic term to describe several IT systems modelling. The MDE concept advocates for the distinction between semantic integration and data integration for IT systems interoperability:

- The semantic integration focuses on the exchange of information between formal models capturing the semantics the concepts that an IT system processes. These representations use specialised Entity-Relationship modelling frameworks to define domain concepts, their relationships and the constraints affecting them. They have to be defined with enough level of formality so concepts are "graphs" rather than just "taxonomies", (see section 2.3.2). More importantly, they are defined at the "knowledge level" described by Newell (1982). Consequently, these models have to be independent from the details of the system that implements them.
- The data integration refers to the transformation of instances of the semantic models to a platform-specific representation that can be processed by a particular computer system. A platform-specific representation can be any type of structured data models including code. The use of XML taxonomies and XML Schemas is becoming a de-facto standard for data integration. Using this approach, computer systems can parse the tagged information within XML files for further processing.

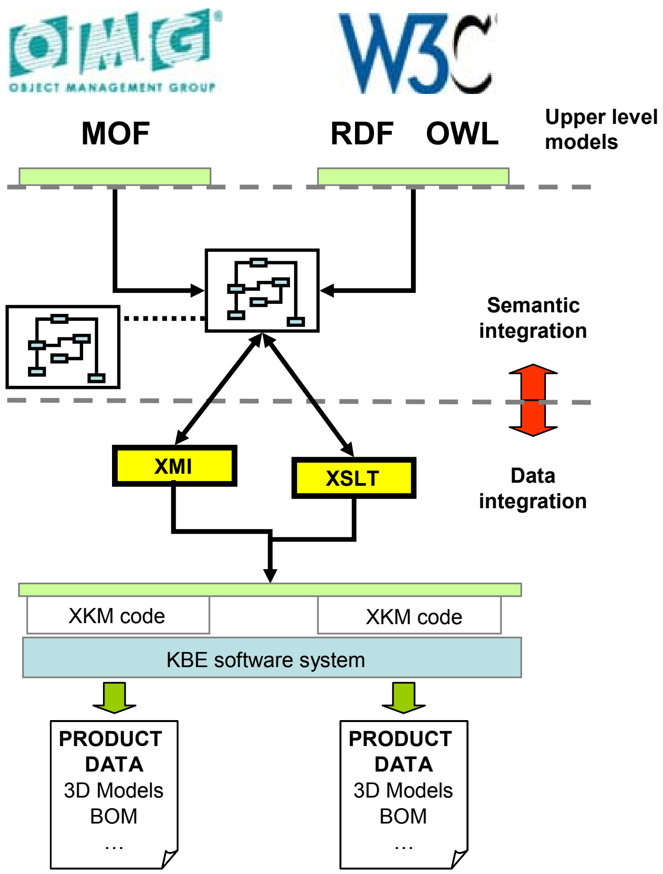


Figure 6-3. Possible routes to implement the metamodel using standard technologies.

The OMG and the W3C are major global standardisation bodies providing unified models to support the MDE view of interoperability. Figure 6-3 illustrates the possible routes for using OMG and W3C technologies in the context of this research. The MOF, the RDF and the OWL are upper level modelling languages that can be used to build the metamodel. Transformation technologies can be used to generate platform-specific KBE codes or to parse them to generate instances of the metamodel to annotate EKRs. A transformation strategy closer to the OMG modelling technologies is to use the XMI technology to generate XML representations of MOF-complaint models, (OMG 2006). On the other hand, XSLT is a technology to transform structured data models that can be used to generate code or generate other XML tagged representations, (Hjelm and Stark 2002).

6.4 Metamodel design and implementation

According to the structure of the metadata to annotate EKRs defined in Section 6.2, two sub-metamodels compose the metamodel developed in this research:

- **The EKR structure metamodel**. Instances of this metamodel describe the composition of a KBE resource. Using this information, a potential user of a KBE resource is able to understand what elements have been used in its development. On the other hand, the structure representation helps to assess if some of them can be reused in other engineering problems.
- **The EKR operation metamodel**. The instances of this model give a description on how the KBE resource operates. A set of basic KBE operations that can be represented using a data flow model are defined in the metamodel design. Using this descriptive model, KBE users can understand the rationale used in the KBE code to generate the desired engineering data

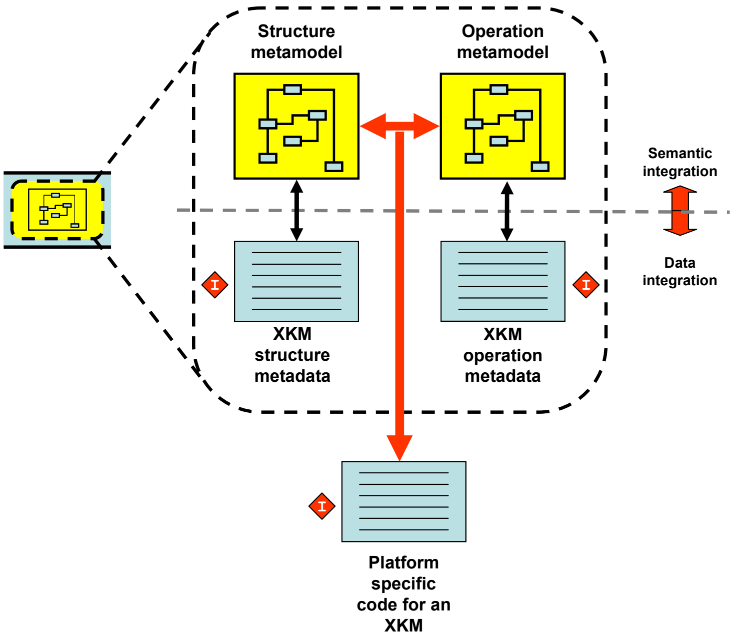


Figure 6-4. MDE architecture for EKRs.

The MDE architecture of the developed metamodel is illustrated in figure 6-4. The entities contained both metamodels define the rules that govern the generation of metadata instances (XKM structure and operation metadata). The semantic integration between the structure and the operation metamodels allows the mapping between their entities and instances of platform specific KBE codes containing an XKM.

6.4.1 Metamodel design methodology

The building of metamodels is widely recognised as a highly iterative process. A "learning-by-doing" approach has been adopted in the design of the metamodel. The XKM codes for the nacelle design described in chapter 3 are used as the case of application to develop the metamodel. The first stage in the metamodel building process consists in analysing the XKM codes. The analysis of the overall code structure is used to define a unified decomposition schema of the building blocks within XKMs. The analysis of the individual XKM code objects is used to define the entities in the operation metamodel. The validity of the models is assessed by analysing the semantic correspondence between the two metamodels. The semantic agreement analysis checks whether if instances of each construct have a counter part at both metamodels. Otherwise, a new iteration in the design is carried out. Up to 18 iterations of the metamodel have been developed and refined before the definitive version.

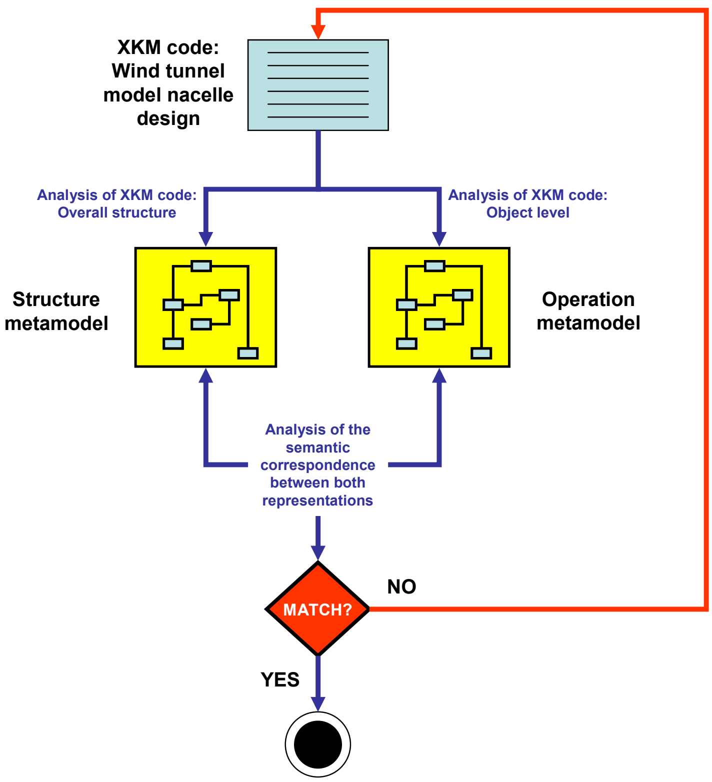


Figure 6-5. Metamodel design process.

6.4.2 The EKR structure metamodel

The entities in the structure metamodel are derived from a decomposition of the building blocks composing XKMs in a similar way as it done in chapter 3. It has been observed that although the syntactic rules to write KBE codes are tied to specific platform languages, commonality exists at the abstract syntax level.

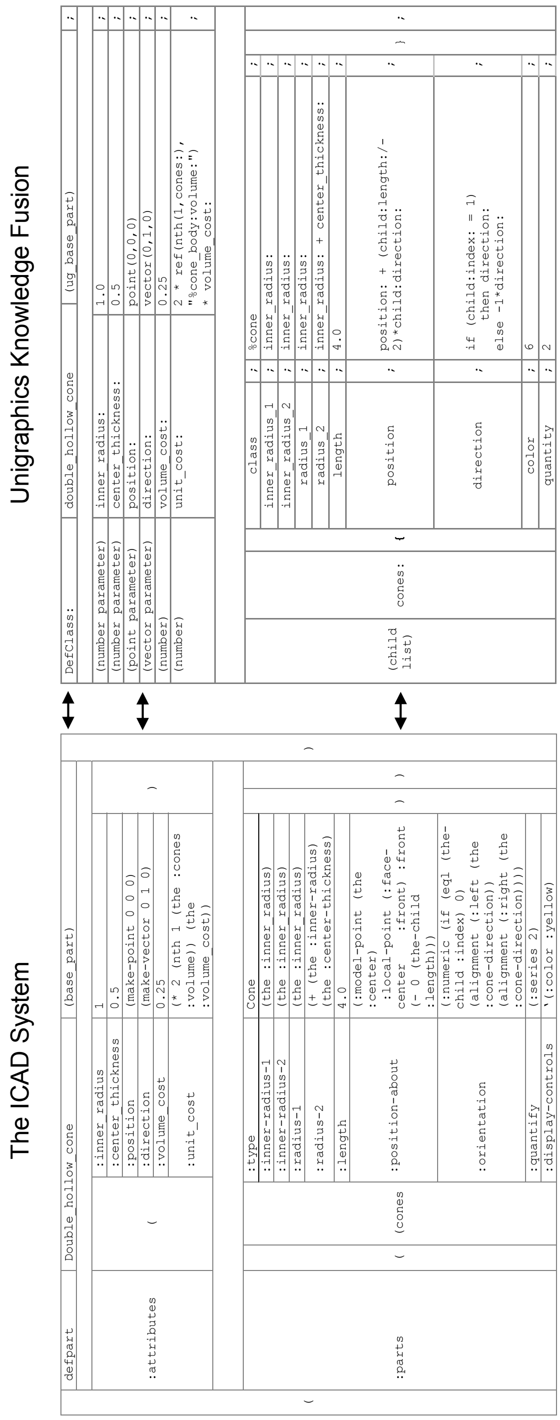


Figure 6-6. Two KBE object codes modelling the same process.

An example of this can be seen in the industrial motivation reported in Chapter 1, where two KBE systems are used to represent the knowledge for the same design task. Furthermore, it can be noticed that the semantic unification of the abstract syntax in KBE systems is the basis for the standardisation effort reported in chapter 4. The same can be perceived in Figure 6-6 where two KBE code objects fulfilling the same data generation functionality have been encoded using the syntax rules available in systems from different vendors.

6.4.2.1 Decomposition schema for XKMs

An initial step to develop the EKR structure metamodel is to identify a set of entities that compose a XKM. The development of a decomposition schema responds to the need to unify and formalise a set of basic building blocks upon which the functionality of an XKM is built. The decomposition schema results from the analysis of existing KBE languages. Resulting from this analysis, common entities across systems are identified. The main reference platform used in the research is *The ICAD System* (KTI 2007) although other systems have been considered.

An XKM contains a descriptive model specifying a task model to generate engineering data through the instantiation of CAD objects and the computation of parameters. The basic building blocks for EKRs are software objects. At this level of granularity, two types of elements can be identified within the XKM code:

- Built-in primitives predefined by the system that the user has chosen to instantiate to generate engineering data.
- Objects defined by the user that contain expressions with different roles such as data instantiation, explicit parameter or equations definition.

At higher levels of granularity, interdependent objects can be grouped into components as described in chapter 3. These components together form an XKM that in this decomposition schema corresponds to an EKR. At lower levels of granularity, the expressions defined by the user at the object level are classified in the decomposition schema according to their role in the XKM specification. The decomposition schema adopted in the research is described in Figure 6-7.

Using current KBE technology, the code is physically stored in a text based form. In code-based KBE systems such as *ICAD, UGS Knowledge Fusion* and *GDL* a text file stores the whole code. In CAD-integrated KBE systems such as *CATIA Knowledgeware*, the KBE functionality is built at runtime by accessing the entities via the user interface.

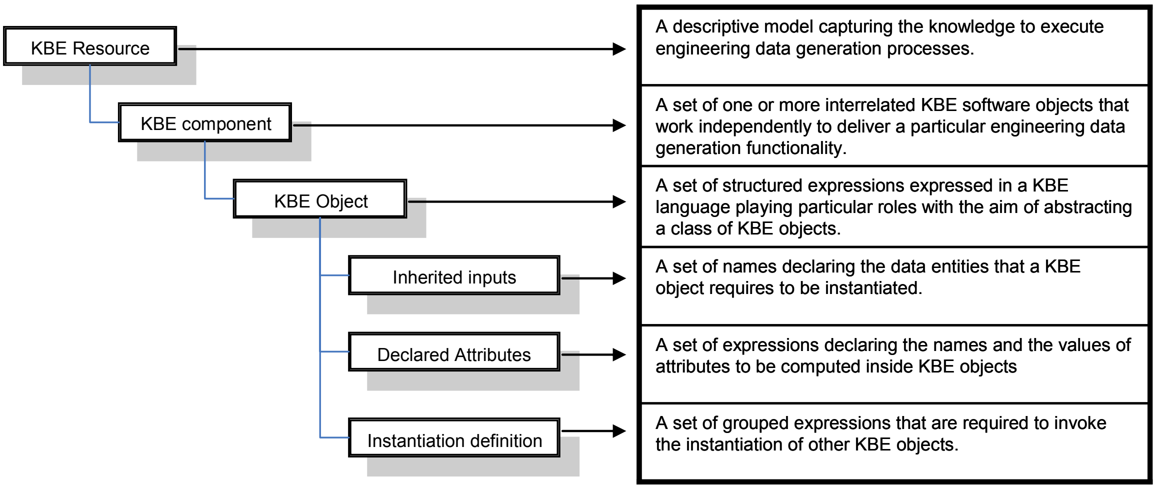


Figure 6-7. XKM decomposition.

6.4.2.2 Metamodel implementation

A formalisation of the decomposition schema described above has been implemented using the *PROTÉGÉ* system, (PROTEGE 2007). *PROTÉGÉ* provides a front end to create and edit frame-based knowledge models that can be used as the target metamodel. The use of *PROTÉGÉ* builds a formal representation of the EKR metamodel. Apart from this, other advantages of using this particular tool influence the choice:

- Although *PROTÉGÉ* uses a platform specific representation of the metamodels a number of back-ends are available to transform them into standard upper-level modelling languages. This includes direct translations to RDF and OWL. A UML backend that can facilitate an indirect translation to MOF.
- *PROTÉGÉ* can be used as a knowledge acquisition system so instances of the metamodel can be created directly on the system. This facilitates the multiple iterations required to design of the metamodel.
- *PROTÉGÉ* can be used as a repository to store instances of the developed metamodel. A built-query engine can be used to search and retrieve instances of the metamodels.
- The system is supported by a large community of KE practitioners. Resulting from this a wide scope of plug-ins exist for the system. They provide enhanced visualisation of the metamodels, advanced query and inference engines, metamodel consistency checking among many other features.

The metamodel is defined within *PROTÉGÉ* using a class structure that represents concepts like the "is-a" relationships. Class definitions contain slots whose values are constrained by data types and cardinality. Further relationships can be built using "instance-of" slots. Using this constructs a property of a concept can be related to instances of one or more other concepts. As *PROTÉGÉ* is a front end, the entities of the metamodel expressed in RDF are built at runtime. An excerpt of the structured RDF code generated by the system is shown in figure 6-8. The complete EKR structure metamodel expressed as an RDF schema can be found in Appendix C. The class structure used in the definition of the EKR metamodel is illustrated in figure 6-9.

```
<?xml version='1.0' encoding='UTF-8'?>
<!DOCTYPE rdf:RDF [
        <!ENTITY rdf 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'>
        <!ENTITY a 'http://protege.stanford.edu/system#'>
        <!ENTITY rdf_ 'http://protege.stanford.edu/rdf'>
        <!ENTITY rdfs 'http://www.w3.org/2000/01/rdf-schema#'>
]>
<rdf:RDF xmlns:rdf="&rdf;"
        xmlns:rdf_="&rdf_;"
        xmlns:a="&a;"
        xmlns:rdfs="&rdfs;">
<rdfs:Class rdf:about="&rdf_;ATT_DECL_DEF"
        rdfs:label="ATT DECL DEF">
       <rdfs:subClassOf rdf:resource="&rdf_;INTERNAL_DECLARATION"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Class-App-lifecycle-relation-label"
        rdfs:label="Class-App-lifecycle-relation-label">
       <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
[...]
```

Figure 6-8. A portion of the RDF code generated by *PROTÉGÉ* at runtime.

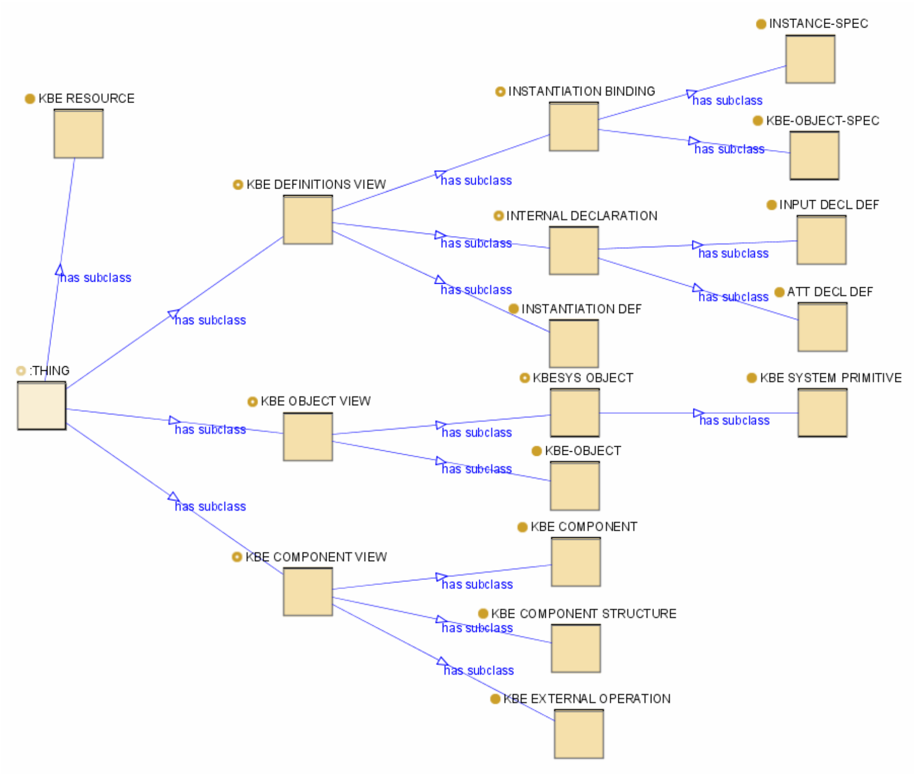


Figure 6-9. Class structure of the EKR metamodel as defined in *PROTÉGÉ*.

The metamodel is structured as a set of views that correspond to the levels of granularity identified in section 6.4.2.1.

- **KBE resource view.** This is the top level part the EKR metamodel. It contains the string slot annotating the name of the resource. The *PROTÉGÉ* interface allows the creation of instances for the rest of the entities in the metamodel by using a graph interface. On the other hand, the resource view is linked to the component view by an "instance-of" slot, (Figure 6-10).

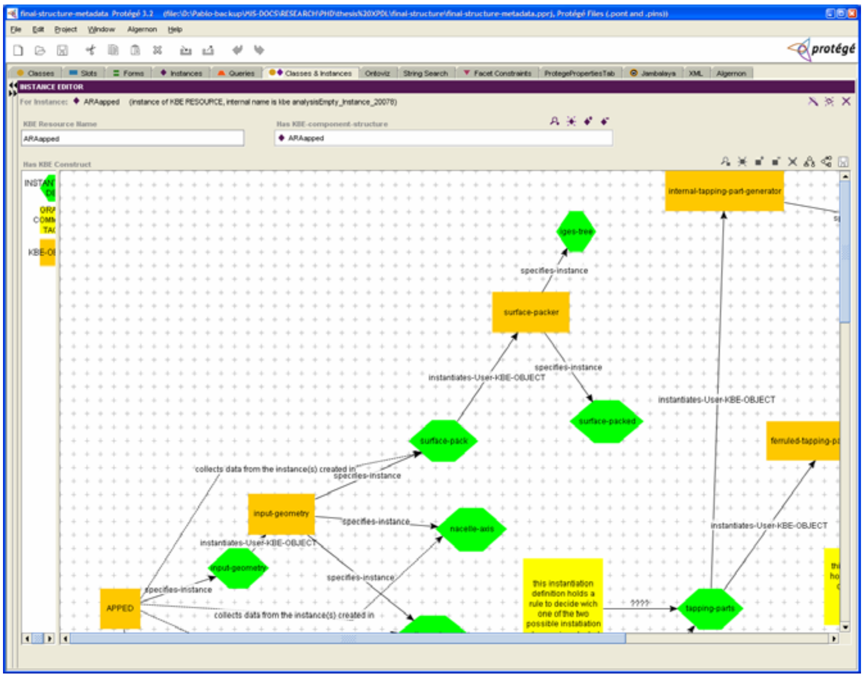


Figure 6-10. Resource view in PROTÉGÉ.

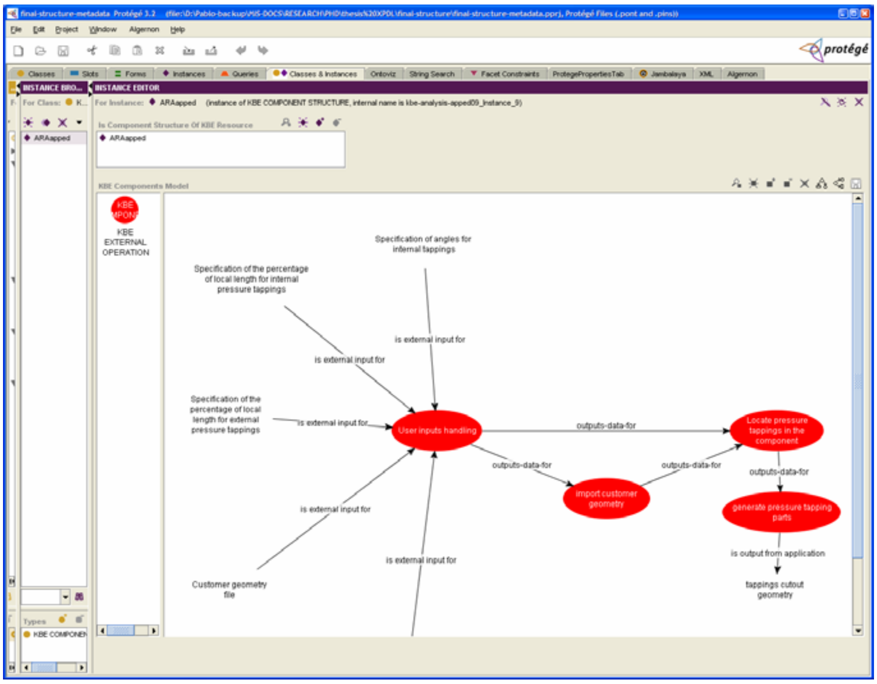


Figure 6-11. Component view in *PROTÉGÉ*.

- **KBE component view.** This part of the metamodel represents the groups of objects that assemble components. The set of constructs used in the component view allow the definition of inputs and outputs from the components, (Figure 6-11).
- **KBE object view**. This part of the metamodel describes the internal structure of an XKM object. Instances of this view annotate the individual expressions used in the XKM code to declare inherited inputs, declared attributes and instantiation definitions. As the description of these entities requires multiple data fields, a fourth view named "KBE definitions view" is used to model these entities, (Figure 6-12).

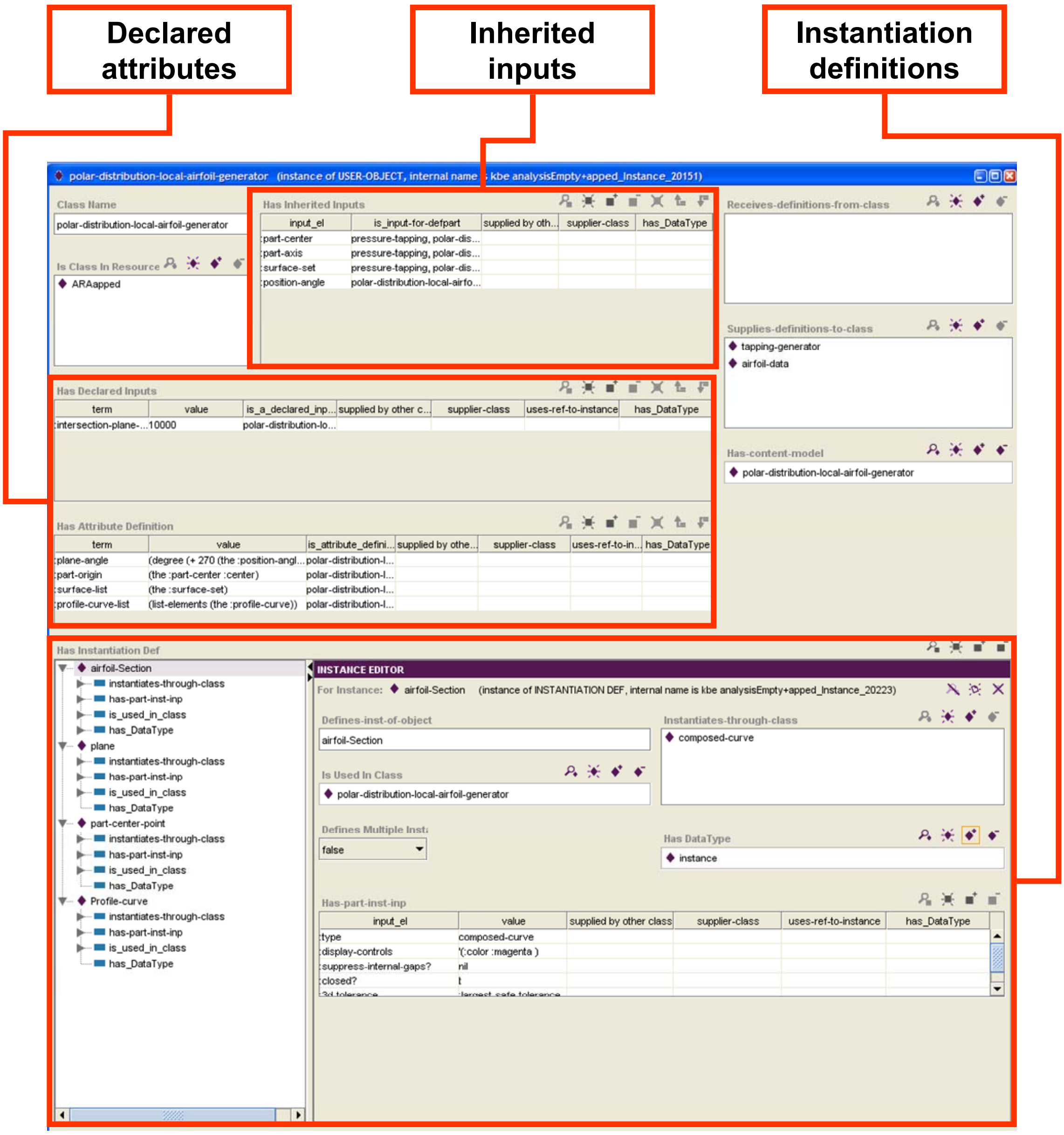


Figure 6-12. The object view of the metamodel in *PROTÉGÉ*.

6.4.3 The EKR operation metamodel

In the EKR operation metamodel design, the focus is to express the rationale that XKMs follow to generate engineering data. As it can be seen on figure 5-2, (section 5.2), a directed graph helps to visualise the procedural rationale followed within an *ICAD* software object. In the design of the metamodel the aim is to express the dependency between operations defined in XKMs. A graph representation is facilitates this visualisation.

Table 6-2. Activities in the EKR operation metamodel to express the procedural rationale of XKM objects.

RFP	Types of entities to visualise the procedural rationale of XKMs	Semantics of each entity as a procedural rationale activity	Activities in the metamodel design
(1)	Entities that model the procedure	**Collect data either from users or from other objects**	**Collection activity (role: inherited inputs)** Expresses the input of data to a XKM at the component or object levels of granularity
	Entities that specify the use of other entities	**Specify the instantiation of other objects and the data bindings required to do so**	**Instantiation activity (role: instantiation definitions)** Expresses the specification made within a user defined object to instantiate another one
(2)	Entities that refer to domain concepts	**Model domain concepts:** Define terms using a domain vocabulary	**Definition activity (role: declared attributes)** Expresses the addition of domain knowledge in the form of terminologies, their values and their relationships
(3)		**Model domain concepts:** Define the values of domain terms	
(4)		**Model domain concepts:** Define relations between the domain terms	
(5)		**Model domain concepts:** Define engineering rules	**Definition activity (role: declared attributes)** A particular type of definition that expresses the addition of inferences using IF-THEN conditionals

A formalisation of this concept for the metamodel consists in assigning specific meanings to the activities in a directed graph. In the design of the metamodel, the meaning of the activities is related to the role that the expressions play in the code. Table 6-2, relates the types of entities required to visualise the rationale of a XKM object (section 5.3), their interpretation as activity nodes in a dependency graph and the resulting set of activities in the EKR operation metamodel. The table also relates these elements to the 5 requirements of an abstract syntax for XKMs resulting from the survey research, (section 4.2.3.1).

6.4.3.1 Metamodel implementation

Beyond the use of directed graphs to express how XKMS operate, the research proposes the use of descriptions with more detailed process semantics. Instead of defining a whole abstraction describing the semantics of process definition within the metamodel, an early design decision is to use an existing standard metamodel. The advantages of this approach are:

- Using an existing standard metamodel exploits the concept of semantic integration and do not "reinvent the wheel".
- Standard process definition metamodel provide more sophisticated modelling framework than directed graphs to express the logics of processes.

Examples of these extended capabilities of directed are the definition of split and join gateways, embedded sub-processes and data bindings. A range of meta-languages to describe processes can be reviewed in Harvey (2005). Using a task-based modelling formalism the data flow within KBE objects can be modelled using a unified framework. A task is a logical unit of work that is carried out in a process. In the IT domain, the scope of these process models is the description of tasks either performed by human participants or computer systems.

The XML Process Definition Language (XPDL) is the standard metamodel used in this research to build the EKR operation metamodel. The XPDL specification is owned by the Workflow Management Consortium, (WFMC 2005). The choice of XPDL is influenced by the following features:

- The XPDL metamodel allows the modelling of both non executable and executable business processes.
- XPDL is designed for the interoperability between systems that use process descriptions. The XPDL standard defines an XML Schema validate files and exchange tagged data between systems.

The XPDL metamodel is composed of two sub-metamodels, corresponding to the definition of packages and processes. The XPDL metamodel uses a package structure as the mechanism to store process models. This strategy is designed to group process models that share certain characteristics as the participants so they do not need to be redefined in each process model, (figure 6-13). The process metamodel includes the entities that are necessary to define a workflow model, (figure 6-14).

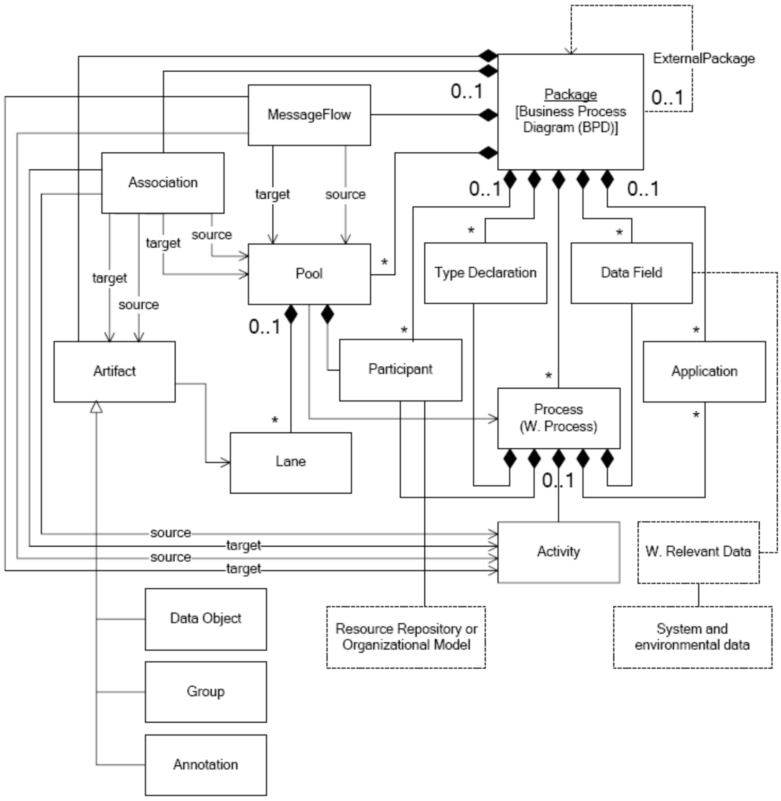


Figure 6-13. XPDL package definition metamodel, from (WFMC 2005).

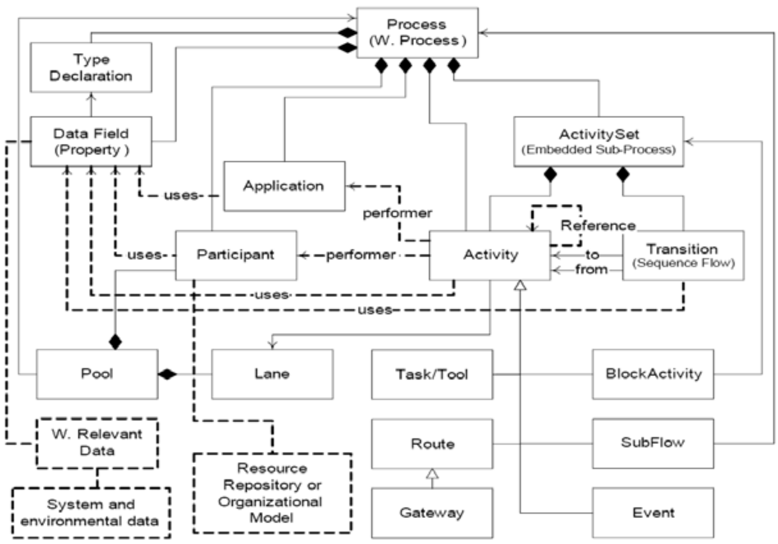


Figure 6-14. XPDL process definition metamodel, from (WFMC 2005).

Four types of activities can be defined within a XPDL process definition:

- **Generic Activity**. It is a generic activity representing a task unit.
- **Block Activity**. It is an activity that can be unfolded into an embedded process.

- **Route Activity**. It does not represent any task but it can be used to define logic gates in the form of forks and joins.
- **Subflow Activity**. It links an activity with an external process definition.

In this research, the notion of process definition is used to create a descriptive model for the data flow within a XKM at the object level of granularity. The strategy to achieve this consists of assigning specific roles to XPDL constructs so they express the desired semantics as described in table 6-2. The result is a set of XKM-related activities defined on top of the available activity constructs in XPDL. A description of each activity and the prescribed types of XPDL activity constructs that they can use is shown in Table 6-3.

Table 6-3. Usage of the predefined activities in the EKR operation metamodel.

Activity type	Description	XPDL Activities			
		GENERIC ACTIVITY	BLOCK ACTIVITY	ROUTE ACTIVITY	SUBFLOW ACTIVITY
Collection activity	Expresses the input of a data entity whose definition exists outside a XKM object.	Collection of inputs for a KBE object	N/A	N/A	N/A
Definition activity	Expresses the assignment of values to domain terms through expressions within a XKM object.	Assigns an activity to a simple definition expression (i.e. "term=1")	Models complex definition expression within an embedded process (i.e. "term=2*b")	N/A	N/A
	Expresses the assignment of values to domain terms through expressions containing Engineering Rules	N/A	Models a complex definition expressions having a conditional within an embedded process (i.e. "term= IF c1 THEN A Otherwise B)	N/A	N/A
Instantiation activity	Expresses the instantiation of an external XKM object.	N/A	N/A	N/A	Expresses the data bindings between object definitions and the inputs to instantiate

In the same way that *PROTÉGÉ* is used as a front end to create RDF descriptions, an XPDL editor has been used in the metamodel development. *Jawe* is a graphic editor that creates XPDL complaint files at runtime, (JAWE 2007). Figure 6-15 shows the graph representation in *Jawe* of the XKM object encoded using *ICAD* in figure 5-2 as well as a piece of its concrete syntax.

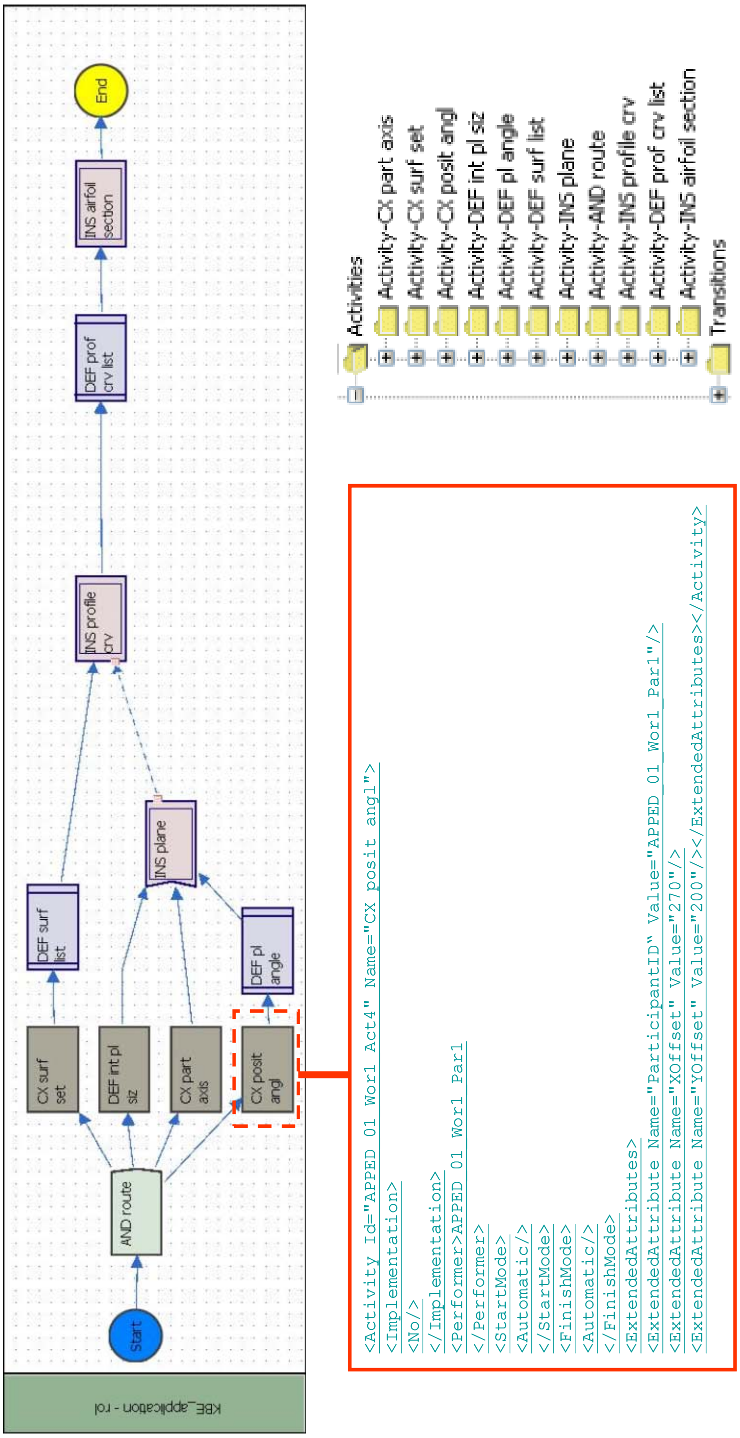


Figure 6-15. A XKM object expressed as a data flow graph.

6.5 Semantic agreement between the structure and the operation metamodels

In the design of the two sub-metamodels, special attention has been paid to ensure semantic agreement between the structure and the operation views. This aspect is important to build automatic code/metadata generators based on the proposed metamodels. The correspondence between both sub-models requires that having an instance of one of them, an instance of the other one can be built. The general correspondence between both metamodels is illustrated in figure 6-16.

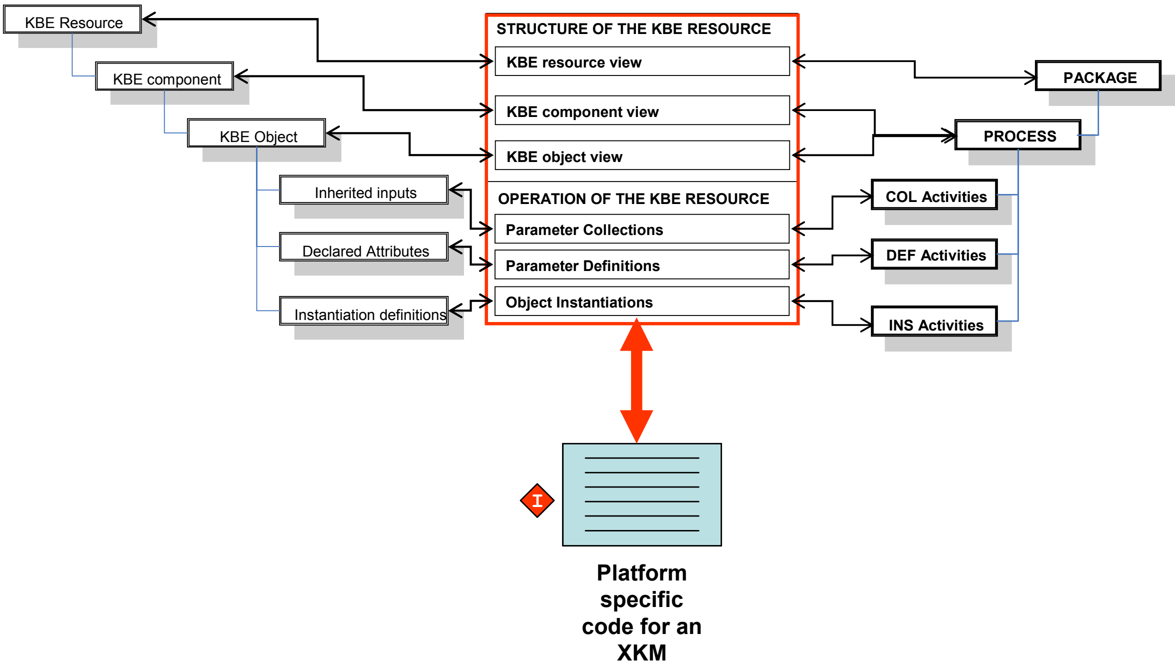


Figure 6-16. Overall correspondence between the structure and operation metamodels.

6.5.1 Correspondence between resources and packages

In the operation metamodel, process models are stored within packages. A package is a container for a number of process models that can be called from other packages. An instance of a resource in the structure metamodel is stored as a unique package containing the components and objects defined by the user. The correspondence between instances of a KBE resource in the structure metamodel and the package entity in the operation metamodel is used to create an instance of the latter in the form of an XPDL package, (figure 6-17). Once a package exists, a process is created within it for each instance of the KBE component entity in the structure metamodel. The correspondence between KBE objects and components for the purposes of building an instance of the operation metamodel is described in the next section. The package structure in the XPDL metamodel allows different process models to be connected through the subflow activity. In the structure metamodel, a subflow activity is used to represent the instantiation activity. This represents the inheritance relationships between objects found in XKM codes. Following this approach, the connected processes within a package are equivalent to an XKM software object encoded by the user in a KBE software tool.

Additional packages can be created for each KBE primitive defined in a particular software system (i.e. line entity, Bspline). In the case of these packages, only collection activities and definition activities are used.

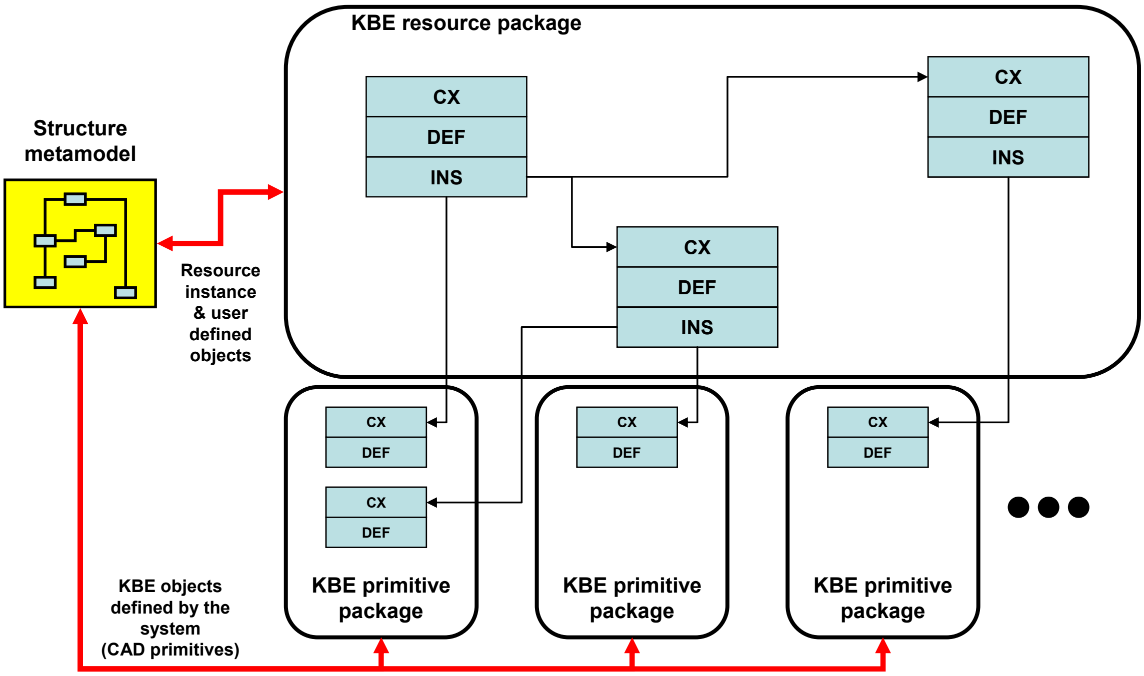


Figure 6-17. Creating a package instance from a resource instance in the structure metamodel.

6.5.2 Correspondence between objects/components and processes

The process level in the operation metamodel corresponds to the object view in the structure model. It is important to notice that the structure metamodel distinguishes between objects and components. A component is a unit of functionality composed by one or more objects. The grouping of objects into components models the association of objects into an independent structure that fulfils a particular domain task. At the KBE coding language level various software systems such as *ICAD* and *Knowledge Fusion* offer the "mixins" functionality to link objects in a way they can interoperate by sharing their internal definitions. The concept of mixin is modelled in the structure metamodel as the element that declares the association of different objects as unique components. In the operation metamodel, a component is modelled as a composite process in which the distinctions between the entities in each object are made using the concept of swimlines. In XPDL, the semantics of this separation is based on the execution of the process by different participants (in this case XKM code objects). This distinction is illustrated in Figure 6-18. The information declared in the instances of the structure metamodel about the component name and the XKMs that it includes is mapped to the XPDL attributes that define the participants in a process definition instance.

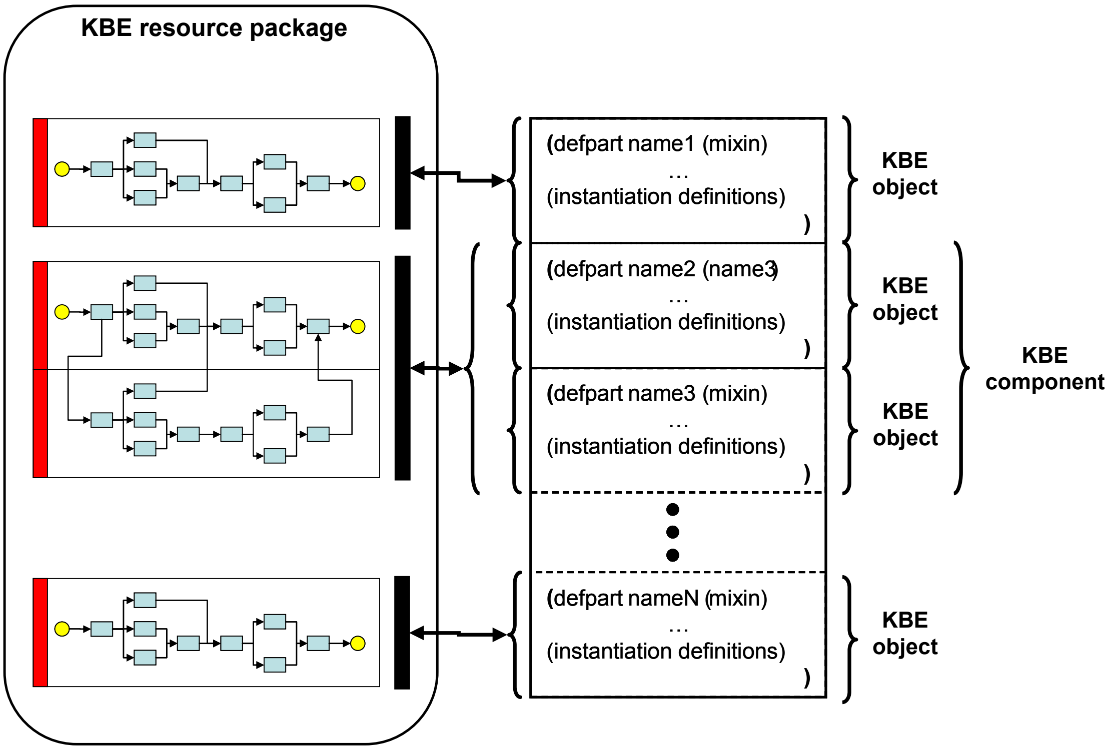


Figure 6-18. Distinction between KBE object and KBE component within an XPDL package.

6.5.3 Correspondence between object definitions and process activities

The creation of data flow models for user defined KBE objects inside the packages uses the XPDL process entity. Within a process in the operation metamodel, the object definitions correspond to the predefined activities in table 6-3. For each instance of the inherited inputs, declared attributes and instantiation definitions, a collection activity, a definition activity and an instantiation activity are created respectively. The creation of activity transitions requires a heuristic search within the code corresponding to each definition. In the development of instances of data flow graphs within the operation metamodel a systematic procedure is followed. Its steps are summarised here:

1. Create the process start bubble
2. Create a process end bubble.
3. Create a route activity and a transition after and before the start and the end bubbles respectively.
4. Connect from the route activity after the start bubble all the activities that do not have in their code any string matching the name (term) of any other definitions.

5. For each activity, if there is a string in the code matching the name of another activity, a transition is created from the latter to the current activity.
6. After this analysis, any activity that does not have any outgoing transition is connected to the route activity before the end bubble.

An example of correspondence is illustrated in Figure 6-19. The notation used in the activity graphs uses "CX" for collection activities, "DEF" for definition activities and "INS" for instantiation activities. The correspondence between the attribute definition expressions and the graph can be seen as well as observing that the upper side of the figure that shows part of the structure metamodel.

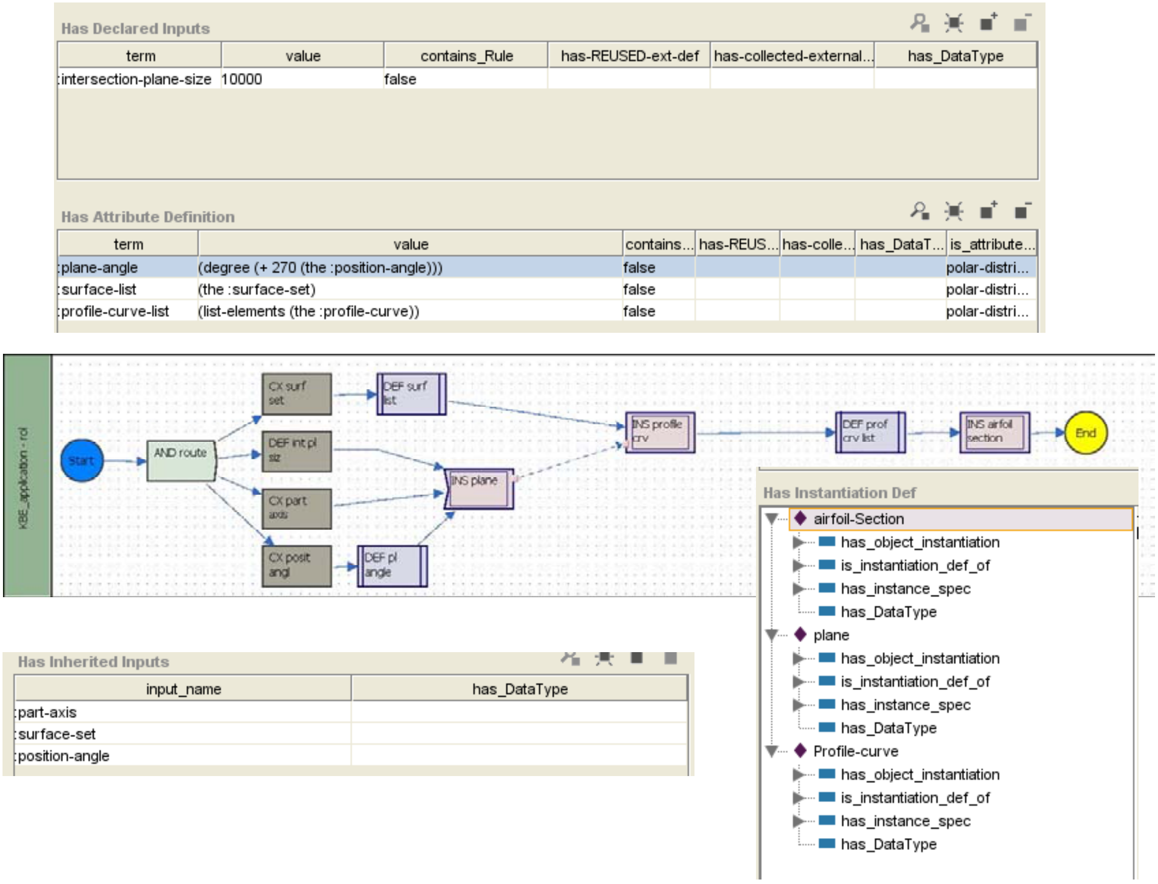


Figure 6-19. Entities in the structure metamodels to create data flow graphs at the object level.

Apart from the semantic agreement to build the graph, other data entities have correspondence between the structure and the operation metamodel. In the XPDL process metamodel, process definitions have associated a set of special parameters. They allow the definition of data bindings between interconnected processes as described in section 6.5.1. The correspondence between the entities at both sides is illustrated in Table 6-4.

Table 6-4. Correspondence between definitions in the structure metamodel and particular constructs in the XPDL process metamodel.

Entities in the structure metamodel	***Entities in the operation metamodel***	
	Workflow variables	Formal parameters
Inherited inputs	✓	Transferred with the MODE attributes settled to IN
Declared attributes	✓	×
Instantiation definitions	✓	Transferred with the MODE attributes settled to OUT

6.5.3.1 Representing complex definitions

The representation of XKM activities is modelled in both the structure and operation metamodels up to the expression's level of granularity, (Figure 6-20).

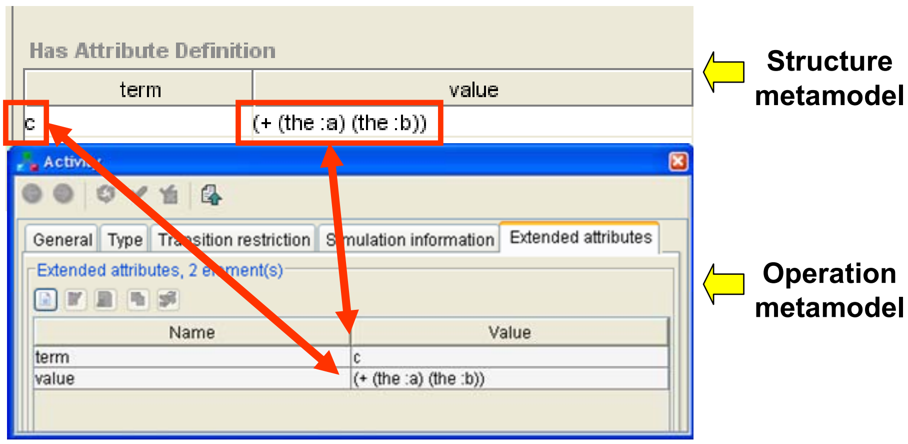


Figure 6-20. Scope of the metamodels up to the code level of granularity.

A metamodel to describe the semantics of complex expressions is introduced at the operation metamodel. This particular abstraction has no correspondence to entities in the structure metamodel. However, its implementation would be facilitated by the representations of the XKM code available in the structure metamodel.

The expression abstraction is related to the distinction made between simple and complex definitions in table 6-3. This distinction refers to whether if they depend on other definitions to be computed. For example, the ":intersection-plane-size" definition in figure 6-19 is a simple definition. As it can be seen in the graph it is represented using a generic activity construct from the XPDL process metamodel. The creation of complex definitions use the block activity construct.

In this further formalisation, the role of elements within XKM code expressions is made explicit using a graph-based format. The semantics of the expressions is represented using a generic inference catalogue provided in the CommonKADS framework, (Schreiber et al. 1999). The types of generic inferences described by the catalogue are shown in figure 6-21. Considering the activities from table 6-3 as inferences, they can be associated to the CommonKADS catalogue as indicated in the figure.

	COL	DEF	INS
ABSTRACT		✓	
ASSIGN		✓	
CLASSIFY		✓	
COMPARE		✓	
COVER		✓	
CRITIQUE		✓	
EVALUATE		✓	
GENERATE		✓	
GROUP		✓	
MATCH		✓	
MODIFY		✓	
OPERATIONALISE		✓	
PROPOSE		✓	
PREDICT		✓	
SELECT	✓	✓	
SORT		✓	
SPECIFY		✓	✓
VERIFY		✓	

Figure 6-21. CommonKADS inference catalogue and its relation to the activities defined in the operation metamodel.

Using this approach, the expressions within definition activities can be described as illustrated by the example in figure 6-22. A correspondence between the expressions in the code and the graph can be observed. It can be seen that the graph shows dependencies on what needs to be computed to get a definition such as ":thickness-left-by-the-ferrule" attribute.

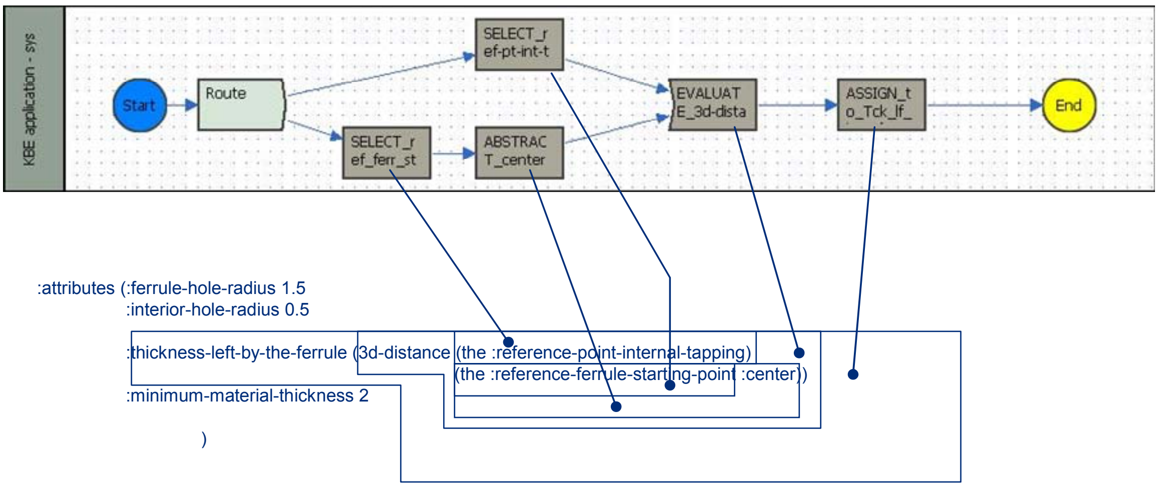


Figure 6-22. An expression within a definition activity described using the entities in the CommonKADS inference catalogue.

6.5.3.2 Representing engineering rules

A particular case of complex expressions is the ones that contain engineering rules in the form of IF-THEN expressions. In this case, the operation metamodel can be used to make explicit the logics of the engineering rules. In the structure metamodel, each definition associated to XKM codes that contain engineering rules is annotated with a Boolean data slot (see figure 6-19). The activities within operation metamodel instances that correspond to definitions containing engineering rules are distinguished in the graph by the notation "RDEF" instead of "DEF".

This operation requires some heuristic search within the expression text so the condition is associated to a route activity having an "OR" post condition. The results of evaluating the condition can be expressed as constrained transitions. An example of an engineering rule modelled using this strategy is illustrated in figure 6-23.

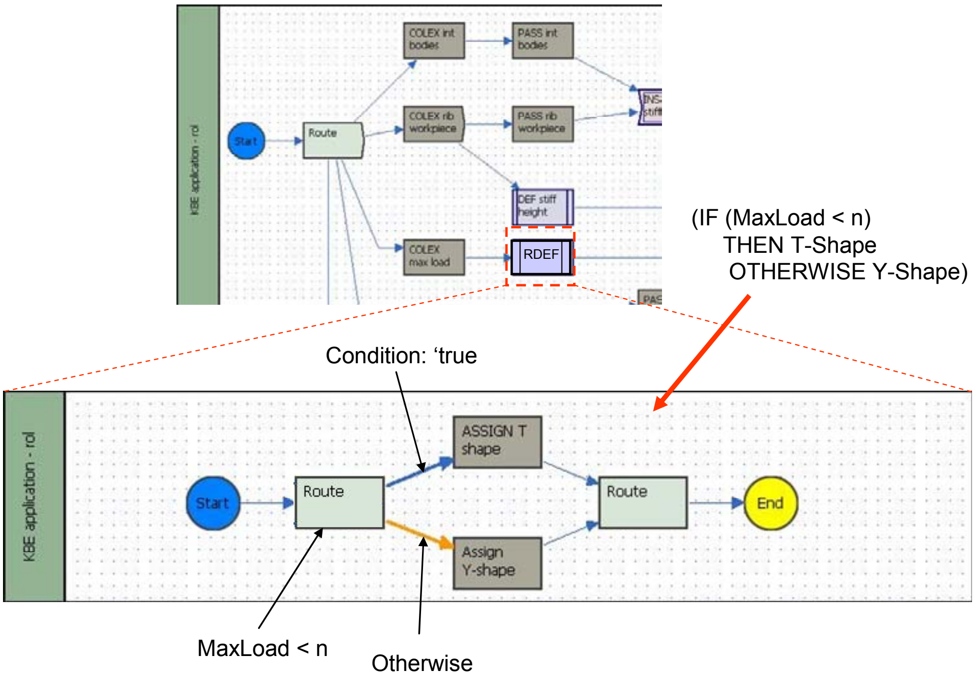


Figure 6-23. Example of engineering rule in the operation metamodel.

6.6 Transformations and code generation

The definition of the metamodel allows creating instances manually as an approach to document XKMs. However, its ultimate objective is to support the automatic generation of code and metadata. In order to create instances of the metamodel automatically, data needs to be transferred from platform-specific XKM codes to the defined metadata templates. Following the MDE principles this task is undertaken by using data transformations and code generation techniques.

The semantic agreement between the metamodels gives the overall rules of correspondence to perform such transformation. However, the transformation happens at the data integration level. This concept is illustrated in figure 6-24.

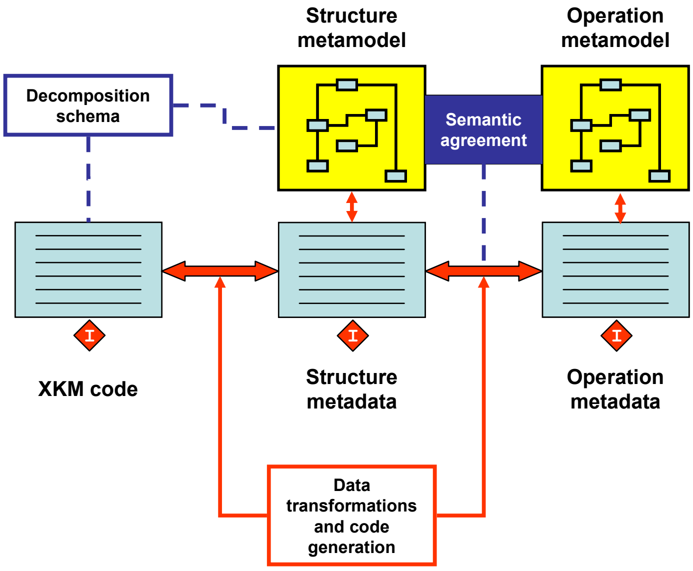


Figure 6-24. Data transformations and code generation.

The transformation of data from/to platform specific XKM code needs to be implemented for each particular system. Since enough level of commonality exists among KBE languages, the transformation rules shall not differ much from one to another. An important distinction is important regarding the mapping of code at two levels of granularity:

- The resource level results in the identification of components and objects, (figure 6-25).
- The object level results in the identification of definitions and connections between objects, (figure 6-26).

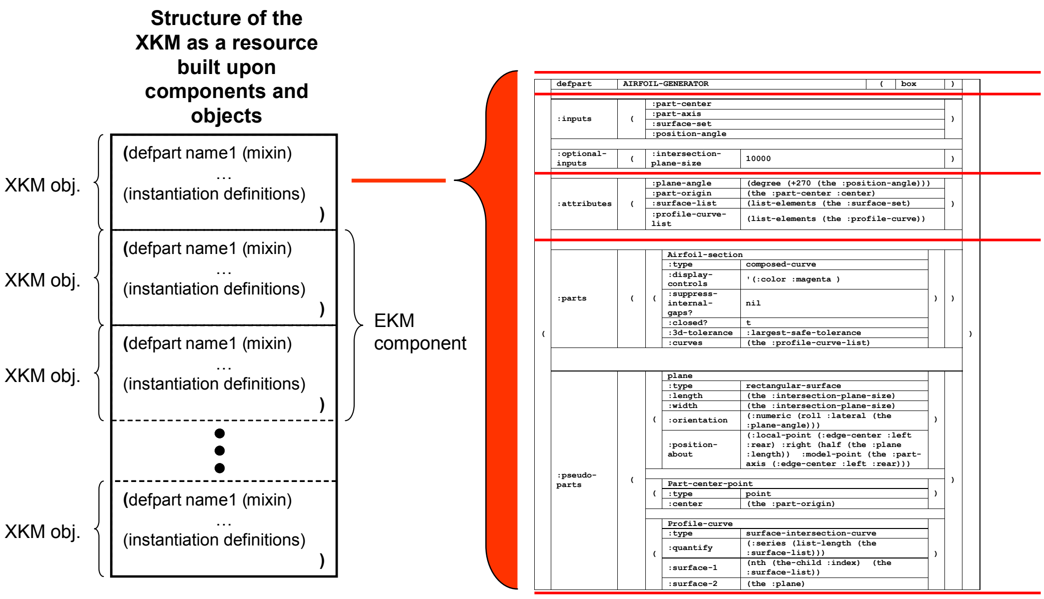


Figure 6-25. Decomposition of the XKM code at the resource-component level

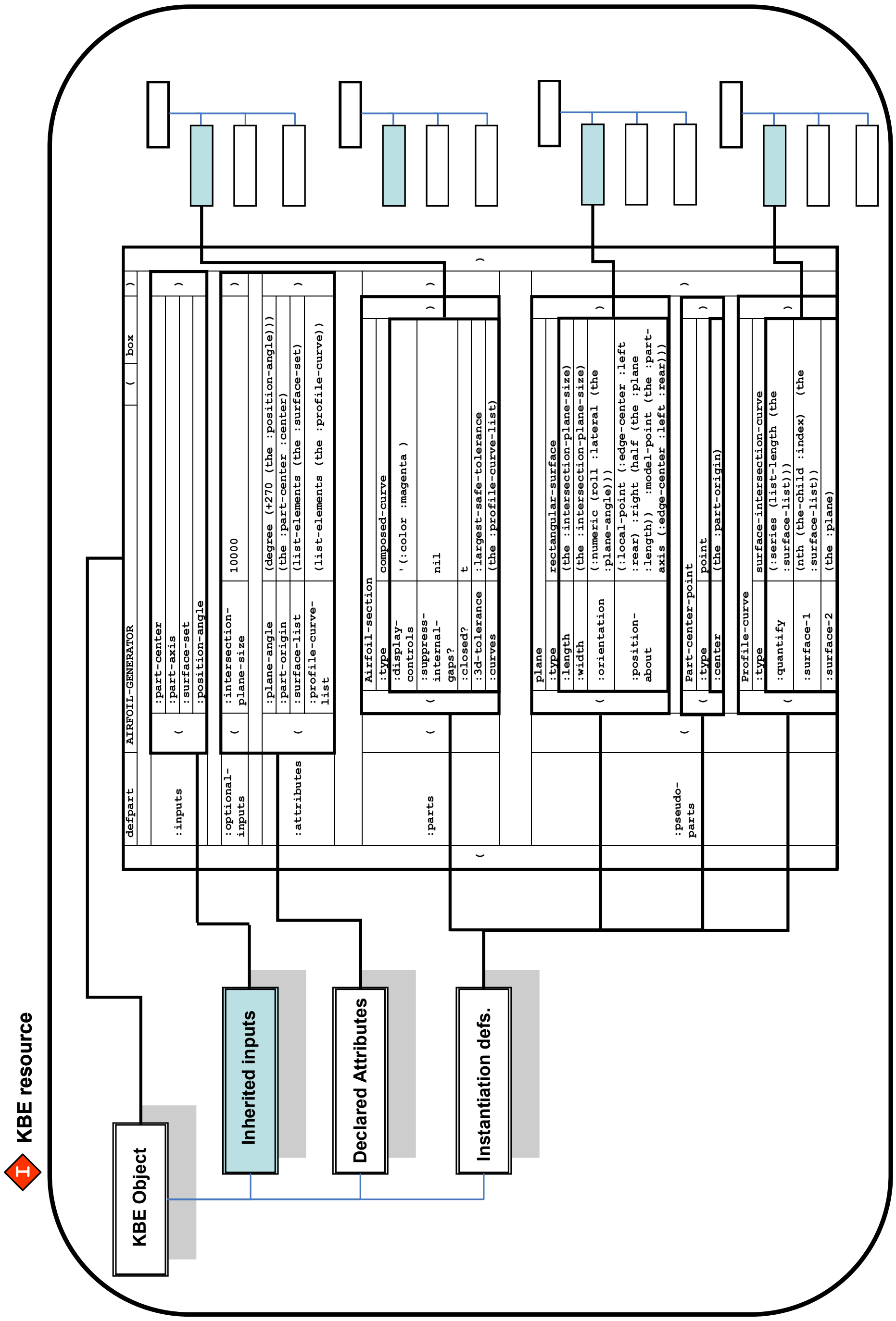


Figure 6-26. Decomposition of the XKM code at the object level.

Using the metamodels developed in this research, a transformation engine would search and retrieve pieces of code. The transformation rules are based on the semantic agreement between the XKM code and the two sub-metamodels. The particular mapping rules for *ICAD*, *Knowledge Fusion* or other systems generate the two sub-metamodels by following platform-specific transformation rules. Once an instance of one of the sub-metamodels exists, a code generator would follow the semantic agreement between them to generate the other one. An example of these data mappings across KBE codes and the structure and operation metamodels is shown in

Figure 6-27. These transformations are possible since the three languages are structured enough (unlike natural language) so their symbols can be the focus of precise searches using algorithms.

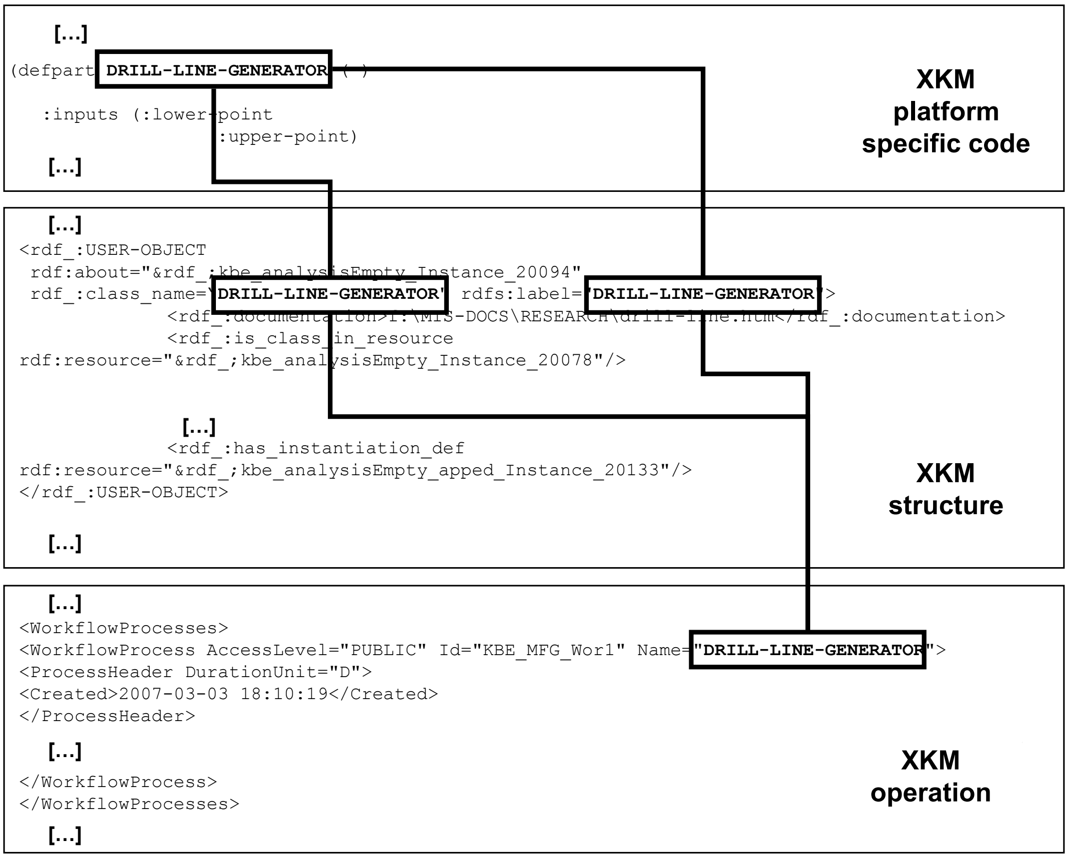


Figure 6-27. Data mappings between the XKM codes,

6.7 Concluding remarks

The design of the metamodel to transform XKMs into EKRs has been reported in this chapter. An XKM becomes an enterprise resource once it is annotated and indexed within an enterprise repository. The developed metamodel is a solution to annotate XKMs that otherwise would be undifferentiated data items within enterprise repositories. The resulting design fulfils the design requirements summarised in Chapter 5. The metamodel expressed XKMs as processes (first requirement). The rest of the design requirements are fulfilled by the metamodel due to its ability to document XKMs.

The developed metamodel is decomposed into a structure and an operation sub-metamodels. 40 classes and 89 data slots are defined in the metamodel to annotate XKMs. On the other hand, the sub-metamodel to describe the operation of XKMs defines three specialised types of activities on top of the XPDL standard metamodel for process description. The modelling strategy leading to two interconnected sub-metamodel have two fundamental objectives:

- To create a structural representation that can be integrated with domain knowledge model.
- To create a representation that can be integrated with engineering process definition models.

The formalisation of the structure metamodel using a *PROTÉGÉ* model allows the integration of its instances with domain knowledge models expressed on standard languages such as RDF or OWL. On the other hand, the use of the XPDL representation to formalise the operation metamodel facilitates the integration of EKRs within other business process models. This includes workflows involving human and computer executable tasks.

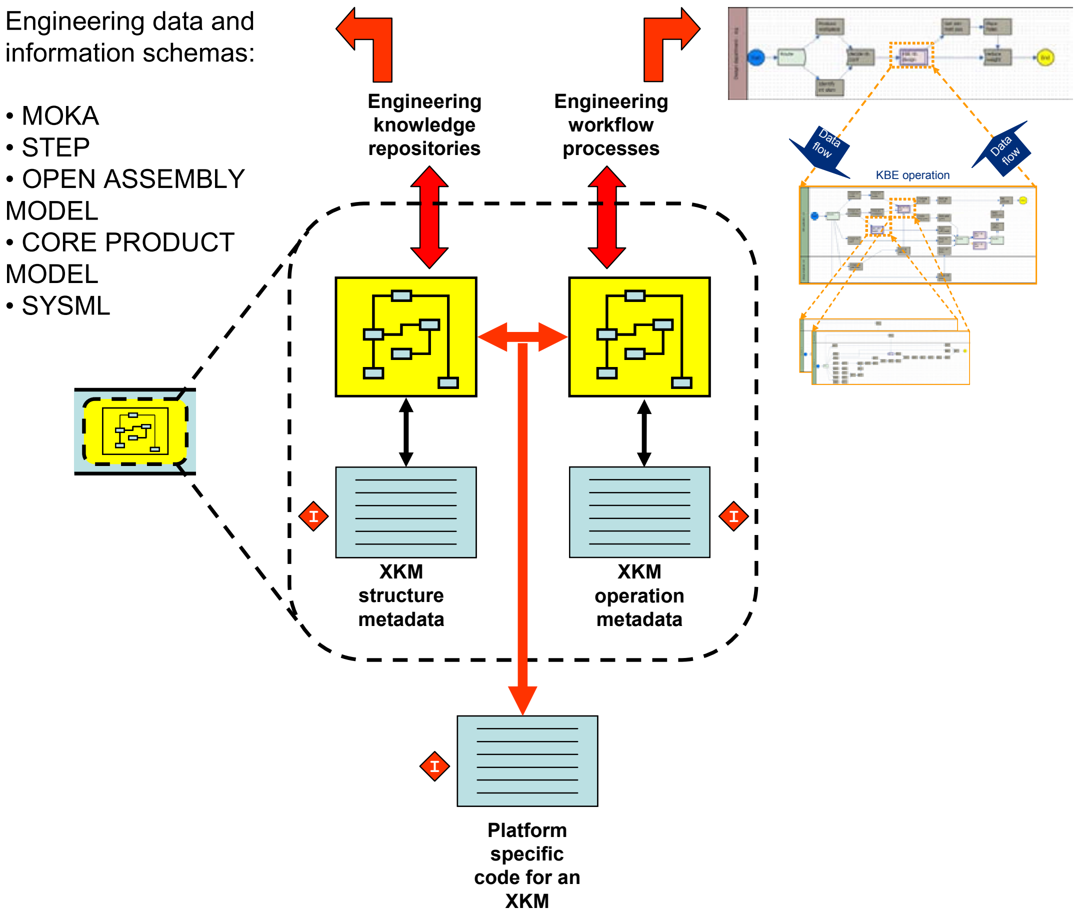


Figure 6-28. Integration of XKMs as EKRs with other enterprise data models.

The resource structure metamodel plays a central role in the mappings from the KBE code to the EKR metamodel. This is because this metamodel is based on a decomposition schema that identifies the entities of interest (code building blocks) within the XKM. The structure metamodel is an abstract syntax specifically designed for KBE languages. At the object level of granularity, the metamodel is a response to the abstract syntax for KBE systems solicited in the OMG RFP described in 4.2.3.1. In addition, it also provides a decomposition schema at the resource-component level that is not covered by the RFP.

As part of the research, the basic rules to perform transformations for the automatic generation of XKM codes EKRs metadata have been developed. Implementation of these transformations is beyond the scope of the research. However, the information provided is useful for programmers to develop data mapping engines. Key standard technologies to this implementation are the XML Metadata Interchange (XMI) and XSLT. XMI is an integral part of the OMG's MDE strategy (known as Model Driven Architecture). It is designed to create mappings from metamodels that comply to the MOF upper level semantic language, (OMG 2006). On the other hand, XSLT is a more generic mapping approach that can be used to query and transform data between KBE codes and the XML-based representations of the two metamodels (Hjelm and Stark 2002).

The immediate use of the metamodel describing KBE resources is as a systematic way to document their structure and operation. Apart from providing a systematic documentation model, this work is the basis for KBE resources metadata to be generated automatically. The research contributes to achieve this objective by providing semantic unification between the entities within KBE codes and a descriptive model of their structure and operation.

Chapter 7

METAMODEL ILLUSTRATION AND VALIDATION

7.1 Introduction

This chapter gives a detailed view on how the metamodel can be used to annotate XKMs by providing some simple examples. The illustrations are also used as a vehicle to communicate the metamodel design to a group of experts with the aim to get a qualified validation. The criteria to select the experts to assess the metamodel are based on the following:

- KBE technology expertise
- Knowledge modelling management and storage using enterprise data repositories
- Influential position within organisations using intensively KBE technology

As in the case of the survey research reported in Chapter 4, a group of well qualified practitioners have participated in the validation. Among them, it is important to highlight the participation of R&D personnel from one of the world's major PLM vendors in the market of complex engineering products. The validation group showed great interest in the research and in all the cases they hosted in-depth workshops to cover the technicalities of the metamodel design.

7.2 Metamodel illustration

An illustration of the use of the metamodel to annotate XKM codes is given in this section. The example is based on a simple case and it is intended to describe the procedure to building instances of the structure and operation metamodels.

7.2.1 Building an instance of the structure metamodel

A simple example is used here to reproduce the process of building an instance of the metamodel to describe the structure and operation of a XKM. The two simple *ICAD* code objects used in the illustration are shown in figure 7-1.

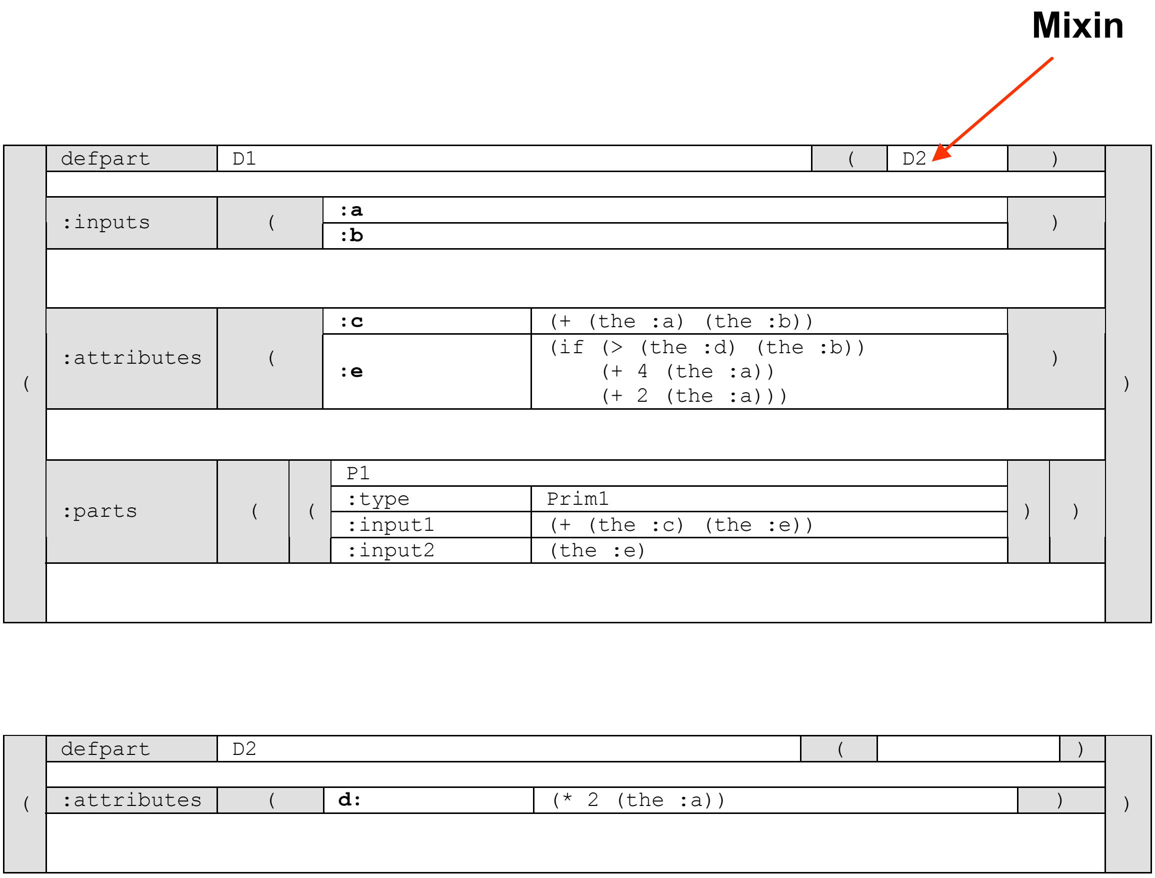


Figure 7-1. Simplified *ICAD* code objects.

The two objects represent in this example an XKM contained in a text file. The creation of an instance of the metamodel transforms them into a structured EKR. Figure 7-2 shows the aspect of the resulting *PROTÉGÉ* class tree after the creation of the metadata corresponding to the code in figure 7-1.

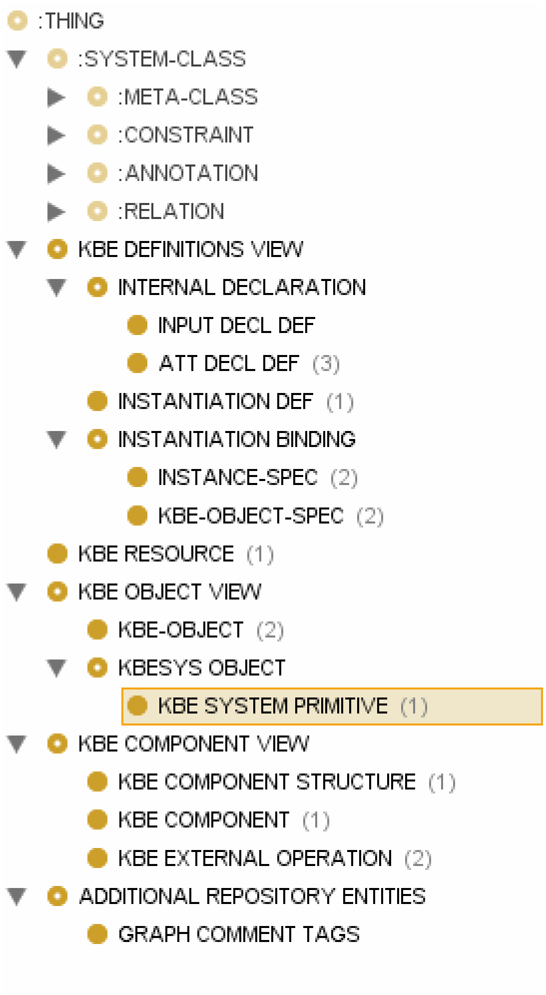


Figure 7-2. The resulting *PROTÉGÉ* class tree

An initial analysis of the code creates an instance of the KBE RESOURCE class. Using the *PROTÉGÉ* system the result is illustrated in figure 7-3. The graph represents the two objects in the code. As **D1** contains one definition within **:parts**, an instantiation definition node is created linked with **D1** using the relation "specifies instance". The relation "uses definition from" that connects **D1** to **D2** is explicit in the code through the definition of a **mixin**. These relations are stored in *PROTÉGÉ* as reified relations defined as classes under the :DIRECTED-BINARY-RELATION metaclass. Although they are not part of the metamodel, they are useful to visualise graphically the structure of the XKM.

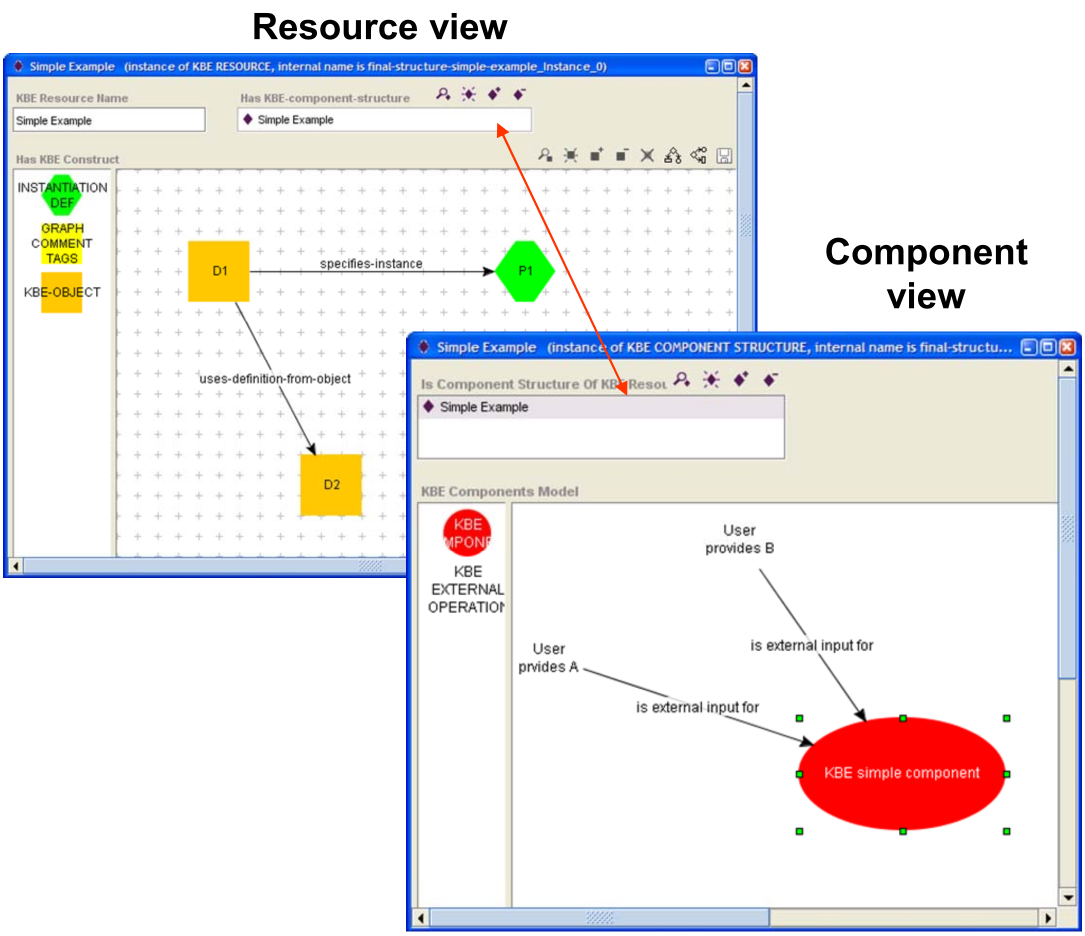


Figure 7-3. Resource and component models.

The appearance of a **mixin** in **D1** also indicates that **D1** and **D2** are part of a component. Then, an instance of the class KBE COMPONENT STRUCTURE is created within the component view. An instance of the class KBE COMPONENT is created to make explicit that D1 and D2 are components, (red oval node in figure 7-3). Since the inputs of **D1** are not in the **:parts** specification of any other object in the code, it can be inferred that the **:inputs** definitions **:a** and **:b** are external to the XKM and provided by a user. Based on this, the graph nodes "User provides A" and "User provides B" are created as instances of the class KBE EXTERNAL OPERATION.

From the identification of **D1** and **D2** as objects within the XKM code, two instances of the class KBE object are created, (Figure 7-4 and Figure 7-5).

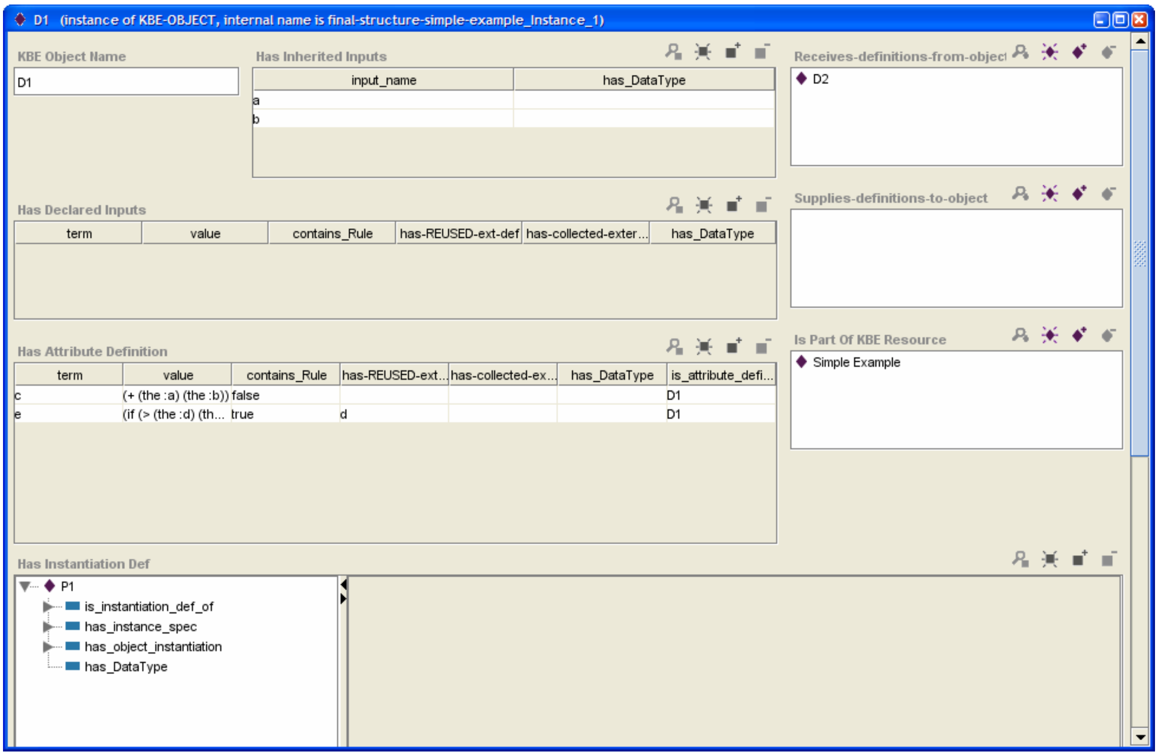


Figure 7-4. Instance of the KBE object class corresponding to D1

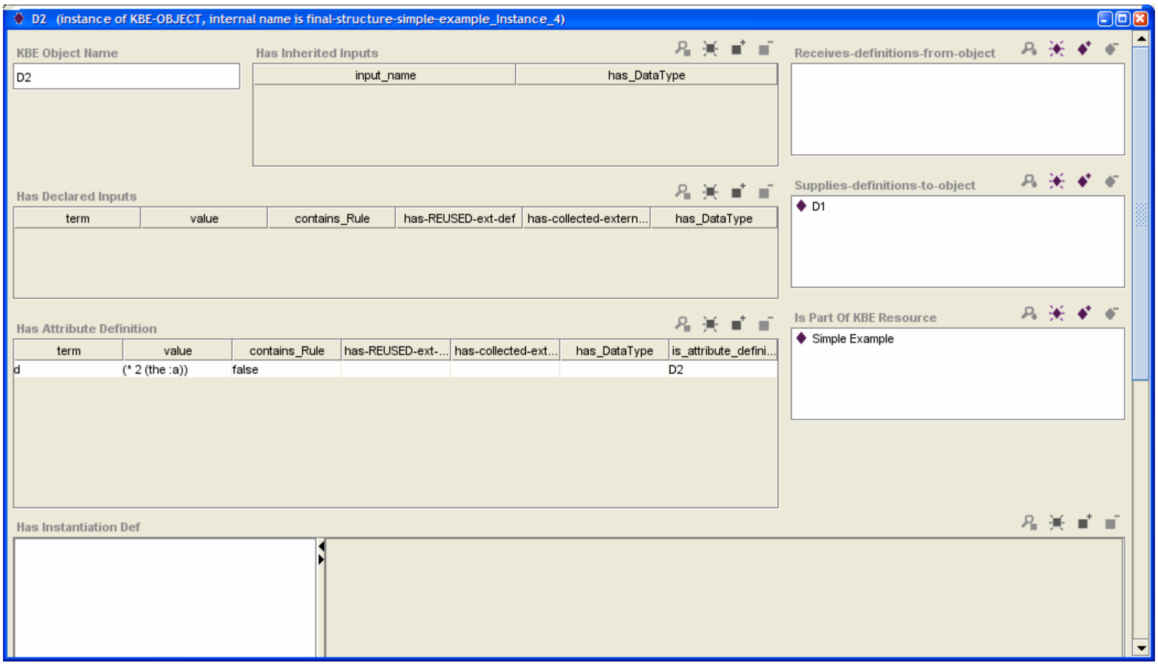


Figure 7-5. Instance of KBE object class corresponding to D2.

The instances of the KBE Object class contain information about the definitions used in the code. In **D1, :a** and **:b** are recognised as inherited inputs because they have no expression attached and they are within the **:inputs** cell. An instance of the class KBE-

OBJECT-SPEC for each and they are linked to the **D1** instance through the has_inherited_inputs field in figure 7-4. The has_attribute_definition form in figure 7-4 and figure 7-5 show instances of ATT DECL DEF class. An instance of this class is created for each definition within the **:attributes** cell for **D1** and **D2,** (figure 7-6). The relevant information collected in this instance is the domain term used in the code (**e** in the example of the figure), the code itself and a boolean field expressing whether if it uses an engineering rule.

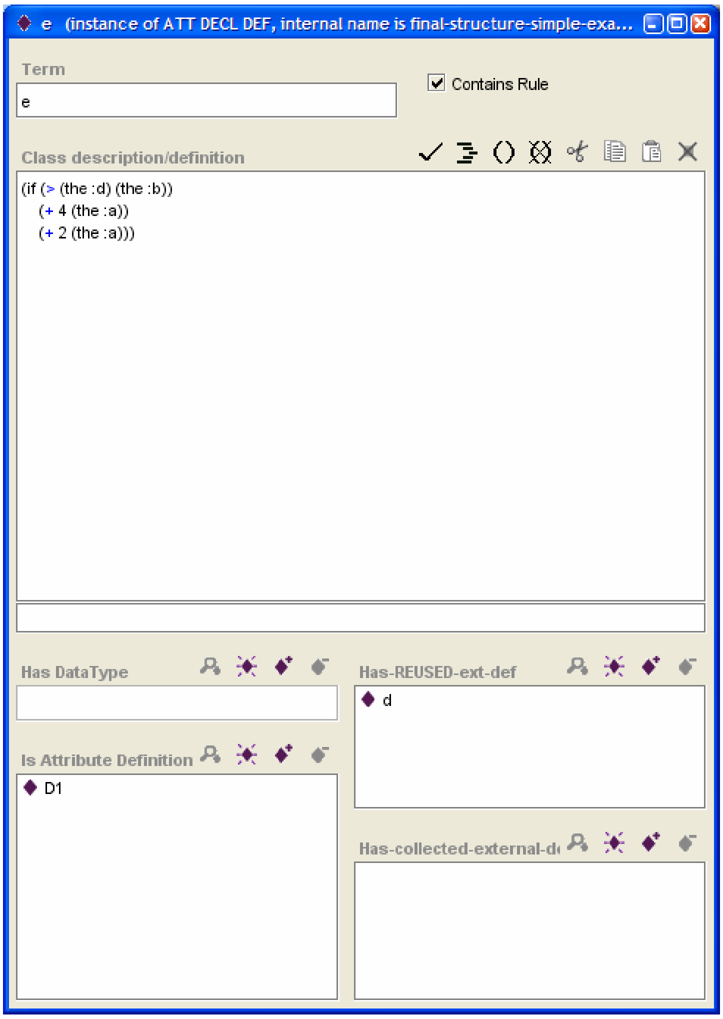


Figure 7-6. instance of the ATT DECL DEF class.

The "has_declared_input" form is used for instances of the INPUT DECL DEF in the case that default inputs are used in the code. However, both of them are semantically equivalent.

The **:parts** definitions are expressed in the metamodel as instances of the INSTANTIATION DEF class. For each **:part** definition within an object, an instance is created. Figure 7-7 shows the instantiation definition for **P1**. In the KBE OBJECT instance form, these instances are shown using a tree representation under the Has_instantiation_Def form.

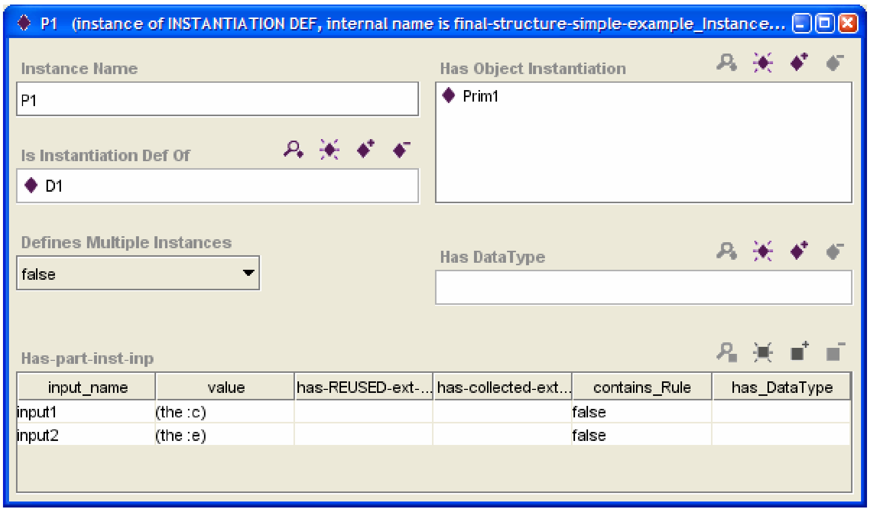


Figure 7-7. The definition for the instantiation of **P1** within **D1**.

Within the instantiation definition in figure 7-7, the has-part-inst-inp form holds instances of the class INSTANCE SPEC. These instances describe the specification for another object that in this case is a KBE system primitive. Within the object **D1**, there is one **:part** definition. Since the **:type** expression is not in the **defpart** definition of any other object, it can be deduced that **Prim1** is a system primitive. Based on this, an instance of the class KBE SYSTEM PRIMITIVE is created.

Finally, the slot "Defines_multiple_instances" is used to declare whether if the instantiation definition uses quantification constructs to create multiple elements.

7.2.2 Building an instance of the operation metamodel

The same example as in the previous section is used here to create an instance of the operation metamodel. This operation can be done either from the structure metadata or from the code. The example is illustrated though screenshots of the resulting process model in the *Jawe* XPDL editor.

Two packages are created to from the structure metadata. The first one contains the process model describing the component that uses **D1** and **D2**. The second one, contains the process describing the KBE system primitive **Prim1** that instantiates **P1**. The aspect of the package tree for the XPDL file is shown in figure 7-8.

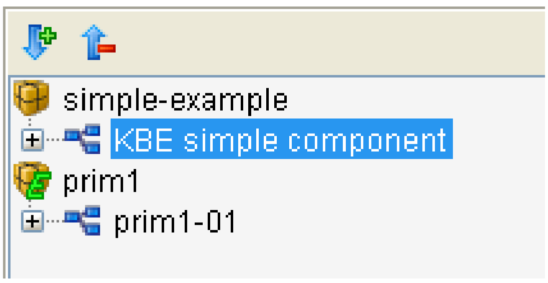


Figure 7-8. The two packages created for the example.

For each component, in the structure metamodel a process model is created within the KBE SIMPLE COMPONENT package. The name used for the process is the same used for the component in the structure metamodel instance. Both in *PROTÉGÉ* and in *Jawe*, internal names stored as "id" are created automatically for each entity created. A transformation engine to generate code/metadata shall consider this aspect as well. Within the KBE SIMPLE COMPONENT process, a participant attribute is created for each code object .

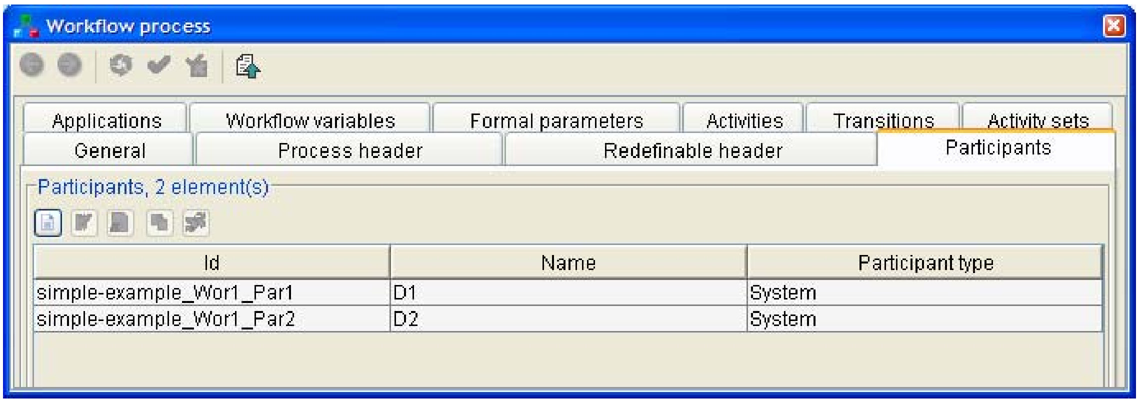


Figure 7-9. XKM code objects as participants in the operation metamodel.

Following the basic rules defined in section 6.5.3, the result creating an instance of the operation metamodel is illustrated in figure 7-10.

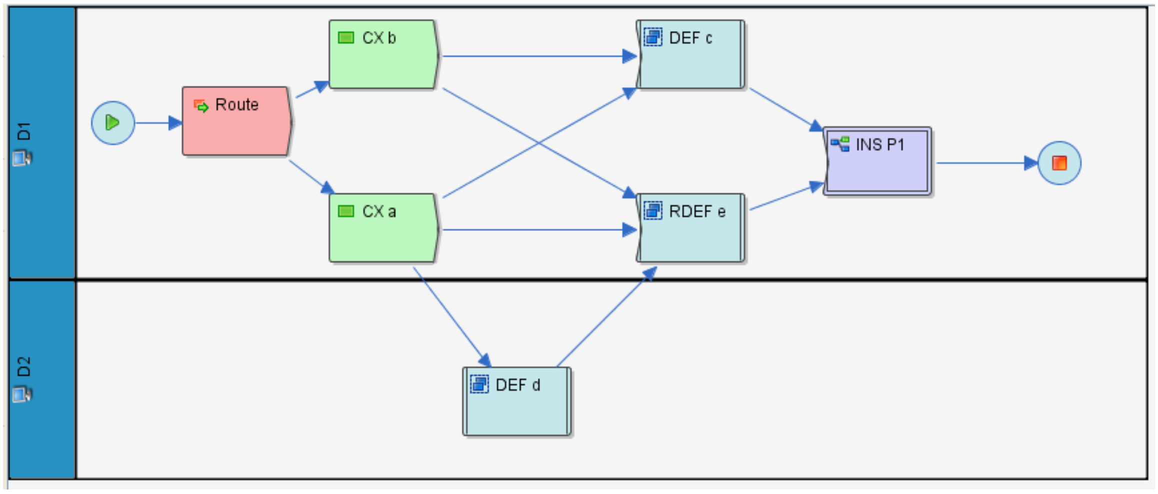


Figure 7-10. Graphical representation of the **D1** and **D2** XKM codes.

The four types of activities defined in the metamodel (CX, DEF, RDEF and INS) are used in the example. The representation of complex definitions including engineering rules uses the approach explained in sections 6.5.3.1. and 6.5.3.2. In the graph they use the XPDL block activity construct. Figure 7-11 and figure 7-12 illustrate the content of the block activities to define **:c** and **:d** by using the CommonKADS inference catalogue.

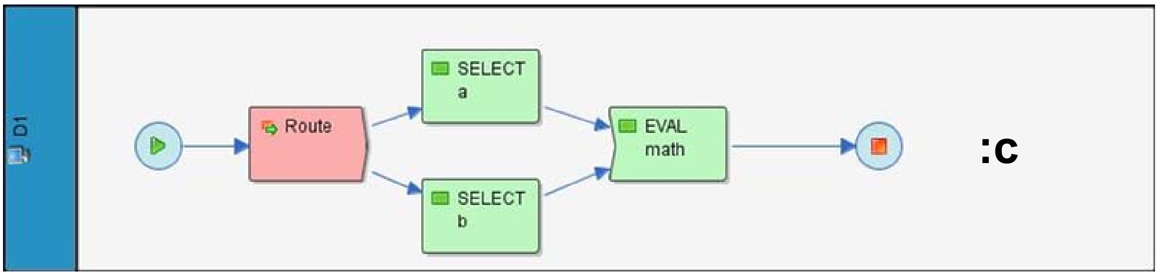


Figure 7-11. **:c** definition.

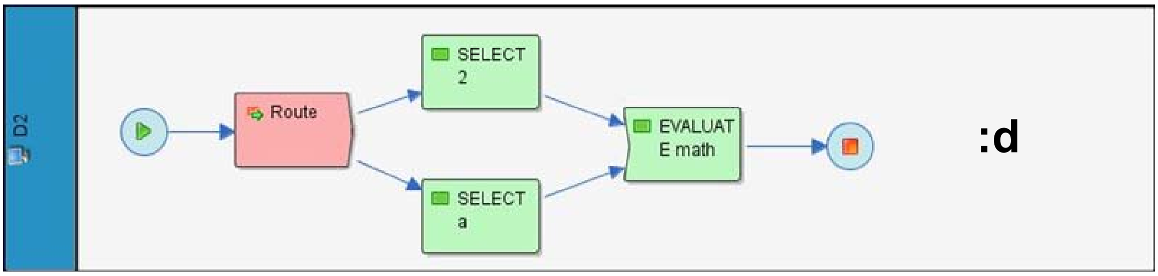


Figure 7-12. **:d** definition.

The definition **:e** is a RDEF activity describing an engineering rule. Unlike in the example in section 6.5.3.2, in the **:e** definition the consequents of the rule contain complex expressions. Then, each of the possible DEF activities use the XPDL block construct, (figure 7-13).

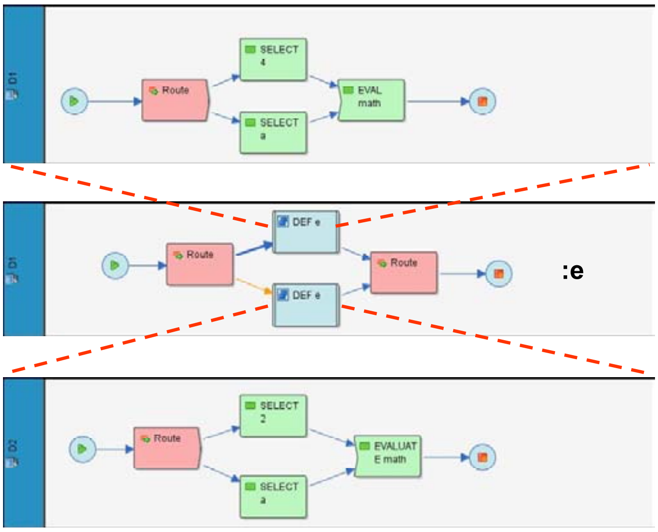


Figure 7-13. **:e** definition.

Apart from these process properties, each of the definitions within **D1** and **D2** are transferred as workflow variables in the KBE SIMPLE COMPONENT process, (figure 7-14). On the other hand, for each of the inherited inputs defined at the structure metadata within **D1** and **D2**, a formal parameter is created within the properties of KBE SIMPLE COMPONENT, (figure 7-15).

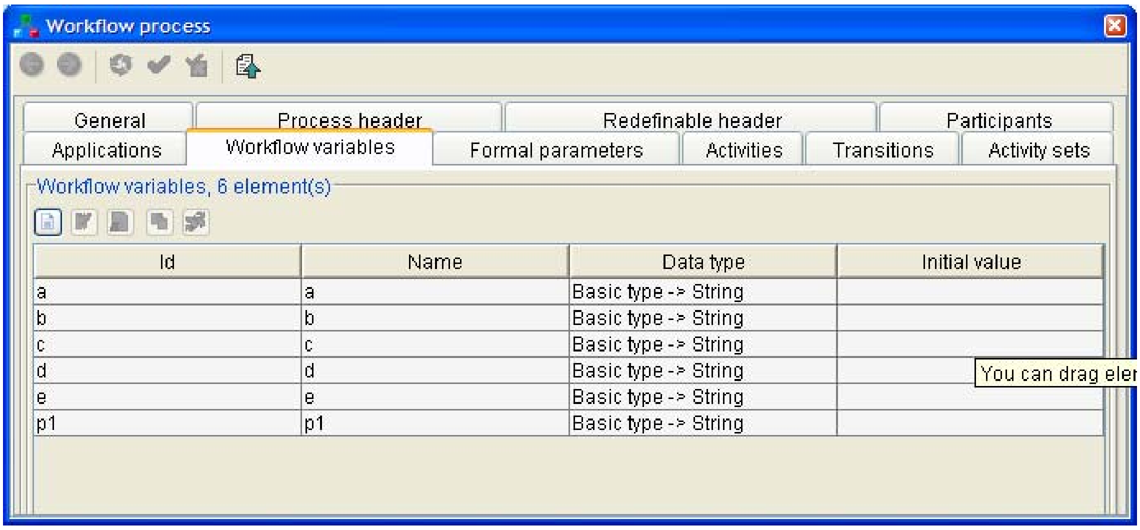


Figure 7-14. Workflow variables.

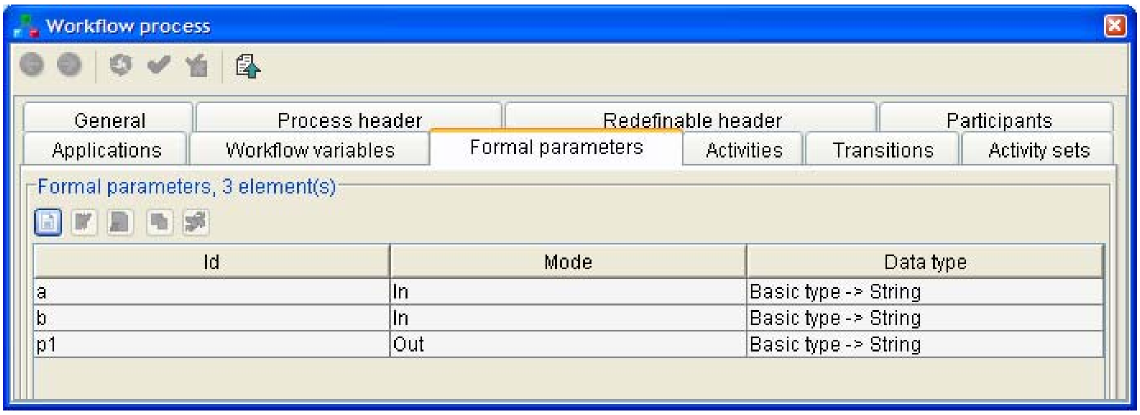


Figure 7-15. Formal parameters.

The objective of mapping the definitions into workflow variables and formal parameters is to manage the interactions between objects. As it can be seen in figure 7-15 the KBE SIMPLE COMPONENT process has **:a** and **:b** as formal parameters settled in the IN mode. This means that another object trying to instantiate **D1** and consequently **D2** needs to supply values for **:a** and **:b** and it is going to receive the result of instantiating **P1** whose mode is set to OUT.

Similarly, the definition INS **P1** is the construct responsible to pass data from the KBE SIMPLE COMPONENT object to the **Prim1** primitive object. The data binding for this operation is illustrated in figure 7-16. As it can be seen the workflow variables **:c**, **:e** and inputs for **Prim1** whereas **P1** (an instance of **Prim1**) is the output.

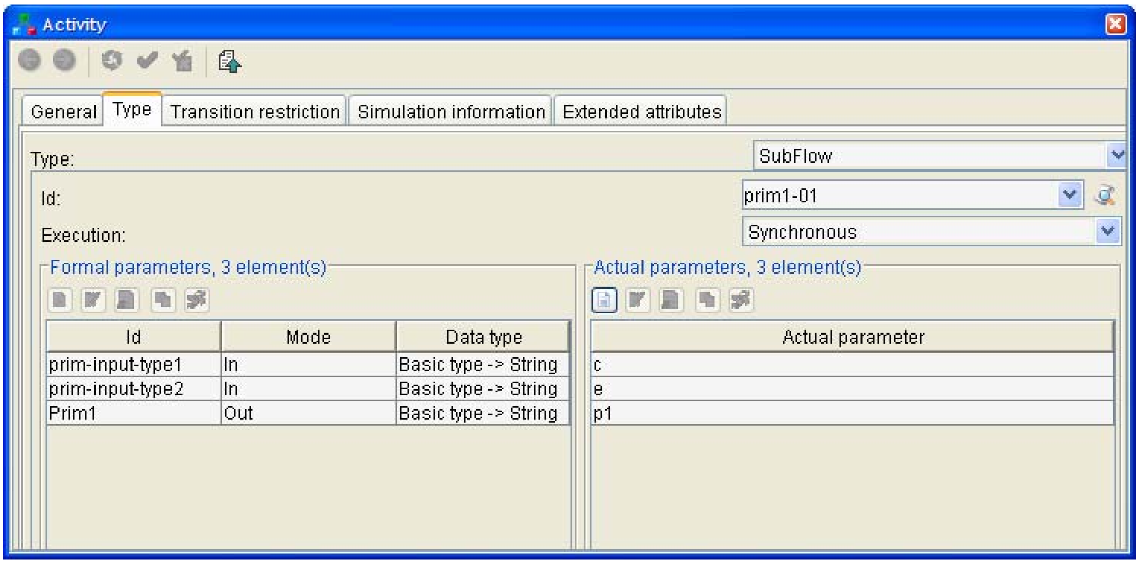


Figure 7-16. Data bindings between KBE SIMPLE COMPONENT and the **Prim1** primitive object described as a process in another package.

7.2.3 Integrating the structure metamodel with domain knowledge representations

A particular metamodel instantiation was created to illustrate the integration of the metamodel with domain knowledge models. A screenshot of this model is shown in figure 7-17. This example takes the knowledge representation schema used in the MOKA informal model. Its particular design, structures the representation using the following pieces of information about a design process: Illustrations, Constraints, Activities, Rules and Entities (known as ICARE forms in the MOKA terminology).

The knowledge is represented in *PROTÉGÉ* through classes containing instances of the ICARE forms. An RDF representation allows the declaration of explicit relationships between the ICARE forms and the entities in the proposed metamodel. A useful case of application of this concept is the association of rich descriptions of a rule (using the MOKA model), with pieces of code within KBE code objects.

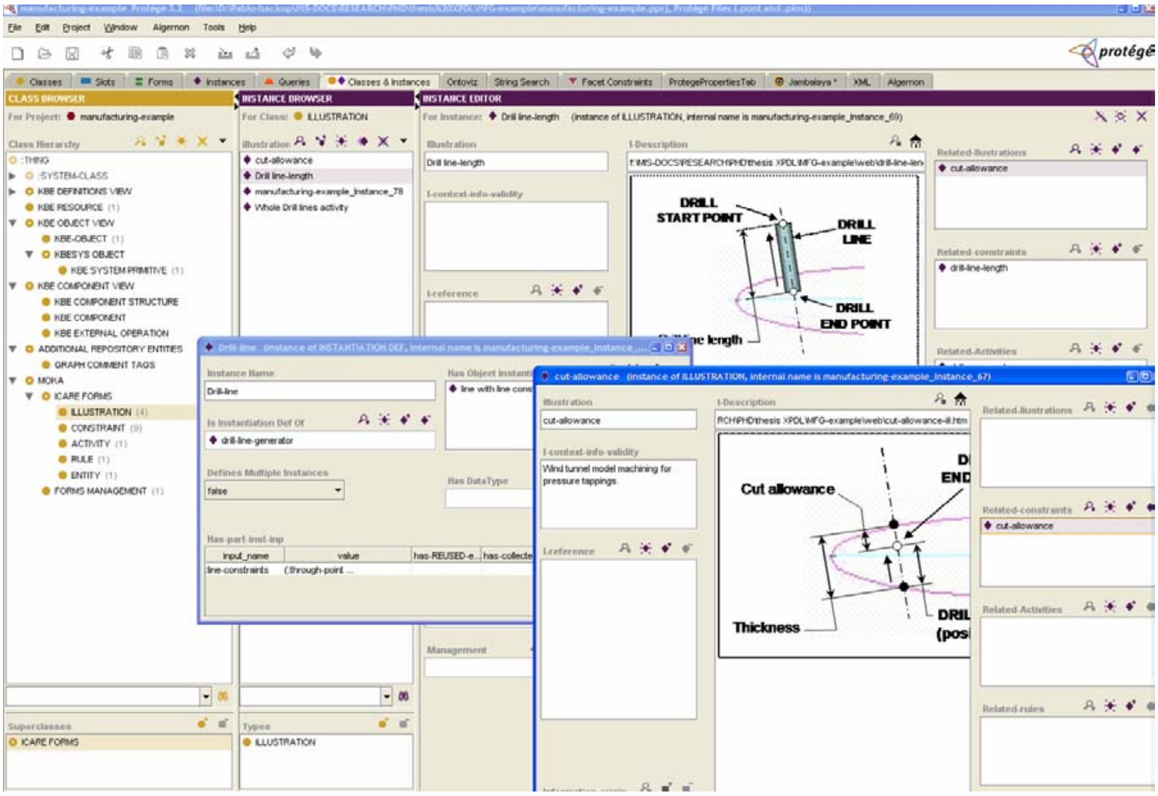


Figure 7-17. Integration of the structure metamodel with the MOKA informal model.

7.3 Metamodel validation

A validation of the metamodel presented in this thesis has been carried out through a series of validation meetings. Three sessions have been arranged with highly experienced practitioners within the community of KBE users and vendors. Details of the participants in the validation meetings are given in table 7-1. In the case of the users, all the participants are advanced KBE technology users. In the case of the vendors, the host team is dedicated to the development of KBE solutions within the overall CAD scope of systems developed by the company.

7.3.1 Validation protocol

The validation meetings are carried out at the offices of the participants. In the validation session, a checklist document is provided to guide the discussion, (see Appendix D). The objective of the validation sessions is settled in advance to the participants and it is enunciated as follows:

- **To asses a metadata model to describe KBE applications as resources in distributed computing environments.**

The procedure followed in the sessions includes the following steps:

- **1. Give a description of the metamodel.** The researcher presents the metamodel to the participants. The metamodel illustration reported in this chapter is used to demonstrate how the metamodel can be used.
- **2. Distribute a validation checklist.** In the checklist, a range of discussion topics are exposed as statements. The main areas include statements about the correctness of the metamodel and the validity of the approach taken to build it. Statements about the applicability of the metamodel and also about its transferability into industrial contexts.
- **3. Discuss the aspects highlighted in the validation checklist.** The checklist is used as a guide for the discussion. The participants are informed that filling the answers is not necessary for the discussion. However, most of them fill them as the discussion moves.

Table 7-1. Participants in the validation meetings.

	Organisation type	**Position in the organisation**	**Session duration**
Participant 1	CAD software firm	R&D director	7 hours
Participant 2	CAD software firm	Senior software engineer	
Participant 3	CAD software firm	Software engineer / Knowledge engineer	
Participant 4	CAD software firm	Software engineer	
Participant 5	CAD software firm	Software engineer	
Participant 6	Global engineering consultancy	Deputy manager, engineering automation	5 hours
Participant 7	OEM aerospace	KBE product line manager	
Participant 8	OEM automotive	Head of KBE	2 hours

7.3.2 Validation results

The checklist prepared prior the validation meetings is designed to focus the discussions during the meetings. A score system uses a scale from 1 to 6 to evaluate the contributions of the presented metamodel. The highest scores for each of the aspects covered during the meetings are shown in table 7-2.

Table 7-2. Highest scores on the metamodel assessment.

	USERS			VENDORS						
1.1 Overall approach: KBE resource description via metadata models									AVRG.	STDEV
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	5	6	5	6	6	4	5		5.29	0.76
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	6	5	6	5	6	3	5	5	5.13	0.99
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	5	6	6	4	6	5	5		5.29	0.76
1.2 Metadata model for describing the structure of KBE resources										
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	5	6	6	5	5	4	5	6	5.25	0.71
The KBE component view is useful to understand the functionality of KBE resources.	5	5	5	5	5	5	4	6	5.00	0.53
1.3 Metadata model for describing the functionality of KBE resources										
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	4	6	5	4	5	4	6	4	4.75	0.89
2.1 The KBE resources metadata supports the comprehension of the following aspects:										
The high-level structure/architecture of a KBE resource	6	6	6	6	5	5	5	6	5.63	0.52
The impact of changes in the KBE resource	6	5	4	6	6		5	5	5.29	0.76
2.2 The KBE resources metadata helps to carry out the following tasks:										
Understanding the domain of the KBE resource	6	6	5	6	4	5	4	5	5.13	0.83
2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them										
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	5	6	4	6	5	5	5	5	5.13	0.64
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	5	6	6	6	5	5	5	5	5.38	0.52
2.6 Use case: KBE resources become annotated PLM items to support										
The presented metadata model contributes to achieve this use case.	5	6	5	6	5		5	5	5.29	0.49
2.8 Use case: KBE resource lifecycle management										
The presented metadata model contributes to achieve this use case.	5	5	6	6	5		4	6	5.29	0.76
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them										
The approach can be scaled up to industrial KBE implementations.	4	5	4	6	5	2	5	5	4.50	1.20
The approach improves existing KBE application documentation practices.	6	6	5	6	6	4	4	6	5.38	0.92
PLM technology can be used as a KBE resource repository.		6	6	6	6	6	6	5	5.86	0.38
3.2 The proposed metadata model for KBE resource description has potential…										
As a mechanism to retain engineering knowledge for future retrieval and reuse.	5	6	5	6	6	3	5	5	5.13	0.99
As a contribution to create a standard to support the interoperability between KBE software systems.	4	6	5	6	5	4	5	5	5.00	0.76

The outcome of the validation meetings is discussed here in the context of the three areas of improvement for which the metamodel has been designed.

7.3.2.1 Contextualisation of KBE within engineering practices

A first connection to the contextualisation of KBE technology has to do with the perceived role of the metamodel. Agreement is found on its use as a way to communicate between XKM developers involved in the development of large applications. A high score (5.25) is achieved on the capabilities of the presented metamodel to share applications with other developers. In the meeting with the aerospace and the consultancy firm participants, a "developers-oriented" view for the use of the metamodel is diverted to the focus on long term retention of engineering knowledge.

A closer integration of KBE technology within the PLM concept seems to be a common concern across practitioners and vendors. This issue guides the discussion how to contextualise KBE technology as another engineering body of practice. The metamodel is perceived as a feasible step forward to provide a solution for this integration that otherwise is a wide issue with many angles to look at.

The description of XKM as data flows is highly appreciated by two of the KBE technology users as well as by two of the software vendor participants. The R&D director of the KBE software development team makes the observation that the use of these representations in KBE technology at an abstraction level closer to the design process is needed.

7.3.2.2 Management of the knowledge encoded in XKMs

In terms of the management of knowledge stored within XKMs, agreement exists on the need to increase their transparency in the way that is supported by the metamodel.

To asses the support to increase the transparency of XKMs, a set of criteria are extracted from a software comprehension model reported in the research from Pacione et al. (1994), (sections 2.1 and 2.2 of the validation checklist). This software comprehension tasks are of use in the context of inverse engineering software programmes. However, they are generic enough as a set of criteria for the comprehension of any programming code. The comprehension tasks cover a wide range of situations. Many of them are out of the scope of the research. This includes the comprehension of the "load of a XKM component at runtime". On those particular statements the discussion with experts describe the little use of the metamodel in those situations but also the little interest for KBE technology users on understanding those low-level issues. However, as it can be seen in table 7-2, the metamodel gets the highest scores as a representation to comprehend the following aspects:

- The high level structure/architecture of an XKM
- The impact of changes in the code of XKM
- The dependencies between XKM code artefacts
- The domain in which the XKM is used.

On the other hand, the metamodel is perceived as a piece of work that can be used to realise the use cases described in section 4.2.3.3. In this particular view, the type of enterprise repository in which the metamodel annotates EKRs is the one in PLM technology. In this direction, one of the participants from the software vendor firm makes the following remark:

> *I personally see the need of managing enterprise intellectual property (IP) in PLM. KBE is one of the most important ways to define engineering IP. Definitely, has a lifecycle (KBE) and its applications should be managed by PLM.*

The R&D director within the CAD software firm acknowledges that supporting the use cases is part of their research strategy for new products related to KBE technology.

7.3.2.3 <u>Enterprise knowledge architectures for KBE technology</u>

The use of the MDE concept in the context of KBE technology is perceived as an approach to modernise the architecture of KBE software systems as well as the XKM development process. In general, the participants at the KBE technology user side tend to acknowledge that the appropriate storage of XKMs using semantic modelling standards has potential to enhance the way they manage their XKMs. However, they also claim that the vendors should drive these advances instead of them.

KBE technology users see MDE as a possibility to facilitate their job in terms of the update and maintenance of systems. However, it has been made clear through the meetings that MDE has value as long as it is applied in the development of XKMs and this includes automatic generation of code and metadata. The participant from the automotive OEM highlights this point in following quotation:

> *A big challenge (for the metamodel) is its application for business benefit. It needs to get something back from the effort to create data. A big opportunity is driving the development (code writing) from the metamodel. Examples of this are the auto update of metadata and the code generation.*

The participant at the aerospace OEM has been involved in the activities in the OMG. His particular case for supporting the development of unified semantic models using MDE is related to the maintenance issues of large applications across programs and through the lifecycle of long-life products.

A high degree agreement is found on the ability of the proposed metamodel to contribute to the business functionalities elicited in chapter 4. This includes the capabilities of the metamodel to support the maintenance of XKMs code and to formalise them using a unified representation. In this direction, the salient features of the proposed metamodel are:

- The use of a specifically designed metadata model to annotate XKMs
- The creation of a blueprint for XKMs within enterprise repositories so retrieval an reuse is more likely to happen

7.4 Concluding remarks

In this chapter, an illustration of how to build instances of the proposed metamodel is presented. A simple example is chosen to make the illustration more comprehensive. The example is used on a series of validation meetings carried out with highly experienced KBE technology experts.

In general, the metamodel is well received by the community of KBE technology users and vendors. Two common issues for which the metamodel provides a response are:

- **Little documentation methods exist for XKM codes**. Documentation methods specifically designed for KBE technology are built in-house. An example is given by one of the industrial practitioners indicating that their codes are very large. In this situation, they document some of the codes using Microsoft Excel spreadsheets since they do not have a restriction on dimensions.

- **Documentation needs to be supported by automatic methods**. The practitioners are concerned on the fact that documenting their models is an overhead. In this respect common agreement exists on the willingness to document as long as the result is executable and not only informative.

Chapter 8

DISCUSSION AND CONCLUSION

8.1 Summary of achievement

A new metamodel to describe XKM in enterprise repositories has been developed and reported in this thesis. The aim of the research leading to such metamodel is: "To transform XKMs into enterprise resources through a metamodel that can describe them". Using the proposed model, XKMs created using KBE technology can be systematically annotated and indexed within enterprise data repositories. The selected approach to build the metamodel using standard modelling techniques responds to the research aim of transforming KBE models described using proprietary representations into EKRs written on platform independent languages. On the other hand, the specific design of the metamodel addresses its role as a common language to describe XKMs. The specific research objectives refer to the performance of the metamodel and are listed as follows:

- The metamodel has to respond the needs of KBE practitioners.
- The information model has to be built using state of the art metamodelling techniques.
- The metamodel has to provide a solution to increase the transparency to the knowledge encoded within KBE applications.
- The metamodel has to be validated by relevant experts in the KBE area.

The research challenge to achieve these objectives is to convey the different schools of thought behind the effective management and delivery of knowledge to improve engineering design operations. This includes the research areas on engineering design improvement, engineering knowledge management and enterprise knowledge architectures. The assessment on the achievement of these objectives is done through an analysis of the internal and external validity of the research. While the internal validity mostly focuses on the correctness of the resulting metamodel, the external validity refers to evidence gathered regarding its applicability and transferability. These aspects are discussed as follows:

- The correctness of the resulting metamodel has been enforced by the use of advanced metamodelling techniques. This implies the review of the available modelling frameworks within the Knowledge Engineering field. The learning acquired makes the researcher capable to make a qualified choice. On the other hand, the understanding of this body of knowledge and the supporting tools and techniques facilitates the modelling while preventing errors in the models. For instance, the *PROTÉGÉ* tool automatically parses an RDF file and also helps to test the metamodel in the iterative process of building it. The external validation also evaluates positively the "fit for purpose" of the metamodel as a common language to annotate KBE codes.
- The applicability of the metamodel is subject of an external validity assessment. On one hand, the technical approach and its connections to metamodel interoperability concepts have been proven to be technically aligned with the OMG approach, a major international standardisation body for data models. On the other hand, the validation process shows the potential of the resulting metamodel to improve the use of KBE technology. The most appreciated features of the metamodel are its application in the maintenance and response to changes on KBE applications and in facilitating the understanding of the knowledge embedded in the codes.
- Regarding the transferability of the research, the external validation of the research confirms the feasibility to use the metamodel as a mechanism to manage KBE resources using enterprise data repositories in the form of PDM and PLM systems.

A distinctive achievement of the proposed metamodel is the acceptance of its role by the validation team as a communication instrument. The model achieves this by facilitating the understanding on what pieces of code compose a KBE application and how it works to generate the desired engineering data. As a consequence, more chances to reuse the knowledge encapsulated on it are given for both developers and users. From the KBE development viewpoint, programmers accessing applications annotated with the proposed metamodel can more easily understand the abstraction approach made to create the application. A common way to represent the structure of KBE codes is useful in many situations. For instance, the update of applications is likely to happen faster when its logical structure is visible. On the other hand, it gives more chances for other developers than the original one to reuse fragments of the code.

8.2 Contribution to knowledge

The development of knowledge models to support engineering design activities is the subject of intensive research. The lessons learnt through years of research on AI, Knowledge Engineering and ICTs for product engineering have lead to new ways of using computer systems to achieve this support (see section 2.2.3). Deploying the right knowledge, at the right time and in the right form is widely appreciated by the research community as an engineering design improvement capability. However, due to the complexity of distributed design operations there is an emerging need to support this process through ICTs. Given the diversity of systems processing data, information and knowledge in these operations, strategies to support the interoperability between them is becoming a critical issue. In the last decade, the research community addressing these issues has progressively aligned its thinking with the work on information and knowledge modelling and management. Examples of these efforts are the ones described in section 2.3. In the UK, a reference research initiative is the EPSRC Grand Challenge project on information and knowledge management through life, focused on delivering long term retention strategies in the engineering design domain (KIM 2007).

Much of the current research in the area approaches this issue from a generic knowledge engineering and management approach. Nevertheless, little work is reported on taking the advantages of a proven technology like KBE as a knowledge management instrument close to CAD technology, a fundamental way of exchanging engineering data across distributed engineering teams. In this direction, the European Commission funded research project MOKA, (Methodology and Tools for Knowledge Based Engineering) is one of the most influential research efforts on engineering knowledge management that focuses on KBE technology. Its results set down a robust methodological support for the acquisition of engineering knowledge for KBE implementation. However, a mechanism to map the knowledge models in MOKA into the KBE software tools is not covered in detail by the methodology, (Preston et al. 2005).

The research reported here approaches the knowledge management issue on the KBE context. Resulting from this, it updates some of the basic principles on how to use the technology as a codification and as a personalisation enabler for engineering knowledge management. The technical approach followed to articulate a response to this issue unifies different approaches followed by the Knowledge Engineering and the Enterprise Engineering schools of thought regarding the way the knowledge is delivered to engineering designers. The former usually focus on representation issues such as the accuracy of the semantics behind knowledge models and what they can express. The latter pays attention to their effective distribution of the knowledge in enterprise data repositories and the procedures followed to do so. These are two key features of the metamodel that integrate the thinking form the two research communities:

- The metamodel presented here uses a formal knowledge representation method to annotate the structure of KBE codes. The research uses state of the art information modelling practices from Knowledge Engineering field to create the proposed metamodel. In particular, the RDF is a standard language built on top of the XML to enrich its expressivity. While XML is able to describe taxonomies of concepts, RDF is also capable to model relationships between those concepts. In the context of the research, these descriptive features of the RDF language are used to make explicit the structure of KBE codes
- The metamodel design is specially targeted to engineering designers as the customers of the knowledge within enterprise data repositories. Their concern is on deciding which KBE application can be reused on a particular task or what changes need to be made on it to do so. The XML Process Description Language standard is the reference language to describe how KBE applications work. Using this approach, a potential re-user can understand the application without being trained on the KBE language and decide if it fits is purpose for approaching a design task.

A more detailed description of the contribution to knowledge of this research is reported here by paying attention to the following viewpoints:

- The metamodel design.
- The contextualisation of XKMs within engineering practices.
- The management of the knowledge encoded in XKMs.
- The development of enterprise knowledge architectures for KBE technology.

8.2.1 Metamodel design

A novel contribution of this research in respect to existing work can be found on the design of the metamodel. Its particular structure allows the description of KBE applications as resources. Such description exists at an intermediate level of abstraction between the software that runs the code and other structured knowledge models. This enables the semantic agreement between the entities composing the proposed metamodel and the entities in other data models representing knowledge about engineering tasks. The particular types of data models for which this research supports this integration are:

- Structured and semi-structured models representing domain knowledge about particular engineering situations. An example of this is the ICARE forms defined within the MOKA informal model.
- Formal representations of engineering processes described in the form of workflow models. An example of this is a business process model represented using a standard notation like XPDL.

A graphical illustration of this concept is shown in Figure 8-1.

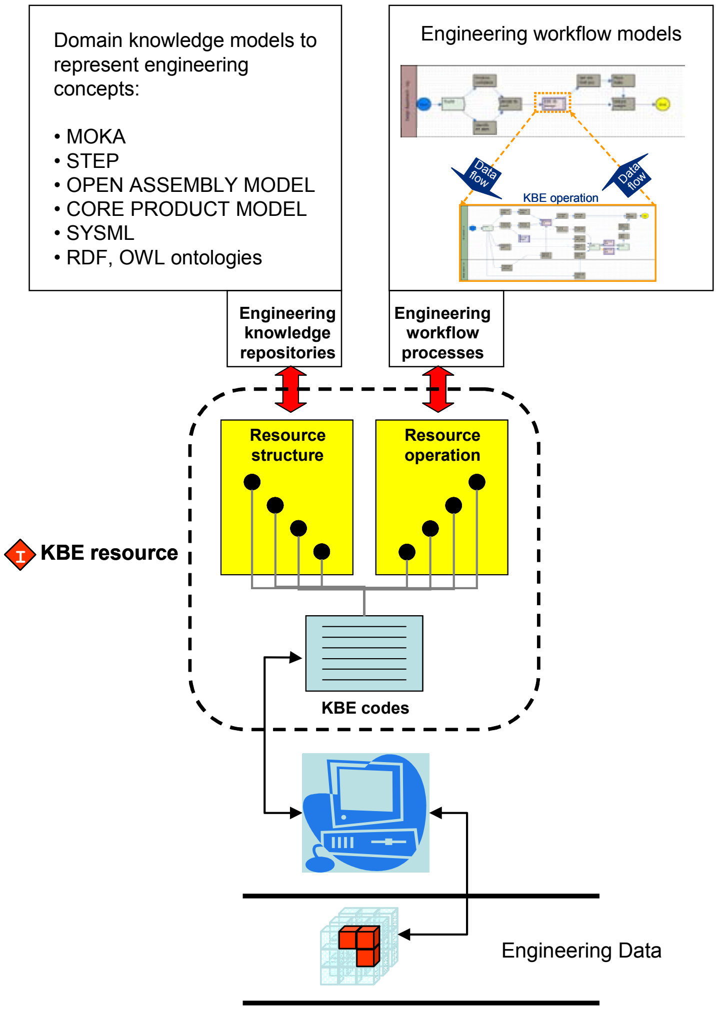


Figure 8-1. Positioning the instances of the developed metamodel.

The proposed metamodel facilitates this integration through a semantic agreement between the concepts at both sides. On one hand, domain knowledge models represented using RDF can hold direct relationships with the entities representing the structure of a KBE application. This concept is illustrated in section 7.2.3, where an RDF implementation of the MOKA informal model is directly linked to pieces of KBE code. Similarly, the semantic agreement between the structure and the operation metamodels allows users to define overall business process using XPDL that could embed a representation of how a KBE code operates.

In addition to these examples, the metamodel could be used to exchange information to other representations of knowledge and process models different from MOKA and XPDL respectively. The Structure metamodel, described using the RDF language (built on top of XML) stores the information in a structured manner. Two routes can be used to exchange knowledge between the proposed metamodel and other domain knowledge models:

- Expressing the domain knowledge model using the RDF and then establishing direct relationships between the concepts on it and the ones in the proposed structure metamodel in the same way as in the MOKA example.

- Writing an algorithm that queries instances of the proposed metamodel and fills the values of a knowledge model written using other structured knowledge such as OWL.

The possibility of creating this algorithm is shown in section 6.6 where the code of an *ICAD* application and instances of the structure and the operation metamodel are mapped. Furthermore, the choice of XML based representations facilitates the task of writing such algorithm. Similarly, it is feasible to map instances of the structure metamodel with a process model different from XPDL. This is possible since the metamodel design uses basic process modelling constructs that are common in any structured process modelling language. As it can be seen in section 6.4.3.1 the operation metamodel assigns roles to generic process model activities that are meaningful in the context of this research.

8.2.2 Contextualisation of EKMs within engineering practices

The research reported here contributes to spread out knowledge management best practices in the context of engineering design. While managing data is becoming a common practice in engineering environments, managing knowledge can be perceived as an obscure task to approach.

In the research journey to create computer systems that "know" how to execute design tasks, the unification of design knowledge has been focus of intensive work (Sim and Duffy 2003). The literature collects evidence on intensive research on the modelling of engineering design knowledge. Much of this work is built upon empirical research to understand and improve design processes. At the technology side, many of these developments have been made available thanks to the research applying AI and Knowledge Engineering techniques in engineering design systems, (see section 2.3.2).

The evolution of engineering design practice using ICTs is positioned in the front line the use of digital data repositories like PDM and PLM. The effective use of these systems implies the authoring of metadata that links the content of digital files to engineering concepts such as product structures, (Fan 2000). This has raised the need of metadata models to describe a wide scope of engineering data models that are specific for the domain. The particular type of domain models that this research focuses on is the task models captured using KBE technology. By enabling this, a KBE application becomes a resource through the specialisation of the description of an otherwise undifferentiated data item. The metamodel proposed in this research serves to the purpose of annotating the content of "KBE items". This implies a finer level of granularity on the description of a KBE item than the non-specialised metadata models that would only annotate context information such as its creation or ownership.

Engineering enterprise systems such as PDM and PLM systems offer a robust management infrastructure for digital data storage and work coordination. In the medium-long term PLM shall also support the management of engineering knowledge as any other resource available in the enterprise. Certainly, not all the engineering knowledge that delivers a product in the market is modelled using KBE. However, by supporting the management of this portion of the knowledge, the research reported here presents a step forward in the realisation of the overall objective. A key feature of KBE technology is its ability to execute task models that generate data that can be directly used in engineering processes. However, the sophisticated languages and KE concepts necessary to build complex tasks models using the technology is a barrier for users outside the group of KBE developers.

The research reported in this thesis approaches this problem from a new perspective. The training of mechanical engineers to become KBE developers seems not to be a realistic strategy. However, the annotation of proven XKMs using the proposed metamodel and their population in enterprise repositories offers new possibilities for the use of the technology. Mechanical engineers can be trained to search and retrieve pluggable XKMs that execute particular engineering jobs. The operation metamodel facilitates this by providing an abstraction of the XKM that can be part of an engineering workflow process. For a mechanical engineer not trained in the use of KBE languages, the representation of the codes as processes facilitates its internal comprehension. On the other hand, the structure metamodel provides a useful representation of XKMs to developers.

8.2.3 Management of the knowledge encoded in XKMs

The review of published work on IT systems to improve design practice shows the importance of creating and distributing knowledge in current engineering operations. At the shadow of advances like PDM and PLM, hesitation exists on whether these systems will support the lifecycle management not only of products but also data, information and knowledge (McMahon et al. 2005). On this wide research front, the international engineering design community is developing strategies to capitalise information and knowledge in the long term (KIM 2007; NIST 2007). In this research journey, KBE technology is one of the candidates for supporting the management of knowledge as it is one of the systems under the umbrella of PDM and PLM, (Lukas et al. 2005). The underlying modelling strategy to build generative modelling systems using KBE is the OO paradigm. In respect to the emerging CAD-integrated KBE systems, code-based KBE has broader set of object oriented knowledge modelling tools to develop more expressive and scalable domain models. A commonly acknowledged pitfall of building large automation systems using KBE is the risk that they become unmanageable "black boxes". The proposed metamodel gives a solution for managing the knowledge contained in XKMs. The metadata associated to XKMs increases the visibility of the code and consequently facilitates the management of their lifecycle.

The ultimate objective of systematising the elicitation and codification of knowledge is to capitalise the large investments made on the technology, (Sainter et al. 1999). These pressures build up the case in the late 90s for the research investments spent in the MOKA project and other parallel research projects such as REFIT (revitalisation of expertise in foundries using information technology), (Lovett et al. 2000). MOKA builds up a strong framework for supporting industrial-scale engineering knowledge management focused on KBE development. However, some the limitations are found in the MOKA methodology.

- Difficulties on the use of the MOKA formal model to establish the connection between a formal representation of the engineering knowledge and the KBE code.
- Little commitment on the use of the emerging concept of data repositories as a platform to manage the knowledge and the executable models resulting from KBE development.

The metamodel proposed in this research gives a response to these issues by adding a layer in the MOKA abstraction process. The additional layer holds a blueprint of the XKMs.

8.2.4 An enterprise knowledge architecture for KBE technology

During the research it becomes apparent that the underlying concepts of KBE as the technology to build KBS for engineering design need to be revised. This is also acknowledged by some researchers in the KBE field (Poenisch and Clark 2006). The review on modern KE techniques, advocates for the separation of domain knowledge from task knowledge, (see section 2.3.2.1). This is supported by the design of the metamodels due to the following reasons:

- It separates the metadata that annotates the task knowledge using the operation metamodel.
- It provides an infrastructure for linking the terminologies used in the code with structured and semi-structured representations of the knowledge through the structure metadata.

In the long term research agenda, the ability to create domain-specific modelling languages can lead to the automatic generation of metadata form semantically rich models. The immediate application is the automatic generation of code from instances of the metamodel to support the traceability and change management of XKMs. On a wider functionality scope, increased semantic interoperability across systems connected through PLM can be the basis for true "out of the box" intellectual capital retention and Knowledge Management. Under an optimistic view, agreement between influential PLM users and vendors through international standard bodies either for semantic modelling (W3C, OMG, OASIS) and engineering data models (ISO) will deliver the interoperability impact to industry (Subrahmanian et al. 2005). However, a more pessimistic view sees the intellectual capital of engineering organisations locked up within the tools of a handful of PLM software vendors. This also implies many more years of the well-known data exchange problems until one vendor dominates the market and the legacy systems have been replaced.

This is a well known issue in the Software Engineering domain. The promises for enhanced reuse at the expense of more abstract coding techniques have been fulfilled to a lesser extent than it was expected. The need to support knowledge retention, systems maintenance and platform migrations has driven the development of systematic models for documenting OO systems. For instance, the UML is the result of an early interoperability effort promoted by large software companies to unify these OO analysis and documentation models. The concept has been widely embraced by the community of software engineering practitioners. Its evolution towards "executable UML" reflects the value of abstract models keeping a trade off between both computers and human's interpretation. Not surprisingly, research has clearly identified a correlation between reusability and easy comprehension of these systems, (Chua et al. 2006).

At the IT systems architecture level the work involves the development of the underlying models unifying the abstract syntax for XKMs. The main reasons for annotating XKMs using the proposed approach are listed as follows:

- The annotation of an XKM using specifically designed metadata acknowledges its existence as a differentiated data item and informs about its content to potential re-users.
- Having metadata attached to XKMs is especially important since their contents are encoded in a way that is not explicit for many of its potential users in engineering contexts.
- Ultimately, an annotated XKM becomes a resource in a repository since it can be indexed using its metadata. This facilitates its retrieval and its reuse at finer levels of granularity than as a whole.

8.3 Conclusions

This research has presented a metamodel for annotating XKMs. The use of the proposed model transforms these models into EKRs that are indexed according to their contents. The design of the metamodel includes mechanisms to describe both the structure and the operation of EKMs. The research methodology followed ensures the quality of the output by:

- A sound set of requirements for the metamodel based on observation and highly qualified inputs.
- The use of state of the art modelling techniques and tools to support the interoperability of the metamodel, preventing basic mistakes and improving the development/testing iterations.
- By its neutral assessment from a group of world class experts in the field representing the community of KBE technology users and developers.

The transformation of KBE models into enterprise resources using the proposed metamodel respond to the industrial motivations of the research in the following aspects:

- **Capitalising the efforts spent in developing KBE resources.** The large and expensive efforts spent in KBE development for particular engineering problem solving activities tend to be not reused due to the lack of common understanding of the capabilities of resulting applications. This becomes a critical issue when it the current proliferation of KBE functionalities in modern CAD/CAM/CAE suites is considered. The extensive ability to introduce knowledge into CAD models even in the simple form of IF-THEN rules will require the development of strategies to manage and to check its consistence. Research in KBE has produced methods to semantically document the contents of KBE applications. However, an approach to document the pragmatics side of KBE resources in the enterprise is necessary for more efficient use of the technology.
- **Managing the life-cycle of KBE resources.** Much of the knowledge that is embedded on KBE models is subject to modifications as it is reused across applications. Maintenance of the knowledge inside KBE due to engineering changes is a key issue. The metamodel supports the maintenance of KBE resources. The data entities associated with the proposed metamodel can be used to trace out KBE resources and to associate them to specific life-cycle states such as "under development" or "not validated".

- **Increasing the transparency of KBE resources.** Engineering problem solving experts hardly understand the purpose and the internal functionalities of existing KBE applications that could support their job. Consequently the identification of a KBE resource and its customisation for a new job mostly depends on the perception of knowledge engineers. Similarly, the lack of understanding on the KBE resource purpose and functionalities makes engineering resource managers to discard the use of KBE supported models or even to order the creation of a new KBE resource that is very similar to one existing already. Knowledge validation and trust are problems associated with knowledge modelling technologies in general. Humans tend not trust what it is not explicit. In the KBE domain the lack of trust ends up in the reluctance to "sign-off" or validate KBE applications. Increasing the level of transparency in rationale of what KBE resources are actually doing shall improve the responses in certifying the knowledge.

The research illustrates the consensus in the engineering community to support the annotation of XKMs within enterprise data repositories. This research contributes realise future PLM-based KM systems that manage XKMs. The integration of KBE/PLM systems in these terms plays two valuable business roles in digital product engineering practice:

- As a knowledge retention strategy adapted to the socio technical reality of product engineering practice. Under this perspective, supporting the capture of knowledge about an engineering product or process at certain point in time is only a short term knowledge retention strategy. Enabling the systematic storage of XKMs within the PLM environment is a solution to manage the lifecycle of engineering knowledge. On the other hand, PLM can be used to coordinate the knowledge capture and encoding processes to consolidate enterprise knowledge retention strategies and the deployment of KBE services. In addition, global competition in the socio technical reality of product/service engineering practice will become unaffordable for non networked teams and non distributed innovation chains. The exchange of data, information and knowledge (and perhaps the prevention to do so) will increasingly need to be carried out through the use of ICTs. PLM is the emerging paradigm for supporting these activities as connectivity and coordination framework.
- As a potential framework for "out of the box" engineering KM toolsets. It is widely accepted that enterprise culture and readiness to adapt is a crucial factor for the success of KM initiatives, (Choi and Lee 2002; Siemieniuch and Sinclair 2002). For instance, the MOKA methodology was built upon extensive KBE practice at large automotive and aerospace manufacturers. However, it is difficult for smaller organisation to take up into a complete KBE implementation strategy like MOKA without such historic background or at least tool vendor support. The proposed metamodel gives a solution for incremental deployment of the technology and systematic documentation.

8.4 Limitations and future work

The proposed metamodel provides a solution for annotating XKMs. Future research work shall address the generation of code for a particular KBE system. The semantic agreement defined in chapter 6 shall be the basis for this work. Possible areas of future research on the design of the metamodel include the following ones:

- Investigate the possibility of using other business process definition languages. An example is the use of the Business Process Definition Metamodel that is under development at the OMG, (OMG 2005).
- At the moment the metamodel do not support the definition of loops in the instances of the operation metamodel. This is caused by the limitations of XPDL 1.0 to support this construct. The XPDL metamodel on its version 2.0 includes more advanced loop structures.
- Another area that can be explored is the use of another metamodel to fully define the semantics of code structures. The SysML parametric model is a potential candidate due its ability to model mathematical expressions, (OMG 2006). However, it may be necessary to use other language to express inferences different from mathematical expressions. In this direction, other generic inference catalogues apart from the one in CommonKADS need to be investigated.

Further research in the development of the metamodels shall test its integration with design knowledge modelling languages. The CPM/OAM developed by NIST and the complete SysML language, are initial candidates.

Finally, the findings also help to create a research agenda leading to further stages of KM/PLM integration research and standardisation. The establishment of a strategy for EKRs built upon XKMs to be managed in PLM shall open broader research questions regarding the integration of personalisation and codification KM instruments in the context of "real-world" engineering situations. Two research areas and their connections are suggested for future action:

- The study of socio-technical issues in the coordination of engineering KM activities through networked enterprise systems. On one hand, the building of trust through IT systems in distributed teams needs to be investigated in order to enable PLM-based KM operations. On the other hand, the understanding of collaborative learning processes in distributed engineering teams is a key input to develop knowledge lifecycle management strategies.
- The exploration of emergent IT technologies to become engineering knowledge management infrastructures. This includes strategies to support the interoperability between different enterprise domains. A promising concept in this direction is the MDA supported by the OMG. Although the concept is on its early stage, results from using the approach for model-based IT system development are starting to be delivered. The spreading out of MDA into engineering environments raises expectations. However, its use to support knowledge intensive processes will require additional research on the semantic interoperability between engineering systems and consistent metamodels to exchange knowledge among them.

REFERENCES

Ahmed, S., Blessing, L. T. M. and Wallace, K. M. (1999). The Relationships Between Data, Information and Knowledge Based on a Preliminary Study of Engineering Designers. In: Proc. of ASME DETC99, Design Engineering Technical Conferences, Design Theory and Methodology Conference, Las Vegas, Nevada, USA., September 1999, The American Society of Mechanical Engineers.

Ahmed, S. and Wallace, K. M. (2005). Encouraging the reuse of design knowledge: a method to index knowledge. *Design Studies,* 26(6), 565-592.

Altshuller, G. S. (1996). *And Suddenly the Inventor Appeared: Triz, the Theory of Inventive Problem Solving*. Technical Innovation Center, Inc. ISBN: 0964074028

Angele, J., Fensel, D., Landes, D. and Studer, R. (1998). Developing Knowledge Based Systems with MIKE. *Automated Software Engineering,* 5, 389-418.

ATHENA (2007). ATHENA project website. WWW document: http://www.athena-ip.org.

Bates, J. P., Morris, A. J. and Payne, P. N. (1997). Knowledge-based geometric modelling of aircraft structures. *Proceedings of the Institution of Mechanical Engineers - Part G.,* 211, 273-284.

Baxter, M. R. (1995). *Product Design: practical methods for the systematic development of new products*. Chapman and Hall.

Bench-Capon, T. J. M. (1990). *Knowledge Represenation: An approach to Artificial Intelligence*. Academic Press Ltd.

Benjamins, V. R. and Fensel, D. (1998). Problem-Solving methods. *International Journal of Human-Computer Studies,* 49(4), 305-316.

Benyon, D. (1990). *Information and Data Modelling*. Alfred Waller Ltd.

Bermell-Garcia, P. (2001). Design knowledge structure in knowledge based engineering applications, MSc. by Research Thesis., Cranfield University.

Bermell-García, P. and Fan, I.-S. (2002). A KBE System for the design of wind tunnel models using reusable knowledge components. In: VI International Congress on Project Engineering, Barcelona, August 2002, AEIPRO.

Blessing, L. T. M. (1994). *A process-based approach to computer supported engineering design*. PhD Thesis, University of Twente, Netherlands.

Blessing, L. T. M., Chakrabarti, A. and Wallace, K. M. (1998). An overview of descriptive studies in relation to a general design research methodology. In: *Designers - the Key to Successful Product Development*. Edited by: E. Frankenberger, P. Badke-Schaub and H. Birkhofer. Springer Verlag, Darmstadt, Germany. 42-56.

Bracewell, R. H., Ahmed, S. and Wallace, K. M. (2004). DRed and design folders: a way of capturing storing and passing on knowledge generated during design projects. In: Proc. of ASME DETC04, Design Engineering Technical Conferences, Design Automation Conference, Salt Lake City, USA, The American Society of Mechanical Engineers.

Bracewell, R. H. and Wallace, K. M. (2007). Introducing the capture of argumentation-based design rationale into industrial practise. WWW document: http://www.users.muohio.edu/burgeje/dred_eindhoven.pdf (Accessed 03 January 2007).

Buckingham-Sum, S. (1996). Analysing the usability of a design rationale notation. In: *Design Rationale: Concepts, Techniques, and Use*. Edited by: T. P. Moran and J. M. Carroll. Lawrence Erlbaum Associates.
Chakrabarti, A. (2002). *Engineering design synthesis. Understanding, approaches and tools*. Springer-Verlag.
Chao, K. M., Smith, P., Hills, W., Florida-James, B. and Norman, P. (1998). Knowledge sharing and reuse for engineering design integration. *Expert Systems with Applications,* 14, 300-408.
Chapman, C. B. and Pinfold, M. (1999). Design engineering - a need to rethink the solution using knowledge based engineering. *Knowledge-Based Systems,* 12(5-6), 257-267.
Chen, Z. B. (2001). An object-oriented intelligent CAD system for ceramic kiln. *Knowledge-Based Systems,* 14, 263-270.
Choi, B. and Lee, H. (2002). Knowledge management and its link to knowledge creation process. *Expert Systems with Applications,* 23(3), 173-187.
Chua, C. E. H., Purao, S. and Storey, V. C. (2006). Developing maintainable software: the READABLE approach. *Decision Support Systems,* 42(1), 469-491.
CimDATA (2005). The value of rules-driven product management. WWW document: http://cimdata.com/newsletter/2005/42/03/42.03.01.htm (accessed 16th August 2006).
Conklin, J. and Begeman, M. L. (1990). gIBIS: A hypertext tool for exploratory policy discussion. *ACM Transactions on Office Information Systems,* 4, 303-331.
Cooper, S., Fan, I.-S. and Li, G. (1999). A Best Practice Guide – Achieving Competitive Advantage through Knowledge-Based Engineering, British Department of Trade and Industry (DTI).
Coyne, R. D., Rosenman, M. A., Radford, A. D., Balachandran, M. and Gero, J. S. (1990). *Knowledge-Based Design Systems*. Addison-Wesley Publishers Ltd.
Crabtree, R. A., Fox, M. S. and Baid, M. K. (1997). Case studies of coordination activities and problems in collaborative design. *Research in Engineering Design,* 9, 70-84.
Cross, N. (1989). *Engineering design methods*. John Willey & Sons. ISBN: 0471922153
Cross, N., Christiaans, H. and Dorst, K. (1996). *Analysing design activity*. Delft University of technology. The Netherlands. ISBN: 0471960608
Cyon (2003). The value proposition of high-end mechanical CAD. WWW document: http://www.cdcza.co.za/The_Value-Proposition_of_High-End_MCAD.pdf.
Daconta, M. C., Obrst, L. J. and Smith, K. T. (2003). *The semantic web: A guide to the future of XML, web services, and knowledge management*. John Willey & Sons. ISBN: 0471432571
Dankworth, C. W., Weidlich, R., Guenther, B. and Blaurock, J. E. (2004). Engineers' CAx education - it's not only CAD. *Computer aided design,* 36(14), 1439-1450.
Darke, J. (1979). The primary generator and the design process. *Design Studies,* 1(1), 36-44.
Davenport, T. H. and Prusak, L. (1998). *Working knowledge*. Harvard Business School Press.
Dimitrev, S. (2004). Language Oriented Programming: the next programming paradigm. WWW document: http://www.onboard.jetbrains.com/is1/articles/04/10/lop/mps.pdf.
Dorst, K. and Cross, N. (2001). Creativity in the design process: co-evolution of problem solution. *Design Studies,* 22, 425-437.

Duffy, A. H. B., Persidis, A. and MacCallum, K. J. (1996). NODES: a numerical and object oriented modelling system for conceptual engineering design. *Knowledge-Based Systems,* 9, 183-206.
Eckert, C. M. and Clarkson, P. J. (2003). The reality of design process planning. In: *Research for Practice - Innovation in Products and Processes. International Conference on Engineering Design. ICED'03*. Edited by: A. Folkeson, K. Gralen, M. Norell and U. Sellgren. The Design Society. 1904670008
Eckert, C. M. and Clarkson, P. J. (2005). *Design process improvement. A review of current practice*. Springer-Verlag. ISBN: 185233701X
Eckert, C. M. and Clarkson, P. J. (2005). The reality of design. In: *Design process improvement. A review of current practice*. Edited by: C. M. Eckert and P. J. Clarkson. Springer-Verlag. 185233701X
Efstathiou, H. J. (1990). Introduction to knowledge-based systems for process control. In: *Knowledge-Based Systems for industrial control*. Edited by: J. McGee, M. J. Grimble and P. Mowfort. IET, The Institution of Engineering and Technology. 978-0-86341-221-9
Eppinger, S. D., Whitney, D. E. and Smith, R. P. (1990). Organizing the Tasks in Complex Design Projects. In: ASME Conference on Design Theory and Methodology, Chicago, Illinois, American Society of Mechanical Engineers.
Eriksson, H., Puerta, A. R. and Munsen, M. A. (1994). Generation of knowledge acquisition tools from domain ontologies. *International Journal of Human-Computer Studies,* 79(293-326).
Eriksson, H., Shahar, Y., Tu, S. W. and Puerta, R. (1995). Task modeling with reusable problem-solving methods. *Artificial intelligence,* 79, 293-326.
Ertas, A. and Jones, J. C. (1996). *The engineering design process*. John Willey. New York. ISBN: 0471136999
Etzkorn, L. and Davis, C. G. (1996). Automated object-oriented reusable component identification. *Knowledge-Based Systems,* 9, 517-524.
Etzkorn, L., Hughes Jr, W. E. and Davis, C. G. (2001). Automated reusability quality analysis of OO legacy software. *Infotmation and Software Technology,* 43, 295-308.
Fan, I.-S. (2000). The power of PDM. *The Manufacturing Engineer,* 79(6), 224-228.
Fan, I.-S., Cooper, S., Sehdev, K. and Grealy, M. T. (1999). Knowledge Based Engineering as CE tool to achieve fast design iterations. In: Proceedings of ISPE International Conference on Concurrent Engineering, Bath, United Kingdom, 1 - 3 September, International Society for Productivity Enhancement.
Fan, I.-S., Li, G., Lagos-Hernández, M. and Bermell-Garcia, P. (2002). A rule-level knowledge management system for knowledge-based engineering applications. In: Proceedings of DETC'02, ASME International 22nd Computers and Information in Engineering, (CIE) Conference, Montreal, Canada, 29 September – 2 October, American Society of Mechanical Engineers.
Fenves, S. J., Rivard, H. and Gomez, N. (2000). SEED-Config: a tool for conceptual structureal design in a collaborative building design environment. *Artificial intelligence in engineering,* 14, 233-247.
Fichman, R. G. and Kemerer, C. F. (1997). Object technology: lessons from early adopters. *Computer,* 30(10), 47-59.
Finger, S. and Dixon, J. R. (1989). A review of research in mechanical engineering design. Part I: Descriptive, prescriptive, and computer-based models of design processes *Research in Engineering Design,* 1(1).
French, M. J. (1999). *Conceptual Design for Engineers*. Springer.

Gao, Y., Zeid, I. and Bardasz, T. (1998). Characteristics of an effective design plan system to support reuse in case-based mechanical design. *Knowledge-Based Systems,* 10, 337-350.
Gero, J. S. and Kannengiesser, U. (2002). The situated function-behaviour-structure framework. In: *Proc. of AID02, The International AI in Design Conference*. Edited by: J. S. Gero. Kluwer.
Gero, J. S. and McNeill, T. (1998). An approach to the analysis of design protocols. *Design Studies,* 19, 21-61.
Gomez-Perez, A. and Benjamins, V. R. (1999). Overview of knowledge sharing and reuse components: ontologies and problem-solving methods. In: *Proceedings of the IJCAI-99 workshop on ontologies and problem solving methods (KRR5), Stockholm, Sweden, 2 August 1999*. Edited by: V. R. Benjamins, B. Chandrasekaran, A. Gomez-Perez, N. Guarino and M. Uschold.
Grieves, M. (2006). *Product Lifecycle Management. Driving the next generation of lean thinking*. McGraw-Hill Inc. ISBN: 0071452303
Gruber, T. R. (1993). A translation approach to portable ontology specifications. *Knowledge Acquistion,* 5(2), 199-221.
Gruber, T. R. and Russell, D. M. (1992). Derivation and use of design rationale information as expressed by designers, Technical report KSL-92-94, Knowledge Sytems Laboratory, Stanford University.
Hales, C. and Gooch, S. (2004). *Managing engineering design*. Springer-Verlag. London. ISBN: 1852338032
Handfield, R. B. (1994). Effects of concurrent engineering on make-to-order products. *IEEE Transactions on Engineering Management,* 41(4), 384-393.
Havey, M. (2005). *Essential Business Process Modelling*. O'Reilly Media Inc. Sebastopol, CA, USA. ISBN: 0596008430
Herveaux, O. and Mille, A. (1999). ACCELERE: a case-based design assistant for closed cell rubber industry. *Knowledge-Based Systems,* 12, 231-238.
Hjelm, J. and Stark, P. (2002). *XSLT: Professional Developer's Guide*. John Wiley & Sons Inc. New York. ISBN: 0471390879
Hobday, M. (1998). Product complexity, innovation and industrial organisation. *Research Policy,* 26(6), 689-710.
Holsapple, C. W. (2005). The inseparability of modern knowledge management and computer-based technology. *Journal of Knowledge Management,* 9(1), 42-52.
Hong, P., Vonderembse, M. A., Doll, W. J. and Nahm, A. Y. (2005). Role change of design engineers in product development. *Journal of Operations Management,* 24, 63-79.
Hubka, V. (1982). *Principles of Engineering Design*. Butterworth.
Hubka, V. and Eder, W. E. (1988). *Theory of technical systems: a total concept theory for engineering design*. Springer-Verlag. Berlin. ISBN: 0387174516
INTEROP (2007). INTEROP Network of Excellence website. http://www.interop-noe.org/.
Jardim-Goncalves, R., Grilo, A. and Steiger-Garcao, A. (2006). Challenging the interoperability between computers in industry with MDA and SOA. *Computers In Industry,* 57(8), 679-689.
JAWE (2007). Website of JAWE: open source Java XPDL editor. http://www.enhydra.org/workflow/jawe/index.html.
Jones, J. C. (1970). *Design Methods: Seeds of Human Futures*. Wiley-Interscience. New York.

KIM (2007). Knowledge and Information Management Through Life, project website. WWW document: http://www-edc.eng.cam.ac.uk/kim/.
Kitamura, Y. (2006). Roles of ontologies of engineering artefacts for design knowledge modelling. In: Proc. of the 5th International Seminar and Workshop of Engineering Design in Integrated Product Development, Gronow, Poland, 21-23 September.
Kitamura, Y., Sano, T., Namba, K. and Mizoguchi, R. (2002). A functional concept ontology and its application to automatic identification of functional structures. *Advanced Engineering Informatics,* 16, 145-163.
Klein, R. (2000). Knowledge Modelling in Design - the MOKA Framework. In: *Proc. of AID00, The International AI in Design Conference*. Edited by: J. S. Gero. Kluwer, Worcester Politechnic, Cambridge Massachusetts, USA.
Kryssanov, V. V., Tamaki, H. and Kitamura, S. (2001). Understanding design fundamentals: how synthesis and analysis drive creativity, resulting in emergence. *Artificial intelligence in engineering,* 15, 329-342.
KTI (2007). KTI-Dassault Systems website. WWW document: http://www.ds-kti.com.
Kulon, J., Mynors, D. J. and Broomhead, P. (2006). A knowledge-based engineering design tool for metal forging. *Journal of Materials Processing Technology,* 177, 331-335.
Kusiak, A. and Wang, J. (1993). Decomposition of the design process. *Journal of Mechanical Design,* 115(4), 687-695.
Langen, P. H. G. (2002). The Anatomy of Design: Foundations, Models and Applications, PhD. Thesis, Vrije Universiteit, Amsterdam, Netherlands.
Lattanzi, M. and Henry, S. (1998). Software reuse using C++ classes. The question of inheritance. *The Journal of Systems and Software,* 41, 127-132.
Ledczi, A., Bakay, A., Maroti, M., Volgyesi, P., Nordstrom, G., Sprinkle, J. and Karsai, G. (2001). Composing domain-specific design environments. *IEEE Computer Magazine,* 34(11), 44-51.
Lee, D. and Lee, K. H. (1999). An approach to case-based system for conceptual ship assistant. *Expert Systems with Applications,* 16, 97-104.
Li, G., Cooper, S., Fan, I.-S., Sehdev, K. and Grealy, M. T. (1999). Knowledge Reuse: Experiences Gained from Integrating Manufacturing Knowledge into Product Design. In: Proc. of ICED 99. International Conference on Engineering Design., Munich, Germany, 24-26 August.
Li, G., Cooper, S., Garcia-Fornieles, J. M. and Fan, I.-S. (1999). Knowledge reuse: experiences gained from integrating manufacturing knowledge into product design. In: Proc. of ICED99, International Conference on Engineering Design, Munich, Germany, 24-26 August, WDK.
Lin, F. T. and Wang, B. (2001). An abductive propositonal logic for design reasoning. *Journal of the Chinese Institute of Engineers,* 24(5), 569-579.
Lin, Y. and Zhang, W. J. (2004). Towards a novel interface design framework: . *International Journal of Human-Computer Studies,* 61, 259-297.
Liu, Y.-C., Bligh, T. and Chakrabarti, A. (2003). Towards an ideal approach for concept generation. *Design Studies,* 24, 341-355.
Lovett, P. J., Ingram, A. and Bancroft, C. (2000). Knowledge-based engineering for SMEs - a methodology. *Journal of materials processing technology*, 384-389.
Lu, C.-Y., Li, Q., Case, M. and Grobler, F. (2006). A socio-technical framework for collaborative product development. *Transactions of the American Society of Mechanical Engineers,* 6, 160-169.

Lukas, U. v., Krause, F.-L., Rothenburg, U., Wöhler, T., Romahn, A., Anderl, R., Melk, K., Awiszus, B., Ufer, R., Binotsch, C., Schützer, K. and Gemignani, B. H. (2005). *Engineering 2010: Setting the course for innovative engineering*. VMM Wirtschaftsverlag.

Maher, M. L. (2003). Co-evolution as a computational and cognitive model of design. *Research in Engineering Design,* 14, 47-63.

Maher, M. L. and Poon, J. (1996). Modelling design exploration as co-evolution. *Microcomputers in civil engineering,* 11(3), 195-210.

Maier, R., Hädrich, T. and Peinl, R. (2005). *Enterprise Knowledge Infrastructures*. Springer. ISBN: 3540239154

McCall, R., Bennet, P., d'Oronzio, P., Ostwald, J., Shipman, F. and Wallace, N. (1990). PHIDIAS: a PHI-based design environment integrating CAD graphics into dynamic hypertext. In: *Hypertext: Concepts, Systems and Applications*. Edited by: A. Rirzk, N. Streitz and J. Andrè. Cambridge University Press.

McMahon, C. (2004). Knowledge management in engineering design: personalization and codification. *Journal of Engineering Design,* 15(4), 307-325.

McMahon, C., Giess, M. and Culley, S. (2005). Information management for through life product support: the curation of digital engineering data. *International Journal of Product Lifecycle Management,* 1(1), 26-42.

Mellor, S. J., Scott, K., Uhl, A. and Weise, D. (2004). *MDA distilled: principles of model-driven architecture*. Addison Wesley. ISBN: 0201788918

Miles, L. D. (1972). *Techniques of value analysis and engineering*. McGraw-Hill. ISBN: 0070419264

Mili, H., Mili, F. and Mili, A. (1995). Reusing software: issues and research directions. *IEEE Transactions on Software Engineering,* 21(6), 528-561.

Mulet, E., Vidal-Nadal, M. R. and Gomez, E. (2002). Experimental research on creative models. In: VI International Congress on Project Engineering, Barcelona, August 2002, AEIPRO.

Neches, R., Fikes, R. E., Finin, T., Gruber, T. R., Senator, T. and Swartout, W. R. (1991). Enabling technology for knowledge sharing. *AI Magazine,* 12(3), 35-56.

Newell, A. (1982). The knowledge level. *Artificial Intelligence,* 18, 87-127.

NIST (2007). Manufacturing Interoperability Programme website. WWW document: http://www.mel.nist.gov/proj/mi.htm.

Nonaka, I. and Takeguchi, H. (1995). *The knowledge creating company*. Oxford University Press.

Nonaka, I., Toyama, R. and Konno, N. (2000). SECI, Ba and the leadership: A unified model of dynamic knowledge creation. *Long Range Planning,* 33, 5-34.

O´Donell, F. J. and Duffy, A. H. B. (2005). *Design performance*. Springer-Verlag. London. ISBN: 185233889X

OMG (2005). Business Process Definition Metamodel, Request for Proposal. WWW document: http://www.omg.org/cgi-bin/doc?bei/03-01-06 (accessed 15 January 2007).

OMG (2005). PLM Services specification. http://www.omg.org/cgi-bin/doc?dtc/2005-03-08 (accessed 15 January 2007).

OMG (2006). The SysML specification. WWW document: http://www.omg.org/cgi-bin/doc?ptc/06-05-04 (accessed 15 January 2007).

OMG (2006). XMI Mapping Specification, V2.1. OMG document: formal/05-09-01. WWW document: http://www.omg.org/cgi-bin/doc?formal/2005-09-01 (accessed 15th July 2006).

Ormerod, T. C., Mariani, J., Ball, L. J. B. and Lambell, N. (1999). Desperado: three in one indexing for innovative design. In: Proc. of INTERACT'99, 7th IFIP Conference on Human-Computer Interaction, IOS Press.
Owen, J. (1997). *STEP: An introduction*. Information Geometers.
Pacione, M. J., Roper, M. and Wood, M. (1994). A novel software visualisation model to support software comprehension. In: Proc. of WCRE'04, 11th working conference on reverse engineering, IEEE Computer Society.
Pahl, G. and Beitz, W. (1996). *Engineering Design. A Systematic Approach*. ISBN: 3540199179
Parmee, I. C. and Bonham, C. R. (2000). Towards the support of innovative conceptual design through interactive designer/evolutionary computing strategies. *Artificial intelligence for engineering design, analysis and manufacturing,* 14, 3-16.
Penoyer, J. A., Burnett, G., Fawcet, D. J. and Liou, S.-Y. (2000). Knowledge based product life cycle systems: principles of integration of KBE and C3P. *Computer aided design,* 32, 311-320.
Poenisch, V. and Clark, A. (2006). Elements of an interface standard for knowledge sources in Knowledge-Based Engineering. *Journal of Computing and Information Science in Engineering,* 6(1), 78-83.
Pratt, M. J. (2005). ISO 10303, the STEP standard for product data exchange and its PLM capabilities. *International Journal of Product Lifecycle Management,* 1(1), 86-94.
Preston, S., Chapman, C. B., Pinfold, M. and Smith, G. (2005). Knowledge acquisition for knowledge-based engineering systems. *International Journal of Information Technology and Management,* 4(1), 1-11.
Prieto-Diaz, R. and Freeman, P. (1987). Classifying software for reusability. *IEEE Software,* 4(1), 6-16.
PROTEGE (2007). Protègè system website. WWW document: http://protege.stanford.edu/.
Pugh, S. (1991). *Total design: Integrated methods for successful product engineering*. Addison Wesley Publishing Company. ISBN: 0201416395
Rachuri, S., Baysal, M., Roy, U., Foufou, S., Bock, C., Fenves, S. J., Subrahmanian, E., Lyons, K. and Sriram, R. D. (2005). Information models for product representation: core and assembly models. *International Journal of Product Development,* 2(3), 207-235.
Reich, Y. (1995). A critical review of general design theory. *Research in engineering design,* 7, 1-18.
Revelle, J. B., Moran, J. W. and Cox, C. A. (1998). *The QFD handbook*. John Willey & Sons.
Reymen, I. M. M. J., Hammer, D. K., Kroes, P. A., Aken, J. E. v., Dorst, C. H., Bax, M. F. T. and Basten, T. (2006). A domain-independent descriptive design model and its application to structured reflection on design processes. *Research in Engineering Design,* 16(4), 147-173.
Rine, D. C. and Sonnerman, R. M. (1998). Investments in reusable software. A study of software reuse investment factors. *The Journal of Systems and Software,* 41, 17-32.
Robinson, M. A., Sparrow, P. R., Clegg, C. and Birdi, K. (2005). Design engineering competencies: future requirements and predicted changes in the forthcoming decade. *Design Studies,* 26, 123-153.

Roy, U., Pramanik, N., Sudarsan, R., Sriram, R. and Lyons, K. (2001). Function-to-form mapping: model, representation and applications in design synthesis. *Computer aided design,* 33, 699-719.
Saaksvouri, A. and Immonen, A. (2002). *Product lifecycle management*. Springer. Berlin. ISBN: 3540403736
Sainter, P., Oldham, K. and Larkin, A. (1999). Achieving Benefits from Knowledge-Based Engineering Systems in the Longer Term as well as in the Short Term. In: Proc. ISPE International Conference on Concurrent Engineering, Bath, UK, International Society for Productivity Enhancement.
Sanchez, J. M., Priest, J. W. and Soto, R. (1997). Intelligent reasoning assistant for incorporating manufacturability issues into the design process. *Expert Systems with Applications,* 12(1), 81-88.
Schmidt, D. C. (2006). Model-Driven Engineering. *IEEE Computer Magazine,* 39(2), 25-31.
Schreiber, G., Akkermans, H., Anjewierden, J., De Hoog, R., Shadbolt, N., Van de Velde, W. and Wielinga, B. (1999). *Knowledge Engineering and Management. The CommonKADS Methodology*. The MIT Press.
Schreiber, G., Wielinga, B. and Breuker, J. (1993). *KADS. A principled approach to Knowledge-Based System development*. Academic Press Ltd.
Schreiber, G., Wielinga, B. and Hoog, R. (1994). Common KADS: a comprehensive methodology for KBS development. *IEEE Expert,* 9(6), 28-37.
Shadbolt, N. and Milton, N. (1999). From knowledge engineering to knowledge management. *British Journal of Management,* 10, 309-322.
Sharman, D. and Yassine, A. (2004). Characterizing Complex Product Architectures. *Systems Engineering,* 7(1), 35-60.
Siemieniuch, C. E. and Sinclair, M. A. (1999). Organizational aspects of knowledge lifecycle management in manufacturing. *International Journal on Human-Computer Studies,* 51, 517-547.
Siemieniuch, C. E. and Sinclair, M. A. (2002). On complexity, process ownership and organisational learning in manufacturing organisations, from an ergonomics perspective. *Applied Ergonomics,* 33, 449-462.
Siemieniuch, C. E. and Sinclair, M. A. (2006). Systems Integration. *Applied Ergonomics,* 37(1), 91-110.
Sim, S. K. and Duffy, A. H. B. (2003). Towards an ontology of generic engineering design activities. *Research in Engineering Design,* 14, 200-223.
Simon, H. A. (1969). *The sciences of the artificial*. The MIT Press. Cambridge, Massachusetts. ISBN: 0262691914
Smithers, T. (1996). On knowledge level theory of design process. In: *Proc. of AID96, The international AI in Design Conference* Edited by: J. S. Gero. Kluwer.
Sriram, R. (2002). *Distributed and integrated collaborative engineering design*. Sarven Publishers.
Sriram, R. and Logcher, R. (1993). The MIT Dice project. *Computer aided design,* 26(1), 64-65.
Sriram, R., Logcher, R. D., Groleau, N. and Cherneff, J. (1992). DICE: an object-oriented programming environment for cooperative engineering design. In: *Artificial intelligence in engineering design. Vol. 3*. Edited by: C. Tong and R. Sriram.
Sriram, R. D. (2006). Artificial intelligence in engineering: personal reflections. *Advanced Engineering Informatics,* 20, 3-5.

Stamantis, D. H. (1995). *Failure mode and effect analysis: FMEA from theory to execution*. American Society for Quality. ISBN: 087389300X
Stark, J. (2005). *Product lifecycle management: 21st paradigm for product realisation*. Springer-Verlag. London. ISBN: 1852338105
Steward, D. V. (1981). The design structure system: a method for managing the design of complex systems. *IEEE Transactions on Engineering Management,* 28(3), 71-74.
Stokes, M. (2001). *Managing engineering knowledge: MOKA methodology for knowledge based engineering applications*. Professional Engineering Publishing. London. ISBN: 1860582958
Str.Direction (2005). Engineering automation for the SME: a viable tool for "mass" customisation. *Strategic Direction,* 21(1), 1-35.
Str.Direction (2005). Widening appreciation of PLM. Investing in delivering innovation. *Strategic Direction,* 21(9), 35-37.
Studer, R., Benjamins, V. R. and Fensel, D. (1998). Knowledge engineering: principles and methods. 25, 161-197.
Subrahmanian, E., Rachuri, S., Fenves, S. J. and Foufou, S. (2005). Product lifecycle management support: a challenge in supporting product design and manufacturing in a networked economy. *International Journal of Product Lifecycle Management,* 1(1), 4-25.
Sudarsan, R., Fenves, S. J., Sriram, R. D. and Wang, F. (2005). A product information modelling framework for product lifecycle management. *Computer aided design,* 37(13), 1399-1411.
Suh, N. P. (2001). *Axiomatic Design*. Oxford University Press. New York. ISBN: 0195134664
Szykman, S. and Sriram, R. (2006). Design and implementation of the web-enabled NIST design repositories. *ACM Transactions on Internet Technologies,* 6(1), 85-116.
Takeda, H. (1994). Abduction for Design. In: *Formal Design Method for CAD, IFIP Transactions B-18*. Edited by: J. S. Gero and E. Tyugu. Elsevier Science Publishers**:** 221-224.
Takeda, H., Sasaki, H., Nomaguchi, Y., Yoshioka, M., Shimomura, Y. and Tomiyama, T. (2003). Universal Abduction Studio - proposal of a design support environment for creative thinking in design. In: *Research for Practice - Innovation in Products and Processes. International Conference on Engineering Design. ICED'03*. Edited by: A. Folkeson, K. Gralen, M. Norell and U. Sellgren. The Design Society.
Tsui, E. (2005). The role of IT in KM: where are we now and where are we heading? *Journal of Knowledge Management,* 9(1), 3-6.
Ueda, K. (2001). Synthesis and emergence - research overview. *Artificial Intelligence in Engineering,* 15, 321-327.
Ullman, D. G. (2003). *The mechanical design process*. McGraw-Hill. New York. ISBN: 0071122818
Ulrich, K. T. and Eppinger, S. D. (2004). *Product design and development*. McGraw-Hill. New York. ISBN: 0071232737
Umeda, Y., Ishii, M., Yoshioka, M. and Tomiyama, T. (1996). Supporting conceptual design based on the function-behavior-state modeler. *Artificial intelligence for engineering design, analysis and manufacturing,* 10(4), 275-288.

Umeda, Y., Takeda, H., Tomiyama, T. and Yoshikawa, H. (1990). Function, behaviour, and structure. In: *Applications of Artificial Intelligence in Engineering*. Edited by: J. S. Gero. Springer-Verlag, Vol.1**:** 177-194.

UMR (2007). University of Missouri-Rolla, Design Repository. WWW document: http://function2.basiceng.umr.edu:8080/view/index.jsp.

VDI (1987). *Systematic approach to the design of technical systems and products*. VDI-Verlag GmbH. Dusseldorf.

WFMC (2005). Process definition interface -- XML Process Definition Language. http://www.wfmc.org/standards/docs/TC-1025_xpdl_2_2005-10-03.pdf.

Whitfield, I. R., Smith, J. S. and Duffy, A. H. B. (2002). Identifying component modules. In: *Proc. of AID02, The International AI in Design Conference*. Edited by: J. S. Gero. Kluwer, Cambridge, UK.

Whitney, D. E. (1996). Why mechanical design cannot be like VLSI design. *Research in Engineering Design,* 8(3), 125-138.

Wielinga, B., Sandberg, J. and Schreiber, G. (1997). Methods and techniques for knowledge management: what has knowledge engineering to offer? *Expert Systems with Applications,* 13(1), 73-84.

Wynn, D. and Clarkson, P. J. (2005). Models of designing. In: *Design process improvement. A review of current practice*. Edited by: C. M. Eckert and P. J. Clarkson. Springer-Verlag.

Yeun, Y. S. and Yang, Y. S. (1997). Design knowledge representation and control for the structural design of ships. *Knowledge-Based Systems,* 10, 121-132.

Yoshikawa, H. (1981). General Design Theory and a CAD System. In: *CAD/CAM*. Edited by: T. Sata and E. Warman. North-Holland Publishing Company.

Yoshioka, M., Sekiya, T. and Tomiyama, T. (2001). An integrated design-object modelling environment - Pluggable metamodel mechanism - *Turkish Journal of Electric Engineering,* 9(1), 43-62.

Yoshioka, M., Umeda, Y., Takeda, H., Shimomura, Y., Nomaguchi, Y. and Tomiyama, T. (2004). Physical concept ontology for the knowledge intensive engineering framework. *Advanced Engineering Informatics,* 18, 95-113.

Appendix A

KBE SERVICES FOR PLM, OMG REQUEST FOR PROPOSAL

Object Management Group

First Needham Place
250 First Avenue, Suite 100
Needham, MA 02494

Telephone: +1-781-444-0404
Facsimile: +1-781-444-0320

KBE Services for PLM

OMG Document: dtc/2005-09-11

Letters of Intent due: February 20, 2006
Submissions due: April 3, 2006

Objective of this RFP

Rapid and cost -effective methods for the design of engineering products can provide significant competitive advantage to manufacturing industries. The effective use of knowledge for avoiding repetitive work has demonstrated significant savings in a variety of engineering programs. However, the cost of using this technology is often beyond the resources of small manufacturing enterprises. There is the further challenge of managing this knowledge throughout the lifecycle of a product. Responding to the rapid convergence of Knowledge Based Engineering (KBE) and Product Lifecycle Management (PLM) applications, this RFP solicits standardization that would facilitate the effective sharing and use of KBE within a PLM environment.

Knowledge-Based Engineering (KBE) is a key technology: (1) for automating aspects of engineering data generation; and (2) for enabling the explicit representation of engineering data generation processes and engineering best practices. The utility of the technology has been recognized by the progressive integration of KBE functionalities in Product Lifecycle Management (PLM) support tools. However, KBE applications face interoperability issues that may restrict the potential of the effective use and deployment of the technology by end users and vendors alike. Standardization of KBE services reduces the risk of these issues and opens the possibility of using KBE as a core technology for the reuse, sharing and maintenance of engineering knowledge across the PLM spectrum of applications.

Responses to this RFP shall fulfill the following objectives:

- Identify and specify a metamodel of functional services that allows current KBE technology to standardize and share the information that generates engineering data.

- Specify the necessary metamodel of services or extensions to current standards so as to enable KBE services to be integrated into PLM systems and consequently benefit from the information management infrastructure available in PLM systems.

For further details see Chapter 6 of this document.

1.0 Introduction

1.1 Goals of OMG

The Object Management Group (OMG) is the world's largest software consortium with an international membership of vendors, developers, and end users. Established in 1989, its mission is to help computer users solve enterprise integration problems by supplying open, vendor-neutral portability, interoperability and reusability specifications based on Model Driven Architecture (MDA). MDA defines an approach to IT system specification that separates the specification of system functionality from the specification of the implementation of that functionality on a specific technology platform, and provides a set of guidelines for structuring specifications expressed as models. OMG has established numerous widely used standards such as OMG IDL[IDL], CORBA[CORBA], Realtime CORBA [CORBA], GIOP/IIOP[CORBA], UML[UML], MOF[MOF], XMI[XMI] and CWM[CWM] to name a few significant ones.

1.2 Organization of this document

The remainder of this document is organized as follows:

Chapter 2 - *Architectural Context* - background information on OMG’s Model Driven Architecture.

Chapter 3 - *Adoption Process* - background information on the OMG specification adoption process.

Chapter 4 - *Instructions for Submitters* - explanation of how to make a submission to this RFP.

Chapter 5 - *General Requirements on Proposals* - requirements and evaluation criteria that apply to all proposals submitted to OMG.

Chapter 6 - *Specific Requirements on Proposals* - problem statement, scope of proposals sought, requirements and optional features, issues to be discussed, evaluation criteria, and timetable that apply specifically to this RFP.

Appendix A – *References and Glossary Specific to this RFP*

Appendix B – General References and Glossary

1.3 Conventions

The key words "**must**", "**must not**", "**required**", "**shall**", "**shall not**", "**should**", "**should not**", "**recommended**", "**may**", and "**optional**" in this document are to be interpreted as described in RFC 2119 [RFC2119].

1.4 Contact Information

Questions related to the OMG's technology adoption process may be directed to *omg-process@omg.org*. General questions about this RFP may be sent to *responses@omg.org*.

OMG documents (and information about the OMG in general) can be obtained from the OMG's web site *(http://www.omg.org/*). OMG documents may also be obtained by contacting OMG at *documents@omg.org*. Templates for RFPs (this document) and other standard OMG documents can be found at the OMG *Template Downloads Page* at *http://www.omg.org/technology/template_download.htm*

2.0 Architectural Context

MDA provides a set of guidelines for structuring specifications expressed as models and the mappings between those models. The MDA initiative and the standards that support it allow the same model specifying business system or application functionality and behavior to be realized on multiple platforms. MDA enables different applications to be integrated by explicitly relating their models; this facilitates integration and interoperability and supports system evolution (deployment choices) as platform technologies change. The three primary goals of MDA are portability, interoperability and reusability.

Portability of any subsystem is relative to the subsystems on which it depends. The collection of subsystems that a given subsystem depends upon is often loosely called the *platform,* which supports that subsystem. Portability – and reusability - of such a subsystem is enabled if all the subsystems that it depends upon use standardized interfaces (APIs) and usage patterns.

MDA provides a pattern comprising a portable subsystem that is able to use any one of multiple specific implementations of a platform. This pattern is repeatedly usable in the specification of systems. The five important concepts related to this pattern are:

1. *Model* - A model is a representation of a part of the function, structure and/or behavior of an application or system. A *representation* is said to be *formal* when it is based on a language that has a well-defined form ("syntax"), meaning ("semantics"), and possibly rules of analysis, inference, or proof for its constructs. The syntax may be graphical or textual. The semantics might be defined, more or less formally, in terms of things observed in the world being described (e.g. message sends and replies, object states and state changes, etc.), or by translating higher-level language constructs into other constructs that have a well-defined meaning. The optional rules of inference define what unstated properties you can deduce from the explicit statements in the model. In MDA, a *representation* that is not *formal* in this sense is not a model. Thus, a diagram with boxes and lines and arrows that is not supported by a definition of the meaning of a box, and the meaning of a line and of an arrow is not a model—it is just an informal diagram.

2. *Platform* – A set of subsystems/technologies that provide a coherent set of functionality through interfaces and specified usage patterns that any subsystem that depends on the platform can use without concern for the details of how the functionality provided by the platform is implemented.

3. *Platform Independent Model (PIM)* – A model of a subsystem that contains no information specific to the platform, or the technology that is used to realize it.

4. *Platform Specific Model (PSM)* – A model of a subsystem that includes information about the specific technology that is used in the realization of that subsystem on a specific platform, and hence possibly contains elements that are specific to the platform.

5. *Mapping* – Specification of a mechanism for transforming the elements of a model conforming to a particular metamodel into elements of another model that conforms to another (possibly the same) metamodel. A mapping may be expressed as associations, constraints, rules, templates with parameters that must be assigned during the mapping, or other forms yet to be determined.

For example, in case of CORBA the platform is specified by a set of interfaces and usage patterns that constitute the CORBA Core Specification [CORBA]. The CORBA platform is independent of operating systems and programming languages. The OMG Trading Object Service specification [TOS] (consisting of interface specifications in OMG Interface Definition Language (OMG IDL)) can be considered to be a PIM from the viewpoint of CORBA, because it is independent of operating systems and programming languages. When the IDL to C++ Language Mapping specification is applied to the Trading Service PIM, the C++-specific result can be considered to be a PSM for the Trading Service, where the platform is the C++ language and the C++ ORB implementation. Thus the IDL to C++ Language Mapping specification [IDLC++] determines the mapping from the Trading Service PIM to the Trading Service PSM.

Note that the Trading Service model expressed in IDL is a PSM relative to the CORBA platform too. This highlights the fact that platform-independence and platform-specificity are relative concepts.

The UML Profile for EDOC specification [EDOC] is another example of the application of various aspects of MDA. It defines a set of modeling constructs that are independent of middleware platforms such as EJB [EJB], CCM [CCM], MQSeries [MQS], etc. A PIM based on the EDOC profile uses the middleware-independent constructs defined by the profile and thus is middleware-independent. In addition, the specification defines formal metamodels for some specific middleware platforms such as EJB, supplementing the already-existing OMG metamodel of CCM (CORBA Component Model). The specification also defines mappings from the EDOC profile to the middleware metamodels. For example, it defines a mapping from the EDOC profile to EJB. The mapping specifications facilitate the transformation of any EDOC-based PIM into a corresponding PSM for any of the specific platforms for which a mapping is specified.

Continuing with this example, one of the PSMs corresponding to the EDOC PIM could be for the CORBA platform. This PSM then potentially constitutes a PIM, corresponding to which there would be implementation language specific PSMs derived via the CORBA language mappings, thus illustrating recursive use of the Platform-PIM-PSM-Mapping pattern.

Note that the EDOC profile can also be considered to be a platform in its own right. Thus, a model expressed via the profile is a PSM relative to the EDOC platform.

An analogous set of concepts apply to Interoperability Protocols wherein there is a PIM of the payload data and a PIM of the interactions that cause the data to find its way from one place to another. These then are realized in specific ways for specific platforms in the corresponding PSMs.

Analogously, in case of databases there could be a PIM of the data (say using the Relational Data Model), and corresponding PSMs specifying how the data is actually represented on a storage medium based on some particular data storage paradigm etc., and a mapping from the PIM to each PSM.

OMG adopts standard specifications of models that exploit the MDA pattern to facilitate portability, interoperability and reusability, either through ab initio development of standards or by reference to existing standards. Some examples of OMG adopted specifications are:

1. *Languages* – e.g. IDL for interface specification, UML for model specification, OCL for constraint specification, etc.

2. *Mappings* – e.g. Mapping of OMG IDL to specific implementation languages (CORBA PIM to Implementation Language PSMs), UML Profile for EDOC (PIM) to CCM (CORBA PSM) and EJB (Java PSM), CORBA (PSM) to COM (PSM) etc.

3. *Services* – e.g. Naming Service [NS], Transaction Service [OTS], Security Service [SEC], Trading Object Service [TOS] etc.

4. *Platforms* – e.g. CORBA [CORBA].

5. *Protocols* – e.g. GIOP/IIOP [CORBA] (both structure and exchange protocol), [XMI] (structure specification usable as payload on multiple exchange protocols).

6. *Domain Specific Standards* – e.g. Data Acquisition from Industrial Systems (Manufacturing) [DAIS], General Ledger Specification (Finance) [GLS], Air Traffic Control (Transportation) [ATC], Gene Expression (Life Science Research) [GE], Personal Identification Service (Healthcare) [PIDS], etc.

For an introduction to MDA, see [MDAa]. For a discourse on the details of MDA please refer to [MDAc]. To see an example of the application of MDA see [MDAb]. For general information on MDA, see [MDAd].

Object Management Architecture (OMA) is a distributed object computing platform architecture within MDA that is related to ISO's Reference Model of Open Distributed Processing RM-ODP[RM-ODP]. CORBA and any extensions to it are based on OMA. For information on OMA see [OMA].

3.0 Adoption Process

3.1 Introduction

OMG adopts specifications by explicit vote on a technology-by-technology basis. The specifications selected each satisfy the architectural vision of MDA. OMG bases its decisions on both business and technical considerations. Once a specification adoption is finalized by OMG, it is made available for use by both OMG members and non-members alike.

Request for Proposals (RFP) are issued by a *Technology Committee* (TC), typically upon the recommendation of a *Task Force* (TF) and duly endorsed by the *Architecture Board* (AB).

Submissions to RFPs are evaluated by the TF that initiated the RFP. Selected specifications are *recommended* to the parent TC after being *reviewed* for technical merit and consistency with MDA and other adopted specifications and *endorsed* by the AB. The parent TC of the initiating TF then votes to *recommend adoption* to the OMG Board of Directors (BoD). The BoD acts on the recommendation to complete the adoption process.

For more detailed information on the adoption process see the *Policies and Procedures of the OMG Technical Process* [P&P] and the *OMG Hitchhiker's Guide* [Guide]. In case of any inconsistency between this document and the [P&P] in all cases the [P&P] shall prevail.

3.2 Steps in the Adoption Process

A TF, its parent TC, the AB and the Board of Directors participate in a collaborative process, which typically takes the following form:

- *Development and Issuance of RFP*

  RFPs are drafted by one or more OMG members who are interested in the adoption of a standard in some specific area. The draft RFP is presented to an appropriate TF, based on its subject area, for approval and recommendation to issue. The TF and the AB provide guidance to the drafters of the RFP. When the TF and the AB are satisfied that the RFP is appropriate and ready for issuance, the TF recommends issuance to its parent TC, and the AB endorses the recommendation. The TC then acts on the recommendation and issues the RFP.

- *Letter of Intent (LOI)*

  A Letter of Intent (LOI) must be submitted to the OMG signed by an officer of the member organization, which intends to respond to the RFP, confirming the organization's willingness to comply with OMG's terms and conditions, and commercial availability requirements. (See section 4.3 for more information.). In order to respond to an RFP the respondent must be a member of the TC that issued the RFP.

- *Voter Registration*

  Interested OMG members, other than Trial, Press and Analyst members may participate in specification selection votes in the TF for an RFP. They may need to register to do so, if so stated in the RFP. Registration ends on a specified date, 6 or more weeks after the announcement of the registration period. The registration closure date is typically around the time of initial submissions. Member organizations that have submitted an LOI are automatically registered to vote.

- *Initial Submissions*

  Initial Submissions are due by a specified deadline. Submitters normally present their proposals at the first meeting of the TF after the deadline. Initial Submissions are expected to be complete enough to provide insight on the technical directions and content of the proposals.

- *Revision Phase*

  During this time submitters have the opportunity to revise their Submissions, if they so choose.

- *Revised Submissions*

  Revised Submissions are due by a specified deadline. Submitters again normally present their proposals at the next meeting of the TF after the deadline. (Note that there may be more than one Revised Submission deadline. The decision to extend this deadline is made by the registered voters for that RFP.)

- *Selection Votes*

  When the registered voters for the RFP believe that they sufficiently understand the relative merits of the Revised Submissions, a selection vote is taken. The result of this selection vote is a recommendation for adoption to the TC. The AB reviews the proposal for MDA compliance and technical merit. An endorsement from the AB moves the voting process into the issuing Technology Committee. An eight-week voting period ensues in which the TC votes to recommend adoption to the OMG Board of Directors (BoD). The final vote, the vote to adopt, is taken by the BoD and is based on technical merit as well as business qualifications. The resulting draft standard is called the *Adopted Specification*.

- *Business Committee Questionnaire*

  The submitting members whose proposal is recommended for adoption need to submit their response to the BoD Business Committee Questionnaire [BCQ] detailing how they plan to make use of and/or make the resulting standard available in products. If no organization commits to make use of the standard, then the BoD will typically not act on the recommendation to adopt the standard. So it is very important to fulfill this requirement.

- *Finalization*

A Finalization Task Force (FTF) is chartered by the TC that issued the RFP, to prepare an *adopted* submission for publishing as a formal, publicly available specification. Its responsibility includes production of one or more prototype implementations and fixing any problems that are discovered in the process. This ensures that the final available standard is actually implementable and has no show-stopping bugs. Upon completion of its activity the FTF recommends adoption of the resulting draft standard called the *Available Specification*. The FTF must also provide evidence of the existence of one or more prototype implementations. The parent TC acts on the recommendation and recommends adoption to the BoD. OMG Technical Editors produce the *Formal Published Specification* document based on this *Available Specification*.

- *Revision*

A Revision Task Force (RTF) is normally chartered by a TC, after the FTF completes its work, to manage issues filed against the *Available Specification* by implementers and users. The output of the RTF is a revised specification reflecting minor technical changes.

3.3 Goals of the evaluation

The primary goals of the TF evaluation are to:

- Provide a fair and open process
- Facilitate critical review of the submissions by members of OMG
- Provide feedback to submitters enabling them to address concerns in their revised submissions
- Build consensus on acceptable solutions
- Enable voting members to make an informed selection decision

Submitters are expected to actively contribute to the evaluation process.

4.0 Instructions for Submitters

4.1 OMG Membership

To submit to an RFP issued by the Platform Technology Committee the submitter or submitters must be either Platform or Contributing members on the date of the submission deadline, while for Domain Technology RFPs the submitter or submitters must be either Contributing or Domain members. Submitters sometimes choose to name other organizations that support a submission in some way; however, this has no formal status within the OMG process, and for OMG's purposes confers neither duties nor privileges on the organizations thus named.

4.2 Submission Effort

An RFP submission may require significant effort in terms of document preparation, presentations to the issuing TF, and participation in the TF evaluation process. Several staff months of effort might be necessary. OMG is unable to reimburse submitters for any costs in conjunction with their submissions to this RFP.

4.3 Letter of Intent

A Letter of Intent (LOI) must be submitted to the OMG Business Committee signed by an officer of the submitting organization signifying its intent to respond to the RFP and confirming the organization's willingness to comply with OMG's terms and conditions, and commercial availability requirements. These terms, conditions, and requirements are defined in the *Business Committee RFP Attachment* and are reproduced verbatim in section 4.4 below.

The LOI should designate a single contact point within the submitting organization for receipt of all subsequent information regarding this RFP and the submission. The name of this contact will be made available to all OMG members. The LOI is typically due 60 days before the deadline for initial submissions. LOIs must be sent by fax or paper mail to the "RFP Submissions Desk" at the main OMG address shown on the first page of this RFP.

Here is a suggested template for the Letter of Intent:

This letter confirms the intent of <___organization required___> (the organization) to submit a response to the OMG <___RFP name required___> RFP. We will grant OMG and its members the right to copy our response for review purposes as specified in section 4.7 of the RFP. Should our response be adopted by OMG we will comply with the OMG Business Committee terms set out in section 4.4 of the RFP and in document omg/02-04-02.

<____contact name and details required____> will be responsible for liaison with OMG regarding this RFP response.

The signatory below is an officer of the organization and has the approval and authority to make this commitment on behalf of the organization.

<___signature required____>

4.4 Business Committee RFP Attachment

This section contains the text of the Business Committee RFP attachment concerning commercial availability requirements placed on submissions. This attachment is available separately as an OMG document omg/2002-04-02.

Commercial considerations in OMG technology adoption

A1 Introduction

OMG wishes to encourage rapid commercial adoption of the technologies (specifications and support measures) it publishes. To this end, there must be neither technical, legal nor commercial obstacles to their implementation. Freedom from the first is largely judged through technical review by the relevant OMG Technology Committees; the second two are the responsibility of the OMG Business Committee. The BC also looks for evidence of a commitment by a submitter to the commercial success of products based on the submission.

A2 Business Committee evaluation criteria

A2.1 Viable to implement across platforms

While it is understood that final candidate OMG submissions often combine technologies before they have all been implemented in one system, the Business Committee nevertheless wishes to see evidence that each major feature has been implemented, preferably more than once, and by separate organizations. Pre-product implementations are acceptable. Since use of OMG specifications should not be dependent on any one platform, cross-platform availability and interoperability of implementations should be also be demonstrated.

A2.2 Commercial availability

In addition to demonstrating the existence of implementations of the specification, the submitter must also show that products based on the specification are commercially available, or will be within 12 months of the date when the specification was recommended for adoption by the appropriate Task Force. Proof of intent to ship product within 12 months might include:

- *A public product announcement with a shipping date within the time limit.*
- *A prototype implementation and accompanying draft user documentation.*

Alternatively, and at the Business Committee's discretion, submissions may be adopted where the submitter is not a commercial software provider, and therefore will not make implementations commercially available. However, in this case the BC will require concrete evidence of two or more independent implementations of the specification being used by end-user organizations as part of their businesses.
Regardless of which requirement is in use, the submitter must inform the OMG of completion of the implementations when commercially available.

In the case of the proposed adoption of support measures, the BC needs to have proof of the intent to use or recommend such support measures within 12 months of the date when the support measures were recommended for adoption by the appropriate Task Force.

A2.3 Access to Intellectual Property Rights

OMG will not adopt a specification or support measure if OMG is aware of any submitter, member or third party which holds a patent, copyright or other intellectual property right (collectively referred to in this policy statement as "IPR") which might be infringed by implementation or recommendation of such specification or support measure, unless OMG believes that such IPR owner will grant a license to organizations (whether OMG members or not) on non-discriminatory and commercially reasonable terms which wish to make use of the specification or support measure. Accordingly, the submitter must certify that it is not aware of any claim that the specification or support measure infringes any IPR of a third party or that it is aware and believes that an appropriate non-discriminatory license is available from that third party. Except for this certification, the submitter will not be required to make any other warranty, and specifications will be offered by OMG for use "as is". If the submitter owns IPR to which an use of a specification or support measure based upon its submission would necessarily be subject, it must certify to the Business Committee that it will make a suitable license available to any user on non-discriminatory and commercially reasonable terms, to permit development and commercialization of an implementation that includes such IPR.

It is the goal of the OMG to make all of its technology available with as few impediments and disincentives to adoption as possible, and therefore OMG strongly encourages the submission of technology as to which royalty-free licenses will be available. However, in all events, the submitter shall also certify that any necessary license will be made available on commercially reasonable, non-discriminatory terms. The submitter is responsible for disclosing in detail all known restrictions, placed either by the submitter or, if known, others, on technology necessary for any use of the specification or support measure.

A2.4 Publication of the specification

Should the submission or support measures be adopted, the submitter must grant OMG (and its sublicensees) a worldwide, royalty-free license to edit, store, duplicate and distribute both the specification and works derived from it (such as revisions and teaching materials). This requirement applies only to the written specification, not to any implementation of it.

A2.5 Continuing support

The submitter must show a commitment to continue supporting the technology underlying the specification or support measure after OMG adoption, for instance by showing the BC development plans for future revisions, enhancement or maintenance.

4.5 Responding to RFP items

4.5.1 Complete proposals

A submission must propose full specifications for all of the relevant requirements detailed in Chapter 6 of this RFP. Submissions that do not present complete proposals may be at a disadvantage.

Submitters are highly encouraged to propose solutions to any optional requirements enumerated in Chapter 6.

4.5.2 Additional specifications

Submissions may include additional specifications for items not covered by the RFP that they believe to be necessary and integral to their proposal. Information on these additional items should be clearly distinguished.

Submitters must give a detailed rationale as to why these specifications should also be considered for adoption. However submitters should note that a TF is unlikely to consider additional items that are already on the roadmap of an OMG TF, since this would pre-empt the normal adoption process.

4.5.3 Alternative approaches

Submitters may provide alternative RFP item definitions, categorizations, and groupings so long as the rationale for doing so is clearly stated. Equally, submitters may provide alternative models for how items are provided if there are compelling technological reasons for a different approach.

4.6 Confidential and Proprietary Information

The OMG specification adoption process is an open process. Responses to this RFP become public documents of the OMG and are available to members and non-members alike for perusal. No confidential or proprietary information of any kind will be accepted in a submission to this RFP.

4.7 Copyright Waiver

Every submission document must contain: (i) a waiver of copyright for unlimited duplication by the OMG, and (ii) a limited waiver of copyright that allows each OMG member to make up to fifty (50) copies of the document forreview purposes only. See Section 4.9.2 for recommended language.

4.8 Proof of Concept

Submissions must include a "proof of concept" statement, explaining how the submitted specifications have been demonstrated to be technically viable. The technical viability has to do with the state of development and maturity of the technology on which a submission is based. This is not the same as commercial availability. Proof of concept statements can contain any information deemed relevant by the submitter; for example:

> "This specification has completed the design phase and is in the process of being prototyped."
>
> "An implementation of this specification has been in beta-test for 4 months."
>
> "A named product (with a specified customer base) is a realization of this specification."

It is incumbent upon submitters to demonstrate to the satisfaction of the TF managing the evaluation process, the technical viability of their proposal. OMG will favor proposals based on technology for which sufficient relevant experience has been gained.

4.9 Format of RFP Submissions

This section presents the structure of a submission in response to an RFP. *All submissions* must contain the elements itemized in section 4.9.2 below before they can be accepted as a valid response for evaluation or a vote can be taken to recommend for adoption.

4.9.1 General

- Submissions that are concise and easy to read will inevitably receive more consideration.
- Submitted documentation should be confined to that directly relevant to the items requested in the RFP. If this is not practical, submitters must make clear what portion of the documentation pertains directly to the RFP and what portion does not.
- The key words "**must**", "**must not**", "**required**", "**shall**", "**shall not**", "**should**", "**should not**", "**recommended**", "**may**", and "**optional**" shall be used in the submissions with the meanings as described in RFC 2119 [RFC2119].

4.9.2 Required Outline

A three-part structure for submissions is required. Parts I is non-normative, providing information relevant to the evaluation of the proposed specification. Part II is normative, representing the proposed specification. Specific sections like Appendices may be explicitly identified as non-normative in Part II. Part III is normative specifying changes that must be made to previously adopted specifications in order to be able to implement the specification proposed in Part II.

PART I

- The name of the RFP that the submission is responding to.
- List of OMG members making the submission (see 4.1) listing exactly which members are making the submission, so that submitters can be matched with LOI responders and their current eligibility can be verified.
- Copyright waiver (see 4.7), in a form acceptable to the OMG.

  One acceptable form is:

  "Each of the entities listed above: (i) grants to the Object Management Group, Inc. (OMG) a nonexclusive, royalty-free, paid up, worldwide license to copy and distribute this document and to modify this document and distribute copies of the modified version, and (ii) grants to each member of the OMG a nonexclusive, royalty-free, paid up, worldwide license to make up to fifty (50) copies of this document for internal review purposes only and not for distribution, and (iii) has agreed that no person shall be deemed to have infringed the copyright in the included material of any such copyright holder

by reason of having used any OMG specification that may be based hereon or having conformed any computer software to such specification."

If you wish to use some other form you must get it approved by the OMG legal counsel before using it in a submission.

- For each member making the submission, an individual contact point who is authorized by the member to officially state the member's position relative to the submission, including matters related to copyright ownership, etc. (see 4.3)
- Overview or guide to the material in the submission
- Overall design rationale (if appropriate)
- Statement of proof of concept (see 4.8)
- Resolution of RFP requirements and requests

  Explain how the proposal satisfies the specific requirements and (if applicable) requests stated in Chapter 6. References to supporting material in Part II should be given.

  In addition, if the proposal does not satisfy any of the general requirements stated in Chapter 5, provide a detailed rationale.

- Responses to RFP issues to be discussed

  Discuss each of the "Issues To Be Discussed" identified in Chapter 6.

PART II

The contents of this part should be structured based on the template found in [FORMS] and should contain the following elements as per the instructions in the template document cited above:

- Scope of the proposed specification
- Proposed conformance criteria

  Submissions should propose appropriate conformance criteria for implementations.

- Proposed normative references

  Submissions should provide a list of the normative references that are used by the proposed specification

- Proposed list of terms and definitions

  Submissions should provide a list of terms that are used in the proposed specification with their definitions.

- Proposed list of symbols

  Submissions should provide a list of special symbols that are used in the proposed specification together with their significance

- Proposed specification.

PART III

- Changes or extensions required to adopted OMG specifications

  Submissions must include a full specification of any changes or extensions required to existing OMG specifications. This should be in a form that enables "mechanical" section-by-section revision of the existing specification.

4.10 How to Submit

Submitters should send an electronic version of their submission to the *RFP Submissions Desk* (omg-documents@omg.org) at OMG Headquarters by 5:00 PM U.S. Eastern Standard Time (22:00 GMT) on the day of the Initial and Revised Submission deadlines. Acceptable formats are Postscript, ASCII, PDF, Adobe FrameMaker, Microsoft Word, and WordPerfect. However, it should be noted that a successful (adopted) submission must be supplied to OMG's technical editors in FrameMaker source format, using the most recent available OMG submission template (see [FORMS]). The AB will not endorse adoption of any submission for which appropriately formatted FrameMaker sources are not submitted to OMG; it may therefore be convenient to prepare all stages of a submission using this template.

Submitters should make sure they receive electronic or voice confirmation of the successful receipt of their submission. Submitters should be prepared to send a single hardcopy version of their submission, if requested by OMG staff, to the attention of the "RFP Submissions Desk" at the main OMG address shown on the first page of this RFP.

5.0 General Requirements on Proposals

5.1 Requirements

5.1.1 Submitters are encouraged to express models using OMG modeling languages such as UML, MOF, CWM and SPEM (subject to any further constraints on the types of the models and modeling technologies specified in Chapter 6 of this RFP). Submissions containing models expressed via OMG modeling languages shall be accompanied by an OMG XMI [XMI] representation of the models (including a machine-readable copy). A best effort should be made to provide an OMG XMI representation even in those cases where models are expressed via non-OMG modeling languages.

5.1.2 Chapter 6 of this RFP specifies whether PIM(s), PSM(s), or both are being solicited. If proposals specify a PIM and corresponding PSM(s), then the rules specifying the mapping(s) between the PIM and PSM(s) shall either be identified by reference to a standard mapping or specified in the proposal. In order to allow possible inconsistencies in a proposal to be resolved later, proposals shall identify whether the mapping technique or the resulting PSM(s) are to be considered normative.

5.1.3 Proposals shall be *precise* and *functionally complete*. All relevant assumptions and context required for implementing the specification shall be provided.

5.1.4 Proposals shall specify *conformance criteria* that clearly state what features all implementations must support and which features (if any) may *optionally* be supported.

5.1.5 Proposals shall *reuse* existing OMG and other standard specifications in preference to defining new models to specify similar functionality.

5.1.6 Proposals shall justify and fully specify any *changes or extensions* required to existing OMG specifications. In general, OMG favors proposals that are *upwards compatible* with existing standards and that minimize changes and extensions to existing specifications.

5.1.7 Proposals shall factor out functionality that could be used in different contexts and specify their models, interfaces, etc. separately. Such *minimalism* fosters re-use and avoids functional duplication.

5.1.8 Proposals shall use or depend on other specifications only where it is actually necessary. While re-use of existing specifications to avoid duplication will be encouraged, proposals should avoid gratuitous use.

5.1.9 Proposals shall be *compatible* with and *usable* with existing specifications from OMG and other standards bodies, as appropriate. Separate specifications offering distinct functionality should be usable together where it makes sense to do so.

5.1.10 Proposals shall preserve maximum *implementation flexibility*. Implementation descriptions should not be included and proposals shall not constrain implementations any more than is necessary to promote interoperability.

5.1.11 Proposals shall allow *independent implementations* that are *substitutable* and *interoperable*. An implementation should be replaceable by an alternative implementation without requiring changes to any client.

5.1.12 Proposals shall be compatible with the architecture for system distribution defined in ISO's Reference Model of Open Distributed Processing [RM-ODP]. Where such compatibility is not achieved, or is not appropriate, the response to the RFP must include reasons why compatibility is not appropriate and an outline of any plans to achieve such compatibility in the future.

5.1.13 In order to demonstrate that the specification proposed in response to this RFP can be made secure in environments requiring security, answers to the following questions shall be provided:

- What, if any, are the security sensitive elements that are introduced by the proposal?
- Which accesses to security-sensitive elements must be subject to security policy control?
- Does the proposed service or facility need to be security aware?
- What default policies (e.g., for authentication, audit, authorization, message protection etc.) should be applied to the security sensitive elements introduced by the proposal? Of what security considerations must the implementers of your proposal be aware?

The OMG has adopted several specifications, which cover different aspects of security and provide useful resources in formulating responses. [CSIV2] [SEC] [RAD].

5.1.14 Proposals shall specify the degree of internationalization support that they provide. The degrees of support are as follows:

a) Uncategorized: Internationalization has not been considered.

b) Specific to <region name>: The proposal supports the customs of the specified region only, and is not guaranteed to support the customs of any other region. Any fault or error caused by requesting the services outside of a context in which the customs of the specified region are being consistently followed is the responsibility of the requester.

c) Specific to <multiple region names>: The proposal supports the customs of the specified regions only, and is not guaranteed to support the customs of any other regions. Any fault or error caused by requesting the services outside of a context in which the customs of at least one of the specified regions are being consistently followed is the responsibility of the requester.

d) Explicitly not specific to <region(s) name>: The proposal does not support the customs of the specified region(s). Any fault or error caused by requesting the services in a context in which the customs of the specified region(s) are being followed is the responsibility of the requester.

5.2 Evaluation criteria

Although the OMG adopts model-based specifications and not implementations of those specifications, the technical viability of implementations will be taken into account during the evaluation process. The following criteria will be used:

5.2.1 Performance

Potential implementation trade-offs for performance will be considered.

5.2.2 Portability

The ease of implementation on a variety of systems and software platforms will be considered.

5.2.3 Securability

The answer to questions in section 5.1.13 shall be taken into consideration to ascertain that an implementation of the proposal is securable in an environment requiring security.

5.2.4 Conformance: Inspectability and Testability

The adequacy of proposed specifications for the purposes of conformance inspection and testing will be considered. Specifications should provide sufficient constraints on interfaces and implementation characteristics to ensure that conformance can be unambiguously assessed through both manual inspection and automated testing.

5.2.5 Standardized Metadata

Where proposals incorporate metadata specifications, usage of OMG standard XMI metadata [XMI] representations must be provided as this allows specifications to be easily interchanged between XMI compliant tools and applications. Since use of XML (including XMI and XML/Value [XML/Value]) is evolving rapidly, the use of industry specific XML vocabularies (which may not be XMI compliant) is acceptable where justified.

6.0 Specific Requirements on Proposals

6.1 PROBLEM STATEMENT

6.1.1 Background of this RFP

Previous activities within ManTIS Domain Task Force (DTF) identified KBE as a key area to address through OMG standards. An RFI was issued which resulted in two responses (see section 6.9). A consensus was reached within the community to focus on the integration of KBE and PLM for product design. Future efforts will focus on extending into process and business enterprise integration.

This RFP is focused on a consensus definition of the information model that would support interoperability between KBE applications that work within a PLM-managed engineering environment. It solicits proposals on a platform-independent model for the exchange of knowledge in terms of the currently available constructs in KBE/PLM systems, such as engineering rules and relations. More advanced constructs such as specific ontologies for functions, design constraints and other fundamental engineering design abstractions are on the agenda for future developments of OMG KBE standards. It was agreed to approach the KBE standardization process in a step-by-step fashion by addressing first the standardization of the KBE services currently available, before moving into more advanced design knowledge modelling services.

6.1.2 KBE Background

KBE systems are knowledge-based software for automating certain engineering design processes. Examples include, among others, ICAD, AML, Engineering Intent, Design++ and Genworks/GDL. A more recent development has been the integration of these stand-alone KBE systems into CAD technology, for example Knowledgeware in CATIA and Knowledge Fusion in UGS NX. The availability of KBE in mainstream CAD platforms increases the market awareness of KBE and results in a potentially wider community using KBE technology. This development increases the importance of establishing standards for the managed exchange of engineering knowledge.

A KBE application comprises a knowledge model and a KBE engine. The knowledge model captures domain-specific product design and process knowledge that is used by the KBE engine to generate one or more candidate designs based on a set of inputs. KBE applications can be represented in a formal language that explicitly describes a domain-specific metamodel for a family of engineered products that the application can produce, or the metamodel can be implicitly captured in a set of parametric templates that generalize a specific instance of a specific design candidate.

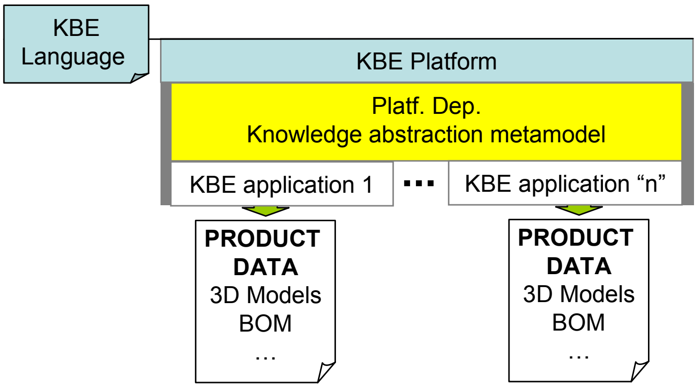


Figure 1. The role of the knowledge abstraction metamodel in a single KBE platform

Figure 1 represents a number of KBE applications, each of which is a piece of executable code for automating certain design task to generate the product model, developed on top of a single KBE platform.

Results from executing a KBE application are normally in the form of geometrical and non-geometrical data specifying various aspects of the design candidate(s) generated. These data are normally input into other software tools for Computer Aided Engineering (e.g., FEM, CFD, etc.) or further detailed design (e.g., CAD).

A KBE application is written using the language constructs available within a KBE platform. These constructs are modelling entities which are frequently at the M1 abstraction level. These constructs are the building blocks for assembling domain-specific KBE applications.

Table 6.1 provides further distinction between the notions of KBE application and KBE platform.

Table 6.1. Differences between the notions of KBE application and KBE platform

KBE application	**KBE platform**
Domain-specific metamodel for a family of engineered products	Platform-dependent knowledge abstraction metamodel
Example: A KBE application that is able to generate the data for a family of clutch assemblies	Example: A KBE platform such as CATIA KW, UGS KW, Technosoft AML or ICAD that, being domain-independent, can be used to build KBE applications in different domains such as "clutch design" or "furniture design".
Metamodel: A specialization of the metamodel on the right side that contains the specifics of certain product domain.	Metamodel: A specialization of "KBE services for PLM" metamodel that works for any product domain.

6.1.3 The need for a standard on KBE services

KBE software automating design data generation has now been on the market for more than 20 years. In the past, KBE technology was mainly used by large automotive and aerospace companies. Recently, KBE has gained momentum with the adoption of the technology by major PLM system vendors.

The KBE technology roll-out has clearly shown the need for interoperability between different KBE applications. This interoperability problem is illustrated in figure 2. Using two different KBE platforms and their respective languages, KBE applications for generating engineering design data for, say, a drive coupling assembly are developed. The two KBE applications share the same abstraction of the PLM data entities that have to be instantiated and the set of rules that govern the design of a family of coupling assemblies. However, using current data exchange standards, it is only possible to transfer an instance of the design and not the knowledge embodied in the design.

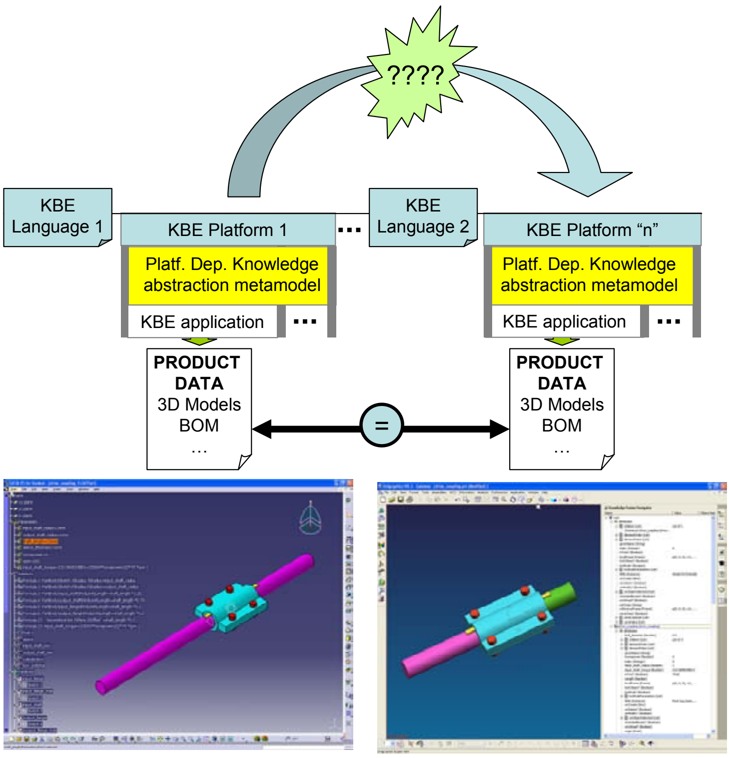


Figure 2. Challenge to KBE interoperability

This example illustrates that being able to produce the same part using different KBE applications implies that there is some semantic equivalency between the knowledge abstraction metamodels contained in the two applications.

Interoperability between KBE applications can be significantly improved if a standard is developed that supports the syntactic agreement between the language constructs available within different KBE platforms, potentially leading to semantic agreement between the different knowledge abstraction metamodels in different KBE platforms.

KBE vendors have developed knowledge abstraction metamodels that use certain constructs which, although named differently, are semantically equivalent. The existence of a standard will reduce interoperability issues on KBE technology and consequently bring benefits to both KBE users and vendors.

6.1.4 The need of managing KBE services within PLM

PLM is a key connection technology that enables generic and cost effective sharing of product and process information across a wide range of software systems and across organizations. The technology has consequently boosted the efficiency of managing collaborative engineering work.

This RFP recognises the potential of using the capabilities under PLM for enabling more efficient management of KBE deployment within organisations. Standards on KBE-PLM integration will support the realization of that potential. Business benefits for end users will include, among others, better management of the knowledge within KBE applications. Software vendors can increase their market by reducing the barriers to the introduction of KBE applications and by increasing the value of their KBE products.

Figure 3 illustrates KBE technology in the context of the product life cycle in a non-integrated PLM-KBE environment. As it is shown, KBE applications are usually employed in the early stages of the product life cycle. KBE specialist engineers collect knowledge using ad hoc or proprietary methods. That knowledge is then coded into the platform-dependent constructs to become a KBE application. The size of these applications varies from small automation scripts to large software applications automating complex engineering tasks.

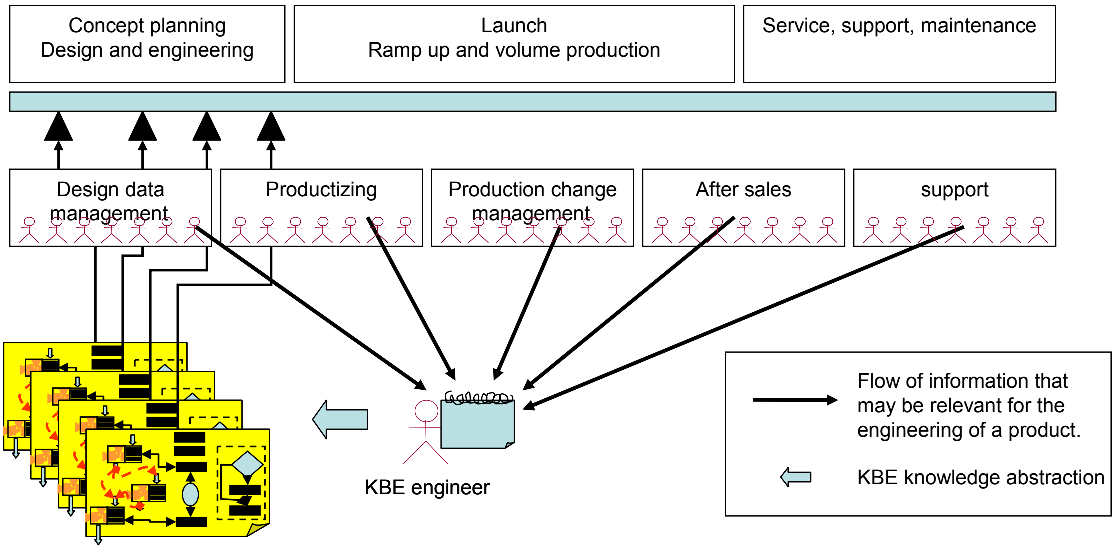


Figure 3. Integration role of the KBE engineer

Limitations on the ability to deploy KBE technology in a collaborative way result in KBE validation problems and knowledge loss. The lack of transparency on what happens inside a KBE application is illustrated in Figure 4. The technology is still very much perceived as "black art" within some organisations. Consequently, validation of the knowledge embodied in KBE applications is a bottleneck on the KBE roll out.

On the other hand, KBE engineers are seldom connected to the diverse parts of the business beyond the engineering function. Those parts of the business are usually sources of knowledge for key updates of the knowledge embodied in KBE applications. This lack of connectivity often results in losses of valuable knowledge, as illustrated in figure 4.

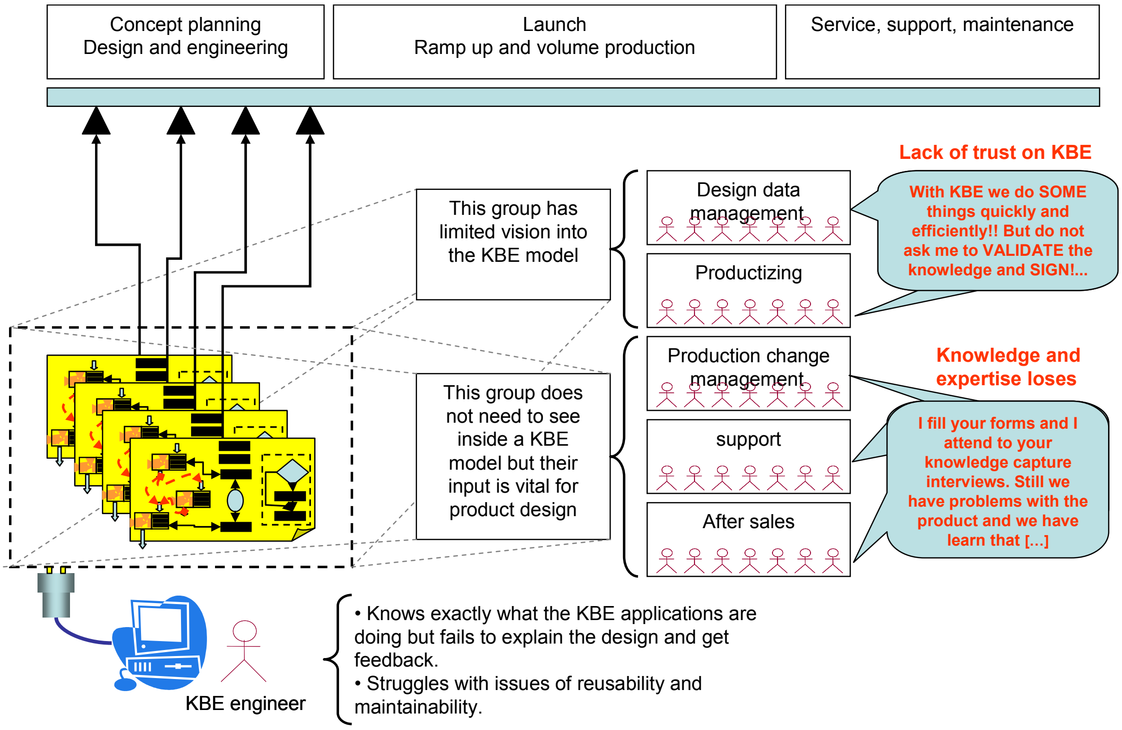


Figure 4. Need for KBE-PLM integration

Software standards enabling KBE-PLM integration will provide significant business benefits. This RFP asks for proposals that address major KBE interoperability and the KBE-PLM connectivity issues.

6.1.5 Basic KBE information processing functionalities

From a functional point of view, there is a common set of information processing operations that can be specified in currently available KBE platforms and are carried out by KBE applications. A standard on KBE services to address the issues, described in 6.5, is intended to support the fulfilment of KBE functionalities described in 6.1.5.1, 6.1.5.2, 6.1.5.3, 6.1.5.4 and 6.1.5.5.

6.1.5.1 Access to geometry and topology information.

KBE application developers use the formal language provided by the KBE platform to assemble different instantiation services that produce engineering data. The most common type of instantiation services used in KBE applications are those generating geometry descriptions, such as parametric features (Figure 5).

Within KBE applications, the data instantiation services process inputs from the user and provide outputs that are transmitted to other data instantiation services.

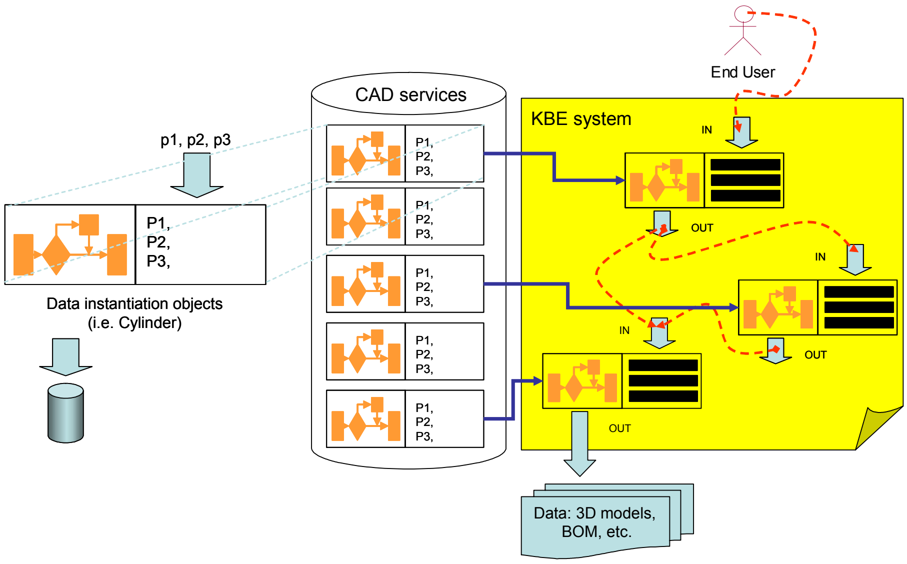


Figure 5. Access to geometry and topology instantiation services

For example, KBE functionality may include the ability to: query and retrieve geometry and topology generation services including data inputs, outputs, available messages and internal object attributes;and explicitly define input/output data flows between data instantiation services within KBE applications.

6.1.5.2 Assignment of domain-dependent design information to attributes of engineering data.

Data instantiation services provided by geometry and topology services are generic and domain-independent. This means that the data entities are generic enough to be used in any engineering domain (such as mechanical engineering or architecture). A common practice in feature-based and parametric CAD is to rename these internal objects in a way that makes sense in the domain. For example, a generic object "cylinder" may have a generic attribute "diameter". These are made explicit in the domain as a "pin" object with an associated "pin_ diameter" attribute (Figure 6).

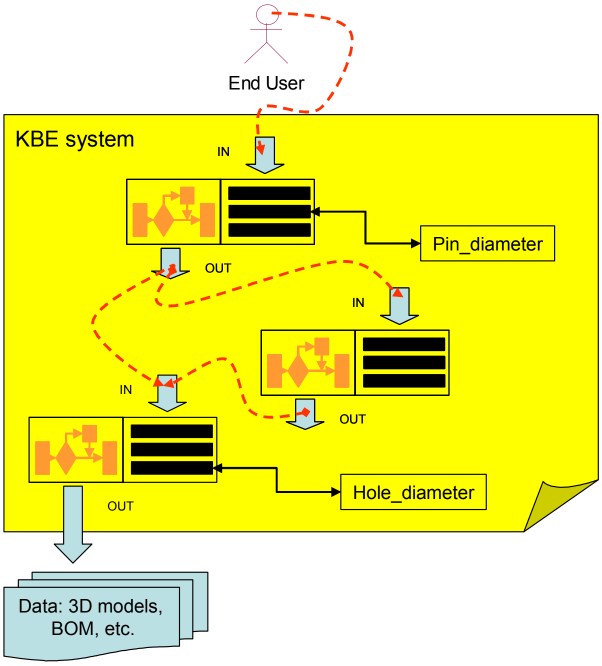


Figure 6. Assignment of domain-dependent design information

For example KBE functionality may include the ability to: assign domain dependent concepts to generic attributes associated to data instantiation services assembled within KBE applications; populate, store, browse, query and edit assigned domain dependent concepts across KBE applications; and trace out the existence of these domain concepts across the PLM spectrum of applications.

6.1.5.3 Creation of domain-dependent engineering attributes.

Explicit definitions of attributes of domain-specific objects are not sufficient to build a complete domain-specific knowledge abstraction metamodel for a KBE application. KBE applications rely on the definition of domain-specific concepts that add engineering meaning to the applications (Figure 7). Programming languages usually allow the creation of these user-defined attributes by declaring their name and datatype. Basic datatypes include “string”, “integer” and “float”. Other datatypes with richer engineering semantics might be defined based on other standards such as ISO STEP and the EXPRESS language.

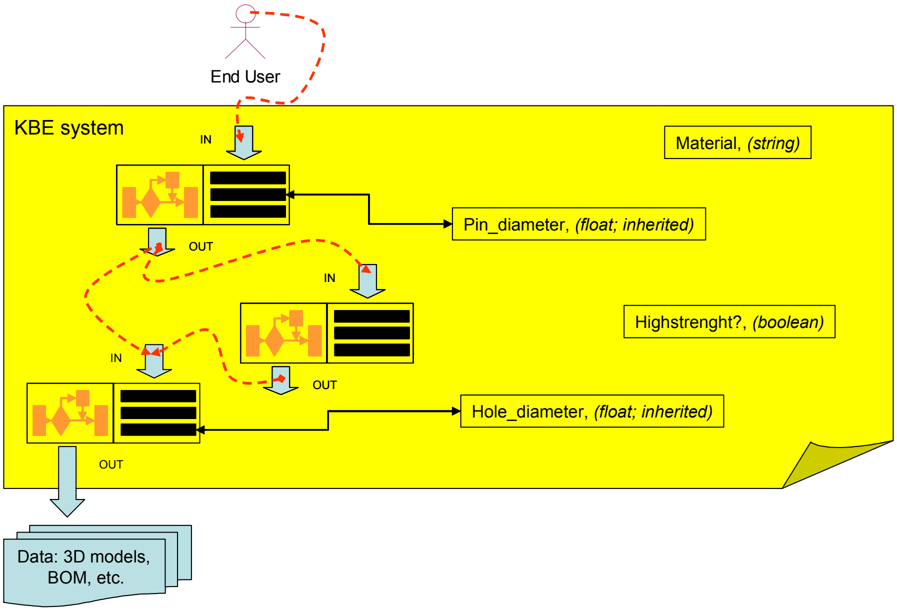


Figure 7. Creation of domain-dependent engineering attributes

This KBE functionality may include the ability to: create and edit user-defined engineering attributes, at least in terms of their name and their association to standardized engineering meta-classes available in PLM services; populate, store, browse query and edit these engineering attributes across KBE applications; and trace out the existence of these engineering attributes across the PLM spectrum of applications.

6.1.5.4 Definition of relationships between engineering attributes.

Once data instantiation services are assembled within a KBE application and a set of engineering attributes is available, information processing can take place. This will allow the KBE applications to mimic some the information processing activities that people follow in generating engineering data. The basic KBE services enabling these functionalities are the definition of relationships and engineering rules.

Relationships between attributes in KBE applications are usually those constraining numerical values, such as "=, >, <" (Figure 8). It is also common to use the subsumption relationship "is-a" for non-numeric datatypes.

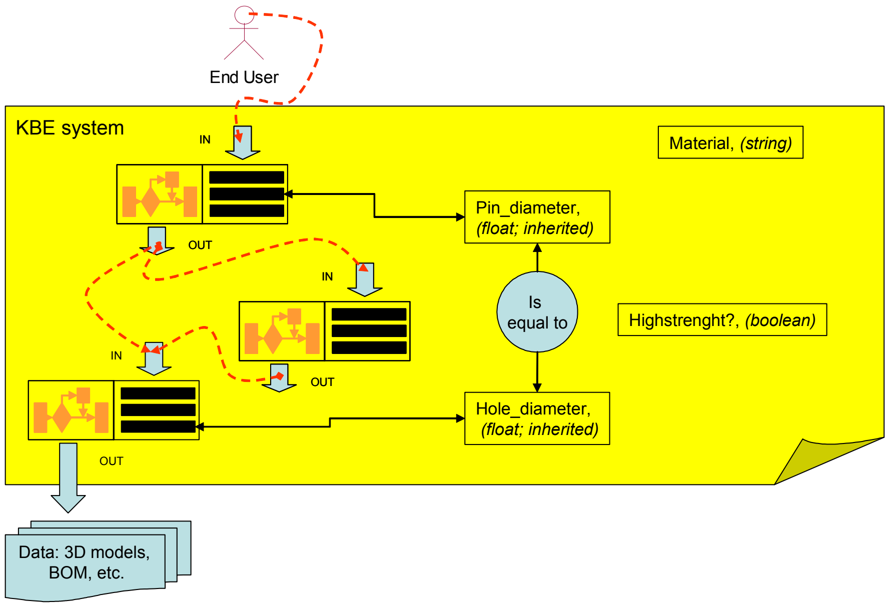


Figure 8. Definition of relationships

This KBE functionality may include the ability to: create and edit basic relationships between engineering attributes made explicit within KBE applications; populate, store, and query these basic relations across KBE applications; and trace out the existence of these basic relationships across the PLM spectrum of applications.

6.1.5.5 Definition of engineering rules that control the generation of engineering data.

For the purposes of this RFP, the definition of an engineering rule is: that it assigns one or more attributes to the product being designed; and that it is submitted to an inference engine to be executed.

Engineering rules form the procedural knowledge that KBE applications use to generate engineering data. "Engineering rules" refer here to a subset of more generic entities known as "production rules". A production rule is a logical statement that specifies the execution of one or more actions in the case that its conditions are satisfied. Distinction between a "production rule" and an "engineering rule" comes with the engineering nature of the latter. Engineering rules specify only the execution of tasks that have engineering meaning. This implicitly means that engineering rules on KBE only operate on engineering objects, attributes and relationships defined in Sections 6.1.5.2, 6.1.5.3, and 6.1.5.4.

A production rule can be defined using a set of data entities that define the "if-part" of the rule and the "then-part" of the rule. At the semantic level, a rule is an information processing entity that computes the state transition of one or more attributes. This is achieved by accepting inputs and providing outputs according to the evaluation of the conditions stated internally by the rule. Figure 9 illustrates a semantic unification of an IF-THEN rule affecting the state of an attribute.

IF-THEN RULE

```
(RULE  (IF  ((Condition-1  Input-Attribute-1 [SubInputs-Adjacents]  Value-1 {SubValues} )
             AND (Condition-2  Input-Attribute-2 [SubInputs-Adjacents]  Value-2 {SubValues} )
                   …)
          (THEN  (Action-T)  (Action-F ) … )
)
```

Figure 9 Example IF-THEN rule

KBE applications use engineering rules as the modelling entities controlling the behaviour of engineering data generation. Engineering rules play the role of capturing engineering decisions.

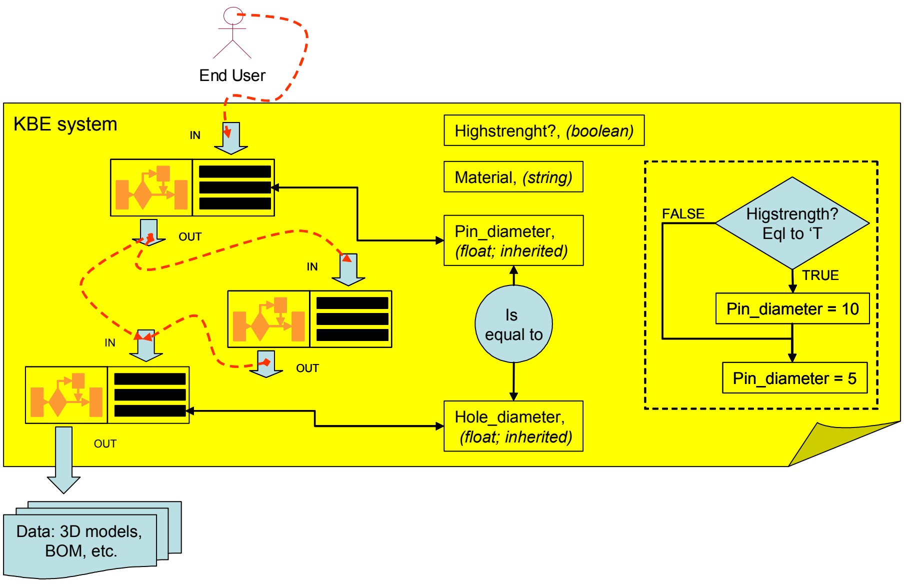


Figure 10. Defining engineering rules

This KBE functionality may include the ability to: create and edit engineering rules within KBE applications; populate, store, and query these engineering rules across KBE applications; and trace out the existence of these engineering rules across the PLM spectrum of applications.

6.1.6 PLM services extension to handle KBE services

The intent of this RFP is to develop seamless integration between KBE and PLM software. For example, one approach might be to link PLM-KBE systems by implementing KBE services as PLM items. The use of PLM technology is largely based on the management of "items". *An item is a systematic and standard way to identify, encode and name a physical product, a product part or component, a material or a* *service.* In this case the items to be managed are the KBE services specified in the metamodel that includes services 6.5.1.1 to 6.5.1.6. Using this definition of KBE services as items, the entire PLM connectivity and management infrastructure can be put at the service of KBE engineers and other actors involved in PLM.

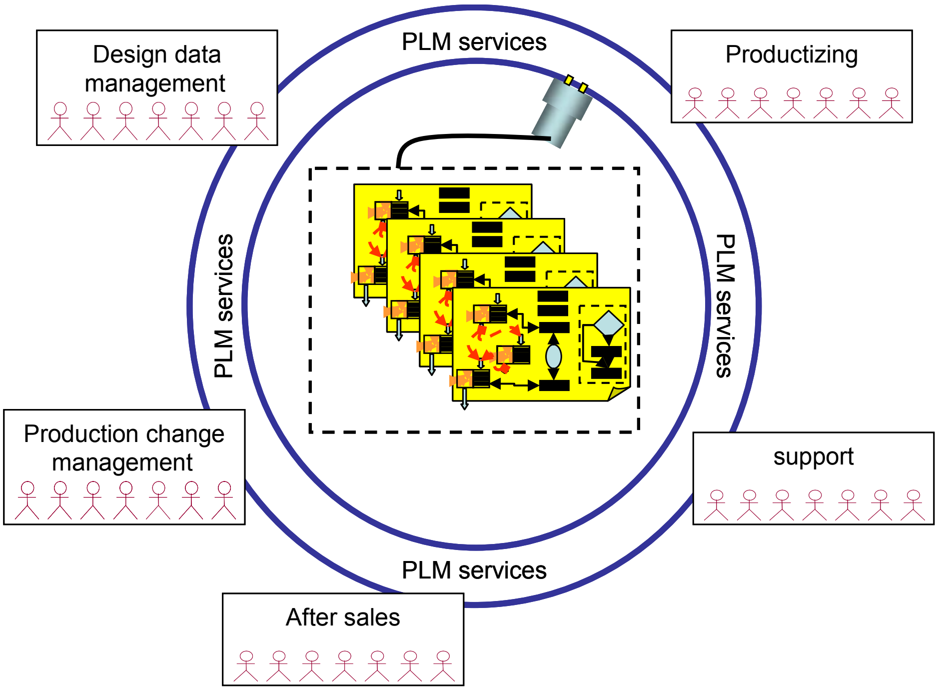


Figure 11 KBE in PLM

6.2 SCOPE OF PROPOSALS SOUGHT

This RFP solicits a metamodel to describe the functionalities of: (1) basic KBE services; and (2) KBE services integration on PLM technology. Following MDA principles, the proposals shall be positioned as illustrated in Figure 12.

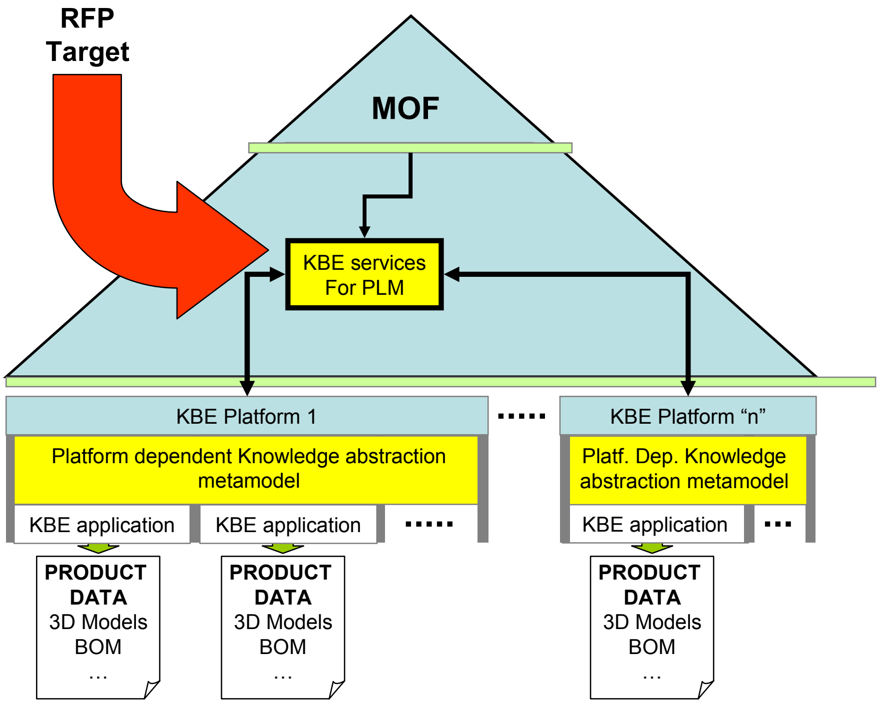


Figure 12. RFP position in MDA

At the basic KBE services level, the key business objective of the proposal is to standardise the structure and behaviour of KBE services in order to address KBE interoperability issues as described in Section 6.1.3. KBE software vendors using the standard will be able to reuse the metamodel for mapping the basic KBE services to their own platform-specific languages. The adoption of the standard should lower the barriers to the takeup of KBE technology and consequently should increase the interest in KBE for those still not aware of the technology. End users will be able to transfer the knowledge encoded in their applications across different KBE platforms. Business benefits of this interoperability are:

- Enhanced KBE interoperability in OEM-supplier relationships.
- Better understanding from KBE engineer A to KBE engineer B.
- Easier migration from one KBE platform to another.

At the KBE-PLM integration level, software vendors shall benefit from the standard due to increased added value at both KBE and PLM sides. End users shall also benefit by increased efficiency of knowledge reuse, sharing and maintenance not only across projects but across products as well.

6.3 RELATIONSHIPS TO EXISTING OMG SPECIFICATIONS

Several OMG standards are closely related to proposals solicited in this RFP:

- PLM services (OMG document, dtc/04-05-05).
- CAD services (OMG document, formal/05-01-07).
- Meta-Object Facility (MOF), version 1.4 (OMG document formal/2002-04-03)
- XML , v2.0 (OMG document, formal/05-09-01)
- UML Infrastructure Specification, v2.0, (OMG document, formal/05-07-05)

6.4 RELATED ACTIVITIES, DOCUMENTS AND STANDARDS

The models that will be specified in response to this RFP may be correlated with one or more of the following documents and standards:

OMG work in progress:
- Reusable assets specification RFP (OMG document ptc/04-06-06)
- Production rule representation RFP (OMG document, bei/04-08-01)
- PLM Services V2.0 RFP (OMG document mantis/05-05-01)
- MOF 2 Query/View/Transform RFP, revised submission (OMG document, ad/05-07-01)
- ODM Ontology Definition Metamodel RFP, revised submission (OMG document, ad/05-08-01)
- Business Semantics of Business Rules RFP, revised submission (OMG document, bei/05-08-01)
- MOF2/EXPRESS Integration and Coexistance (MEXICO). (OMG document, mantis/2005-06-010)

Standards and specifications
- ISO 10303 Standards (STEP).

6.5 MANDATORY REQUIREMENTS

From a functional point of view, this RFP solicits:

6.5.1. A MOF compliant metamodel to represent KBE services. This metamodel shall define a language that explicitly represents KBE services which includes (but is not limited to):

a. Define engineering rules that control the generation of engineering data (see 6.1.5.5).
b. Define relationships between engineering attributes (see 6.1.5.4).
c. Create domain-dependent engineering attributes (see 6.1.5.3).
d. Access to geometry and topology information. For example, the ability to retrieve, query and create geometry and topology is desired (see 6.1.5.1).
e. Assignment of domain-dependent design information to attributes of engineering data (see 6.1.5.2).

6.5.2. The metamodel or extension to an existing metamodel developed for 6.5.1 shall reuse and extend PLM services.
6.5.3. A mapping of the proposed metamodel to at least two KBE platforms.

6.6 OPTIONAL REQUIREMENTS

None.

6.7 ISSUES TO BE DISCUSSED

Proposals shall discuss:
1. How KBE services interact with the range of different engineering data generation facilities beyond geometry generation. This includes existing modules in CAD/PLM such as mechanical analysis or computer aided manufacturing.
2. How the proposed metamodel is used to exchange information that allows the transfer of data from one KBE/PLM system to another.
3. The reuse and extension of existing OMG standards.
4. How data models contained in standards developed by ISO TC184/SC4 can facilitate the fulfilment of the basic KBE services functionalities, i.e., what are the data meta-classes in STEP and how can they be made available in the resulting KBE services for PLM metamodel.
5. How proposals provide means to protect the intellectual property embedded in engineering rules.

6.8 EVALUATION CRITERIA

The primary concerns in evaluating proposals shall be:
- Supported interoperability between KBE platforms.
- Number of supported KBE functionalities.
- Scope of KBE services in PLM.
- Integratability of KBE services with PLM.
- Expansion potential.
- Harmonization with ISO TC184/SC4.

6.9 OTHER INFORMATION UNIQUE TO THIS RFP

There were several responses to a KBE Services RFI. These responses may be useful to submitters:
1. (OMG document: http://www.omg.org/cgi-bin/doc?mantis/03-05-01)
2. (OMG document: http://www.omg.org/cgi-bin/doc?mantis/03-05-02)

6.10 RFP TIMETABLE

Current intentions are to issue the RFP in September 2005 at the Atlanta meeting

Event or Activity	Actual Date
Preparation of RFP by TF	*Sept. 15, 2005*
RFP placed on OMG document server	*Sept. 22, 2005*
Approval of RFP by Architecture Board *Review by TC*	*Sept. 15, 2005* *Sept. 16, 2005*
TC votes to issue RFP	*Sept. 16, 2005*
LOI to submit to RFP due	*Feb. 20, 2006*
Initial Submissions due and placed on OMG document server ("Three week rule")	*Apr. 3, 2006*
Voter registration closes	*Feb. 25, 2006*
Initial Submission presentations	*Apr. 25, 2006*
Preliminary evaluation by TF	*Jun. 26, 2006*
Revised Submissions due and placed on OMG document server ("Three week rule")	*Sept. 4, 2006*
Revised Submission presentations	*Sept. 26, 2006*
Final evaluation and selection by TF *Recommendation to AB and TC*	*Sept. 28, 2006*
Approval by Architecture Board *Review by TC*	*Dec. 2006*
TC votes to recommend specification	*Dec. 2006*
BoD votes to adopt specification	*Jun. 2007*

Appendix A References and Glossary Specific to this RFP

A.1 References Specific to this RFP

< Note to RFP Editors: Insert any references specific to this RFP that are referred to in the Objective Section, Section 6 and any additional sections in the same format as in Section B.1 and in alphabetical order in this section. >

A.2 Glossary Specific to this RFP

< Note to RFP Editors: Insert any glossary items specific to this RFP that are used in Section 6 and any additional sections in the same format as in Section B.2 and in alphabetical order in this section. >

Appendix B General Reference and Glossary

B.1 General References

The following documents are referenced in this document:

[ATC] Air Traffic Control Specification, *http://www.omg.org/technology/documents/formal/air_traffic_control.htm*

[BCQ] OMG Board of Directors Business Committee Questionnaire, *http://www.omg.org/cgi-bin/doc?bc/02-02-01*

[CCM] CORBA Core Components Specification, *http://www.omg.org/technology/documents/formal/components.htm*

[CORBA] Common Object Request Broker Architecture (CORBA/IIOP), *http://www.omg.org/technology/documents/formal/corba_iiop.htm*

[CSIV2] [CORBA] Chapter 26

[CWM] Common Warehouse Metamodel Specification, *http://www.omg.org/technology/documents/formal/cwm.htm*

[DAIS] Data Acquisition from Industrial Systems, *http://www.omg.org/technology/documents/formal/dais.htm*

[EDOC] UML Profile for EDOC Specification, *http://www.omg.org/techprocess/meetings/schedule/UML_Profile_for_EDOC_FTF.html*

[EJB] "Enterprise JavaBeans™", *http://java.sun.com/products/ejb/docs.html*

[FORMS] "ISO PAS Compatible Submission Template". *http://www.omg.org/cgi-bin/doc?pas/2003-08-02*

[GE] Gene Expression, *http://www.omg.org/technology/documents/formal/gene_expression.htm*

[GLS] General Ledger Specification , *http://www.omg.org/technology/documents/formal/gen_ledger.htm*

[Guide] The OMG Hitchhiker's Guide,, *http://www.omg.org/cgi-bin/doc?hh*

[IDL] ISO/IEC 14750 also see [CORBA] Chapter 3.

[IDLC++] IDL to C++ Language Mapping, *http://www.omg.org/technology/documents/formal/c++.htm*

[MDAa] OMG Architecture Board, "Model Driven Architecture - A Technical Perspective*", http://www.omg.org/mda/papers.htm*

[MDAb] "Developing in OMG's Model Driven Architecture (MDA)," *http://www.omg.org/docs/omg/01-12-01.pdf*

[MDAc] "MDA Guide" (*http://www.omg.org/docs/omg/03-06-01.pdf*)

[MDAd] "MDA "The Architecture of Choice for a Changing World™"", *http://www.omg.org/mda*

[MOF] Meta Object Facility Specification, *http://www.omg.org/technology/documents/formal/mof.htm*

[MQS] "MQSeries Primer", *http://www.redbooks.ibm.com/redpapers/pdfs/redp0021.pdf*

[NS] Naming Service, *http://www.omg.org/technology/documents/formal/naming_service.htm*

[OMA] "Object Management Architecture™", http://www.omg.org/oma/

[OTS] Transaction Service, http://www.omg.org/technology/documents/formal/transaction_service.htm

[P&P] Policies and Procedures of the OMG Technical Process, http://www.omg.org/cgi-bin/doc?pp

[PIDS] Personal Identification Service, http://www.omg.org/technology/documents/formal/person_identification_service.htm

[RAD] Resource Access Decision Facility, http://www.omg.org/technology/documents/formal/resource_access_decision.htm

[RFC2119] IETF Best Practices: Key words for use in RFCs to Indicate Requirement Levels, (http://www.ietf.org/rfc/rfc2119.txt).

[RM-ODP] ISO/IEC 10746

[SEC] CORBA Security Service, http://www.omg.org/technology/documents/formal/security_service.htm

[TOS] Trading Object Service, http://www.omg.org/technology/documents/formal/trading_object_service.htm

[UML] Unified Modeling Language Specification, http://www.omg.org/technology/documents/formal/uml.htm

[UMLC] UML Profile for CORBA, http://www.omg.org/technology/documents/formal/profile_corba.htm

[XMI] XML Metadata Interchange Specification, http://www.omg.org/technology/documents/formal/xmi.htm

[XML/Value] XML Value Type Specification, http://www.omg.org/technology/documents/formal/xmlvalue.htm

B.2 General Glossary

Architecture Board (AB) - The OMG plenary that is responsible for ensuring the technical merit and MDA-compliance of RFPs and their submissions.

Board of Directors (BoD) - The OMG body that is responsible for adopting technology.

Common Object Request Broker Architecture (CORBA) - An OMG distributed computing platform specification that is independent of implementation languages.

Common Warehouse Metamodel (CWM) - An OMG specification for data repository integration.

CORBA Component Model (CCM) - An OMG specification for an implementation language independent distributed component model.

Interface Definition Language (IDL) - An OMG and ISO standard language for specifying interfaces and associated data structures.

Letter of Intent (LOI) - A letter submitted to the OMG BoD's Business Committee signed by an officer of an organization signifying its intent to respond to the RFP and confirming the organization's willingness to comply with OMG's terms and conditions, and commercial availability requirements.

Mapping - Specification of a mechanism for transforming the elements of a model conforming to a particular metamodel into elements of another model that conforms to another (possibly the same) metamodel.

Metadata - Data that represents models. For example, a UML model; a CORBA object model expressed in IDL; and a relational database schema expressed using CWM.

Metamodel - A model of models.

Meta Object Facility (MOF) - An OMG standard, closely related to UML, that enables metadata management and language definition.

Model - A formal specification of the function, structure and/or behavior of an application or system.

Model Driven Architecture (MDA) - An approach to IT system specification that separates the specification of functionality from the specification of the implementation of that functionality on a specific technology platform.

Normative – Provisions that one must conform to in order to claim compliance with the standard. (as opposed to non-normative or informative which is explanatory material that is included in order to assist in understanding the standard and does not contain any provisions that must be conformed to in order to claim compliance).

Normative Reference – References that contain provisions that one must conform to in order to claim compliance with the standard that contains said normative reference.

Platform - A set of subsystems/technologies that provide a coherent set of functionality through interfaces and specified usage patterns that any subsystem that depends on the platform can use without concern for the details of how the functionality provided by the platform is implemented.

Platform Independent Model (PIM) - A model of a subsystem that contains no information specific to the platform, or the technology that is used to realize it.

Platform Specific Model (PSM) - A model of a subsystem that includes information about the specific technology that is used in the realization of it on a specific platform, and hence possibly contains elements that are specific to the platform.

Request for Information (RFI) - A general request to industry, academia, and any other interested parties to submit information about a particular technology area to one of the OMG's Technology Committee subgroups.

Request for Proposal (RFP) - A document requesting OMG members to submit proposals to the OMG's Technology Committee. Such proposals must be received by a certain deadline and are evaluated by the issuing task force.

Task Force (TF) - The OMG Technology Committee subgroup responsible for issuing a RFP and evaluating submission(s).

Technology Committee (TC) - The body responsible for recommending technologies for adoption to the BoD. There are two TCs in OMG – *Platform TC* (PTC), that focuses on IT and modeling infrastructure related standards; and *Domain TC* (DTC), that focus on domain specific standards.

Unified Modeling Language (UML) - An OMG standard language for specifying the structure and behavior of systems. The standard defines an abstract syntax and a graphical concrete syntax.

UML Profile - A standardized set of extensions and constraints that tailors UML to particular use.

XML Metadata Interchange (XMI) - An OMG standard that facilitates interchange of models via XML documents.

< Note to RFP Editors: Append additional appendices if needed here and update the list and brief description of appendices in Chapter 1. >

Appendix B

QUESTIONNAIRES TO RANK KBE/PLM BUSSINES FUNCTIONALITIES AND USE CASES

KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	Ismail Deif
Company name:	Dassault-Systemes
Contact address:	c/o ENOVIA Corp. 10330 David Taylor Drive Charlotte, NC 28262, USA
E-mail address:	ismail_deif@enovia.com

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
	X	X		
Original equipment manufacturer.	Consultancy services company.	Software vendor company.	Research institute.	Other, (add).
Comments:				

2. What is the size of the organisation that you belong to?				
		X		
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees.	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
X		X	
I develop KBE applications.	I use KBE applications.	I provide software related support to KBE developers and users.	Other, (add).
Comments:			

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
			X	
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation.	I am part of a PLM software development team.	Other, (add).
Comments:				

2. Technical view

	YES	NO
5. Are you aware of the OMG's Model Driven Architecture and the software standards associated with it?	X	
If affirmative, which ones do you know? UML, MOF, XML, OWL, etc.		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	X	

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the "KBE services for PLM" RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems.
(KBE application from KBE system "A" can be used in KBE system "B")

			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.

Comments:
This is the only hope of moving forward while utilizing the best technologies/approaches/solutions for each domain in a mixed-domain solution. For example, engineering designs combining electrical, mechanical, structural and electronic components will require the application of the best tools for each domain, working in concert.

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process.
(KBE applications can be visualised by non KBE experts)

				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

Transparency is critical for the success of KBE within the traditional enterprises. If it is perceived as a "club" or only for "elite" engineers, it will not succeed. It must become "democratized". But transparency, as well as interoperability, will require the development of strong and relevant standards.

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects. (KBE applications can be more easily retrieved and re-engineered to be reused in more situations)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Definitely, exposing the components of a KBE solution in PLM has the same power as exposing the component artefacts of an engineering design in PLM. You can search and re-use at a much finer level of granularity, and you can approach the problems of versioning, maturity, release management and configuration management methodically and in a unified manner. Note that mature users of KBE now realize that the second-tier problem with KBE is solution management, configuration and reuse.				

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications. (KBE applications can be more efficiently adapted to the changes of the knowledge)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Again, this is so because the principles of PLM are very relevant to KBE applications. Therefore, the formal solutions that PLM offers have direct applicability. Any Application has a lifecycle that needs to conform to the principles of PLM. In order for it to keep current and useful, it must be easy to maintain, update, and distribute. This can be a complex and involved process itself. This is more important than the initial design itself.				

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications. (KBE applications can be more easily created by assembling existing documented components)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Modularity is very important. It is very important for Knowledge/KBE application re-use, as well as for localization of the effects of changes. What applies to software development and engineering design also applies to KBE application development.				

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure. (KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: The business model of each company will be a driver behind whether or not KBE applications will be deployed as services across a network. This applies to both the software providers, such as DS, UGS, Autodesk, Rulestream and others, and KBE application developers, such as Boeing, Airbus, GM, Ford, and many others. For example, both Boeing and Airbus have (or had) specialized KBE groups that developed applications for internal "customers". That is as opposed to other models where local engineering teams develop their own applications and protect their "IP" from others.				

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services. (KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Very important. Related to previous question.				

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM. (Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Not only is the engineering knowledge in the PLM system part of the IP, but the KBE applications themselves represent engineering knowledge that may be in experts' heads, and that must be preserved and managed in the PLM system.				

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Absolutely yes! The KBE system contains more than just the design; it contains the know-how, information flow, and standards of the design. Changes to such a system must be tracked through a change management system to add credibility to the application.				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: This is the only hope for convergence, interoperability, and for moving KBE into the mainstream.				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?

		X		
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.

Comments:

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?

		X		
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term.	It will provide significant benefits to product engineering in the long term.	It will provide significant benefits to product engineering in the short term.

Comments:
The benefits are clear. However, will companies truly attempt to interoperate? If they do not, then there will be limited benefit because whatever success is achieved will be in spite of the companies, and not because they have facilitated it.

It seems that many companies attempt to "lock" their users into their products, which interoperate very well among themselves. But they have limited motivation to interoperate with other companies' products. The standard will make it easier for customers to demand this interoperability, but as the STEP experience shows, it will be a slow process.

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?

	X			
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.

Comments:
My guess is that most PLM customers will not view KBE as a critical component in evaluating PLM. But PLM support <u>may</u> be viewed as critical in evaluating which KBE solution to use.

Maybe I misunderstood the question. Second response: Yes, for the limited set of customers who will employ <u>some</u> KBE technology, this KBE technology will represent an added value to PLM.

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?

		X	X	
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.

Comments:
KBE benefits a lot from support in PLM and from the emergence of the standard.

21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?

		X	X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.

Comments:

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?

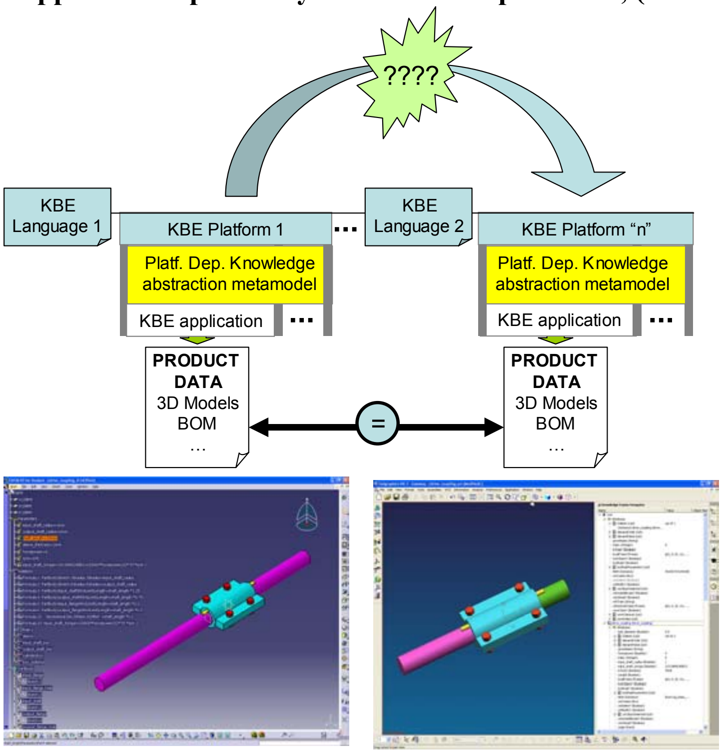
		X	X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.

Comments:
Definitely, the benefits of PLM, in terms of sharing, reuse, maintenance and collaboration can and will extend to KBE. But this will not happen automatically, and will require extensions and enhancements to the KBE standard for PLM. Managing KBE application components in PLM is different from managing engineering design and manufacturing components, so some adaptation and specialization will be required.

23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.				
		X		
Negative impact.	Some positive impact but not in my domain.	Some positive impact in my domain as part of a long term strategy.	High positive impact in my domain but not in my current list of preferences.	High positive impact in my domain. In my current list of preferences.
Comments: The standard can be used to guide our direction to a certain extent. It can also provide the "moral authority" to argue for interoperability. But the bottom line will be the business case, and not the technology.				

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

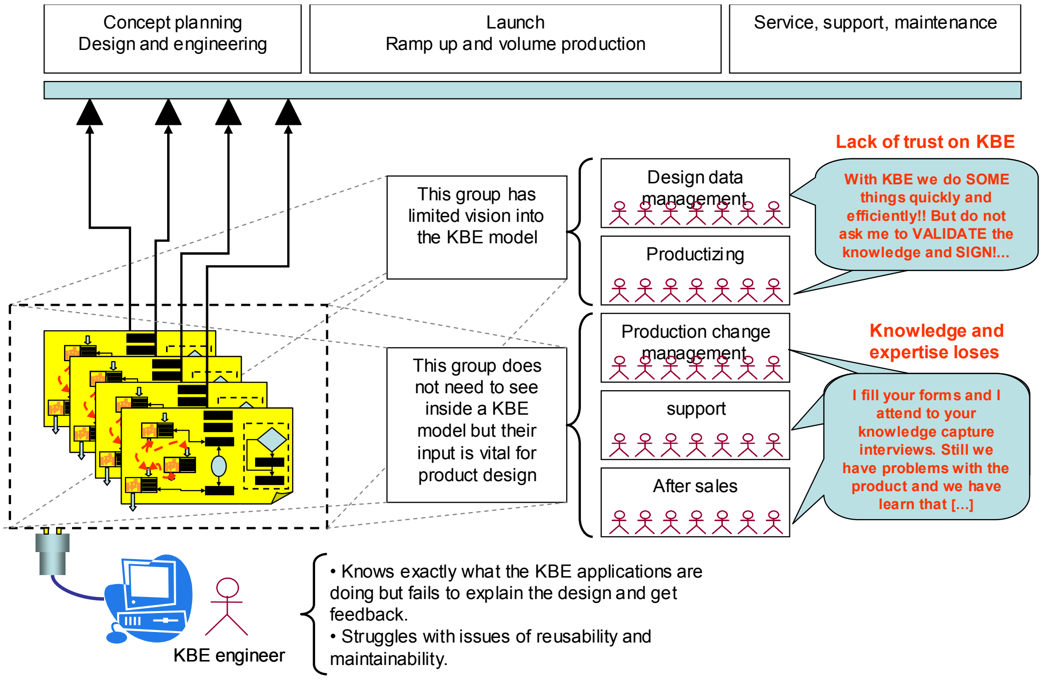
			X	
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

25. Evaluate the appropriateness of providing solutions to the issue.

		X		
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:
It is not easy to solve, but that does NOT mean that it will have limited returns. I didn't see a category for this view.

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

				X
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

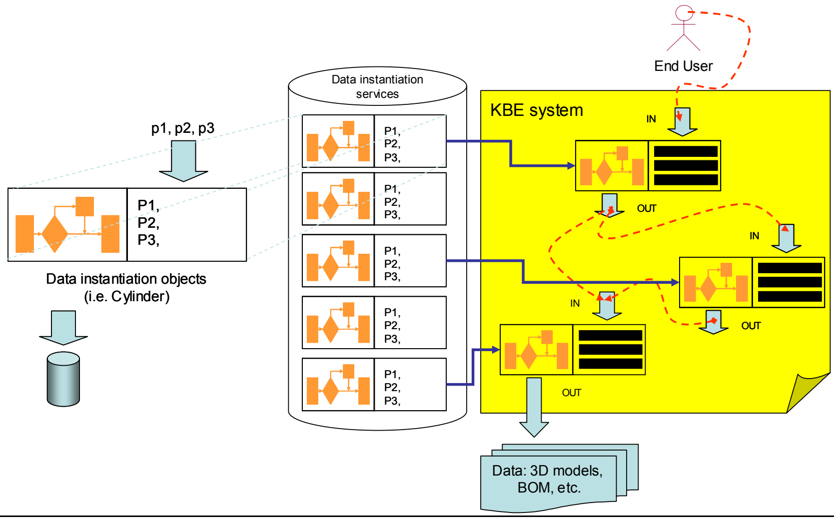
27. Evaluate the appropriateness of providing solutions to the issue.

			X	
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:
Again, it will not be easy, but it is very important.

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

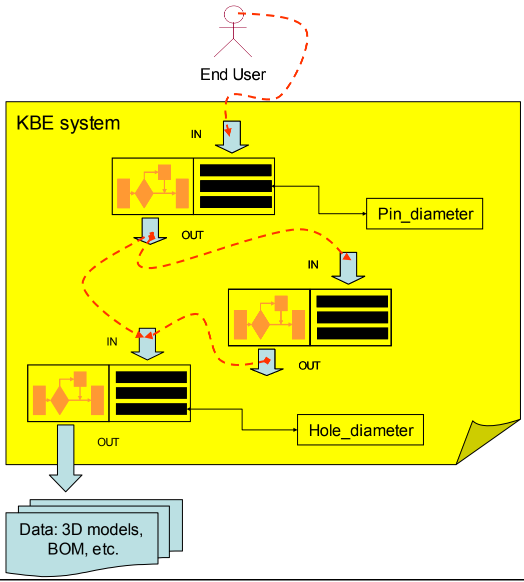
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

29. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:
Traditional KBE focuses on geometry. It is very important, but only the first of many areas that KBE needs to support in the metamodel. The construction of the metamodel should not be limited to a geometric domain of the physical object.

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

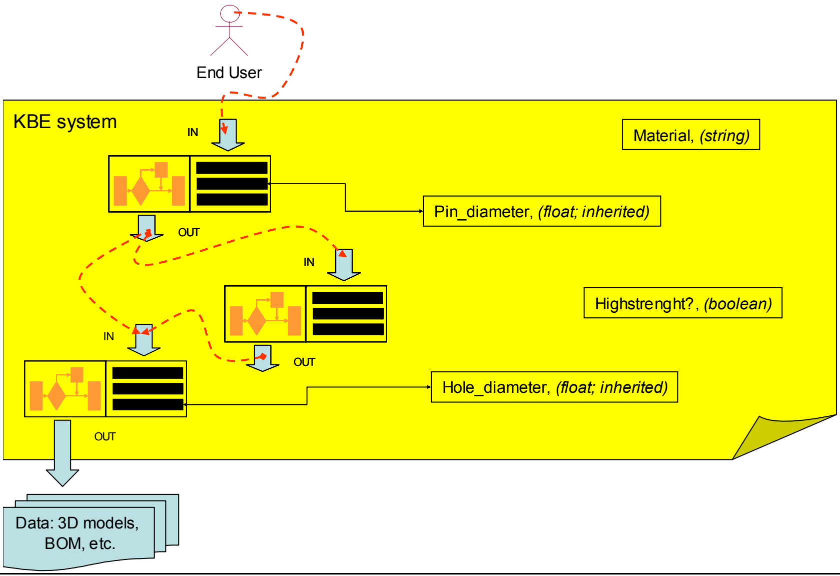
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:
This is critical for true KBE, as opposed to "geometry + parametrics/rules". This also begins to address the issue of Domain-specific Languages, which KBE has been doing all along.

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

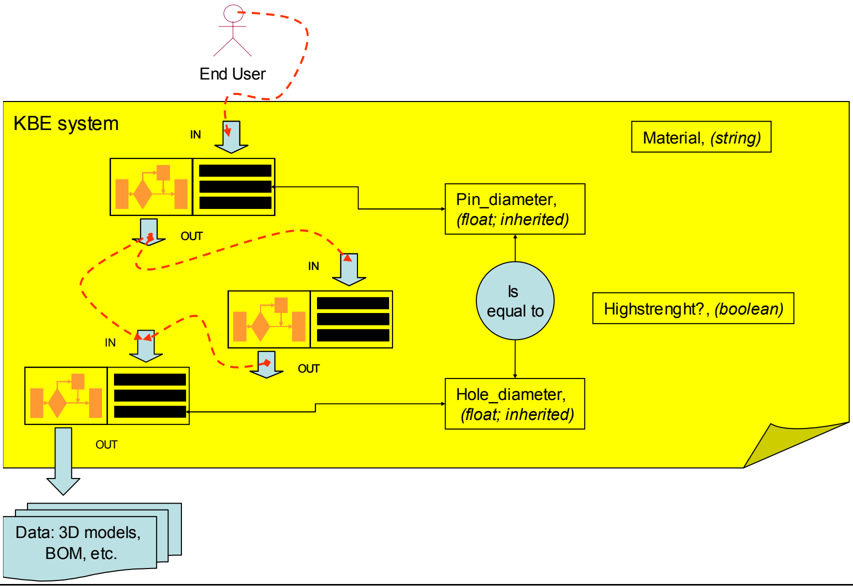
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:
Same comment as 31.

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the “KBE services for PLM” metamodel? What is in your domain the level of interest that you would assign to it?

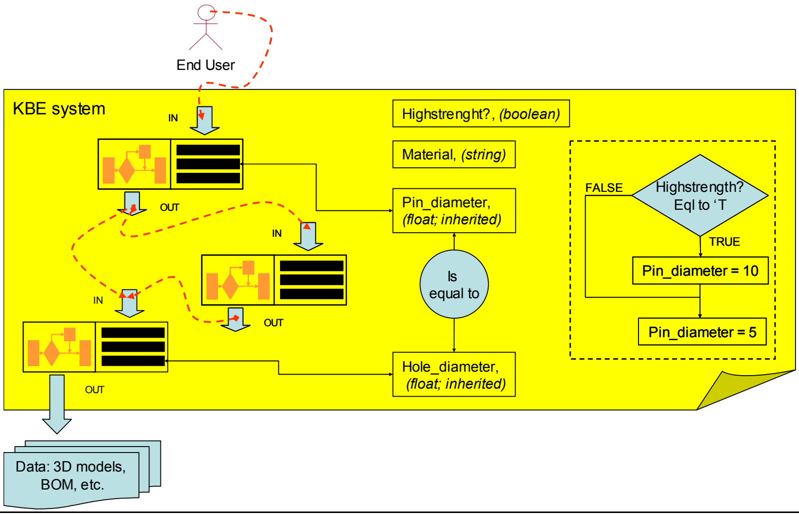
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

35. Evaluate the appropriateness of supporting this functionality on the “KBE services for PLM” metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:
Critical and highly beneficial.

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

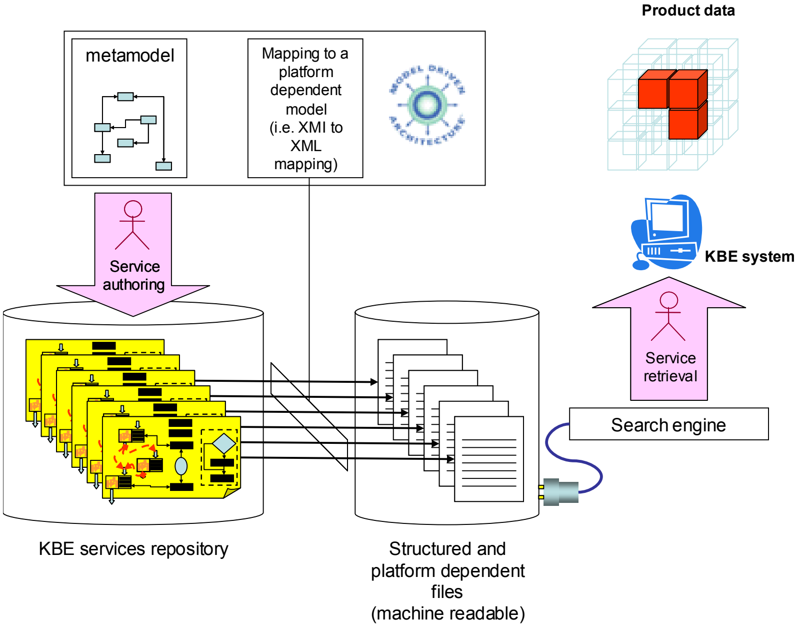
				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:
Critical and highly beneficial.

2.3 Use cases for the standard

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] complaint metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

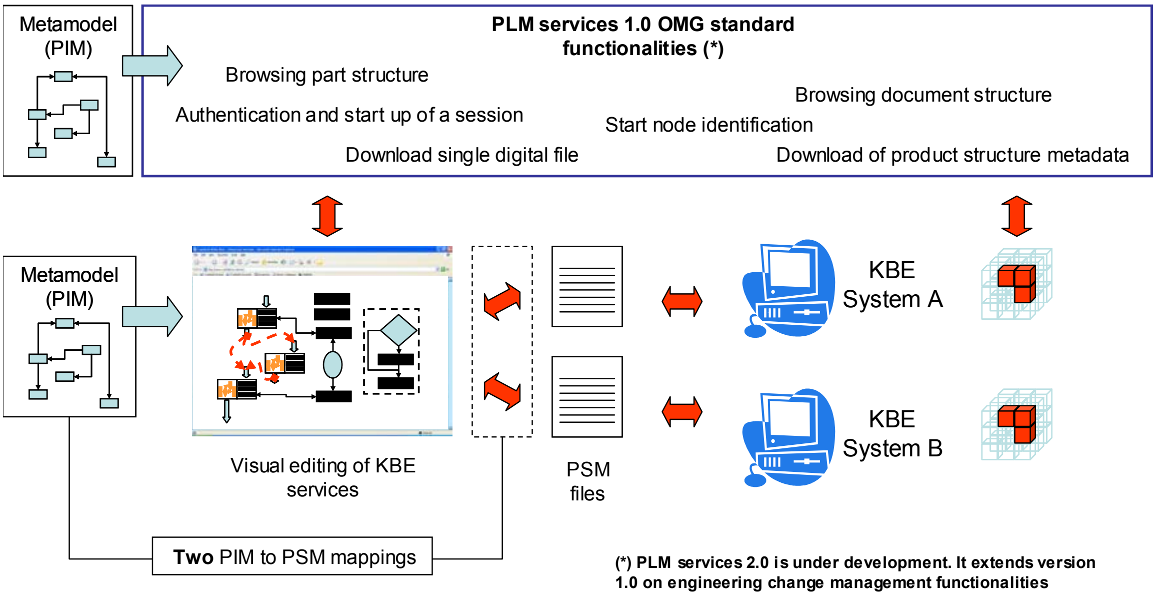
[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
This has tremendously important implications on portability and migration from one engine to another.

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

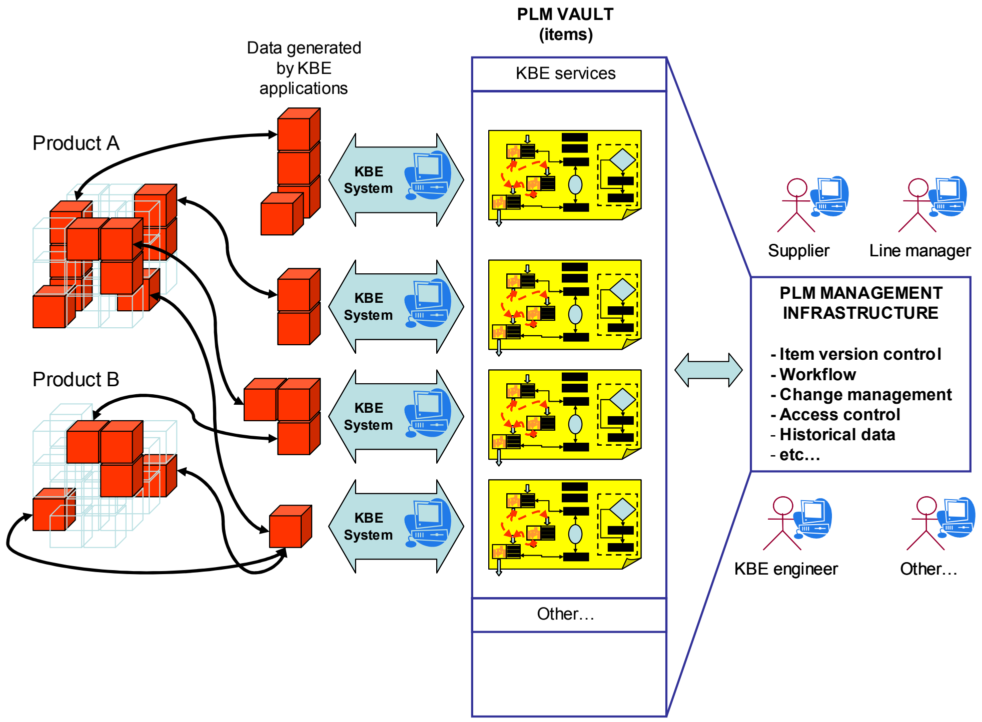
Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor's KBE language).

39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

				X
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
Implications for ease of use and democratization of KBE. In addition, it provides more platform and vendor independence while preserving and protecting the Intellectual Property (IP) of the customer in a clear form.

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



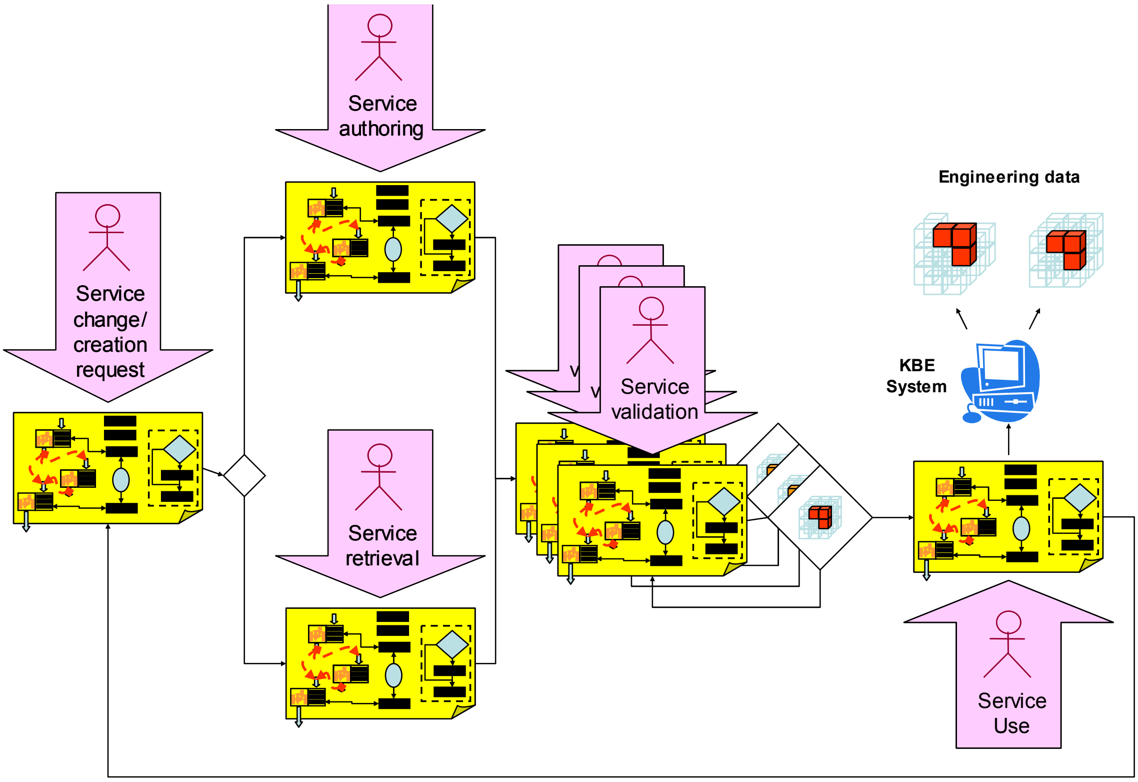
USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

				X
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
Definitely in our plans.

Use case 4: standardised KBE services authoring, reuse and maintenance



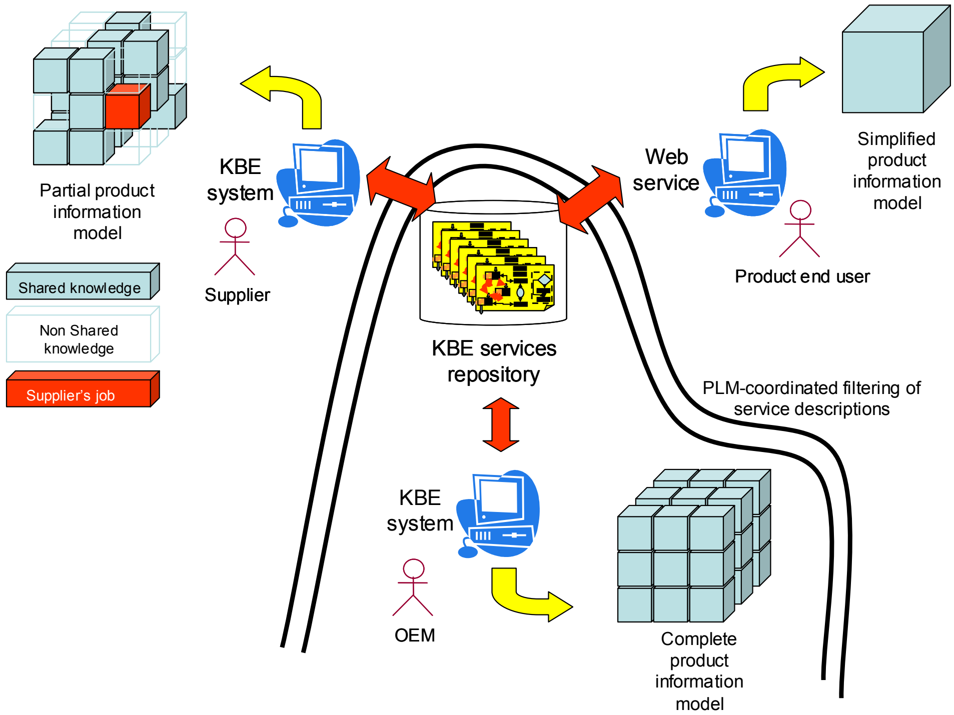
USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

				X
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
If I understand this correctly, I agree that KBE applications must be supported throughout a lifecycle that includes maturity and version consideration, configuration management, security and access policies, verification and validation histories etc.

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

				X
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
Extremely important for IP protection (as noted earlier). We have customers asking for this quite urgently.

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?				
		X		
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development.	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments").
Comments: Extension to process, resource modelling, manufacturing and other areas of PLM. Investigation and development of better/newer paradigms (for example, what comes after "demand-driven"?)				

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	X	
Comments:		

	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).	X	
Comments: I cannot become part because DS is not a member.		

	YES	NO
46. Would you be interested in influencing the development of the "KBE services for PLM" OMG standard?	X	
Comments:		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	DIEM LAM
Company name:	Airbus (UK)
Contact address:	**Airbus UK**. Building 19D, Filton, Bristol BS99 7AR.
E-mail address:	Diem.lam@airbus.com

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
X				
Original equipment manufacturer.	Consultancy services company.	Software vendor company.	Research institute.	Other, (add).
Comments:				

2. What is the size of the organisation that you belong to?				
			X	
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees.	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
X	X	X	
I develop KBE applications.	I use KBE applications.	I provide software related support to KBE developers and users.	Other, (add).
Comments:			

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
X	X	X		
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation.	I am part of a PLM software development team.	Other, (add).
Comments:				

2. Technical view

	YES	NO
5. Are you aware of the OMG’s Model Driven Architecture and the software standards associated with it?	X	
If affirmative, which ones do you know?		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	X	

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the “KBE services for PLM” RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems. (KBE application from KBE system “A” can be used in KBE system “B”)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process. (KBE applications can be visualised by non KBE experts)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects. (KBE applications can be more easily retrieved and re-engineered to be reused in more situations)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications. (KBE applications can be more efficiently adapted to the changes of the knowledge)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications. (KBE applications can be more easily created by assembling existing documented components)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure. (KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services. (KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM. (Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?				
	X			
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?				
			X	
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term.	It will provide significant benefits to product engineering in the long term.	It will provide significant benefits to product engineering in the short term.
Comments:				

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?				
	X			
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?				
	X			
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

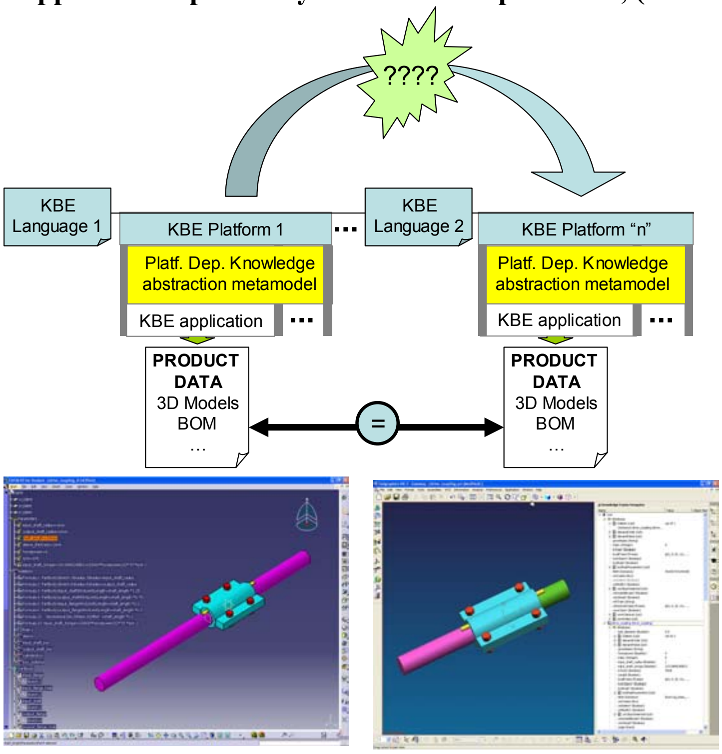
21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?				
	X			
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?				
	X			
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.				
		X		
Negative impact.	Some positive impact but not in my domain.	Some positive impact in my domain as part of a long term strategy.	High positive impact in my domain but not in my current list of preferences.	High positive impact in my domain. In my current list of preferences.
Comments:				

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

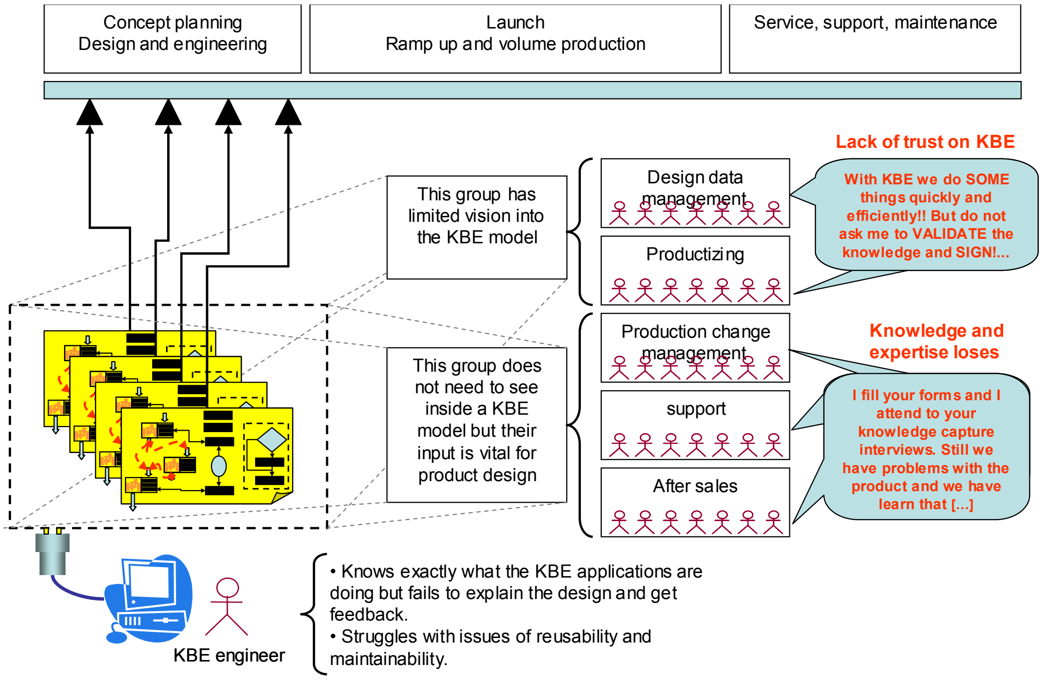
X				
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

25. Evaluate the appropriateness of providing solutions to the issue.

				X
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

X				
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

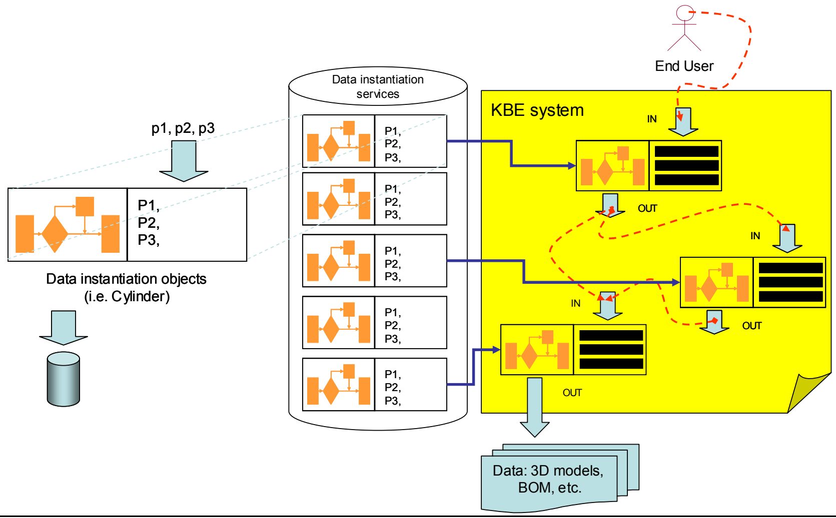
27. Evaluate the appropriateness of providing solutions to the issue.

		X		
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the “KBE services for PLM” metamodel? What is in your domain the level of interest that you would assign to it?

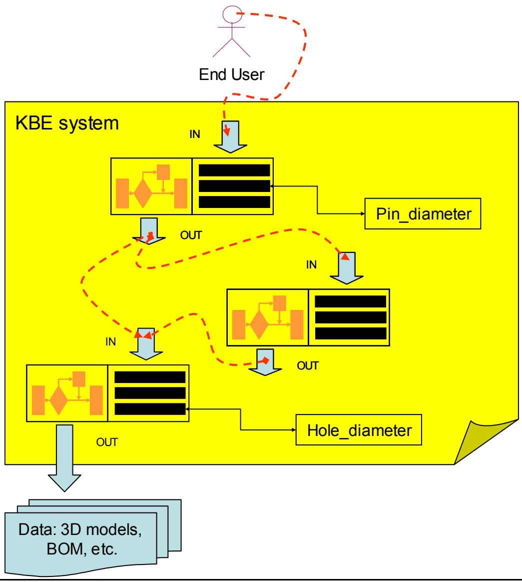
			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

29. Evaluate the appropriateness of supporting this functionality on the “KBE services for PLM” metamodel.

		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

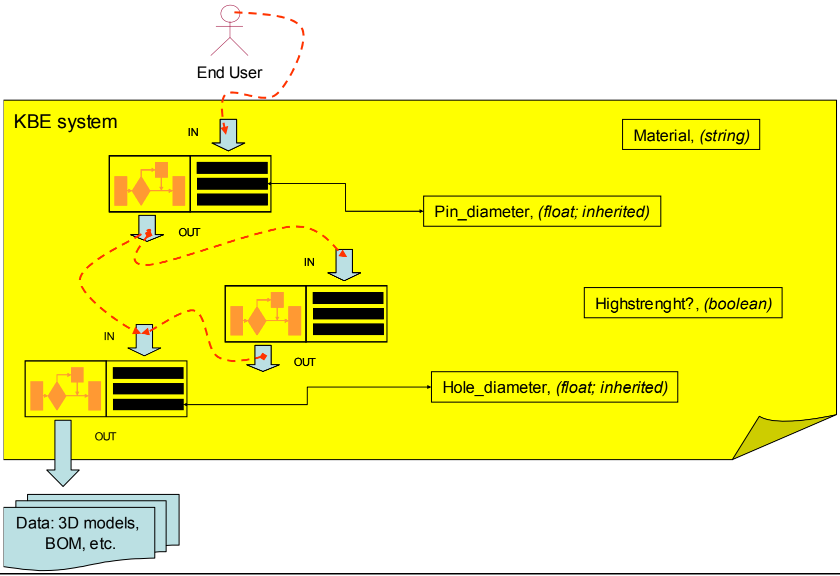
			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

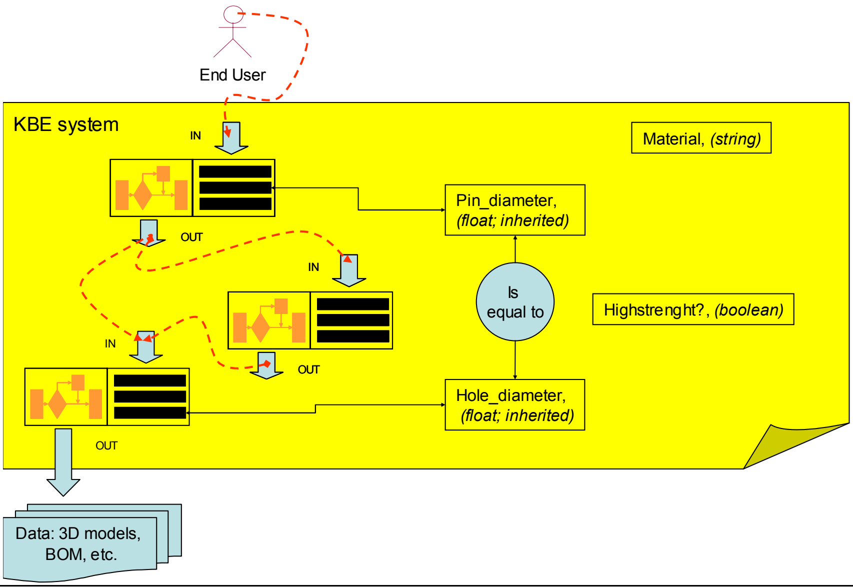
		X		
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

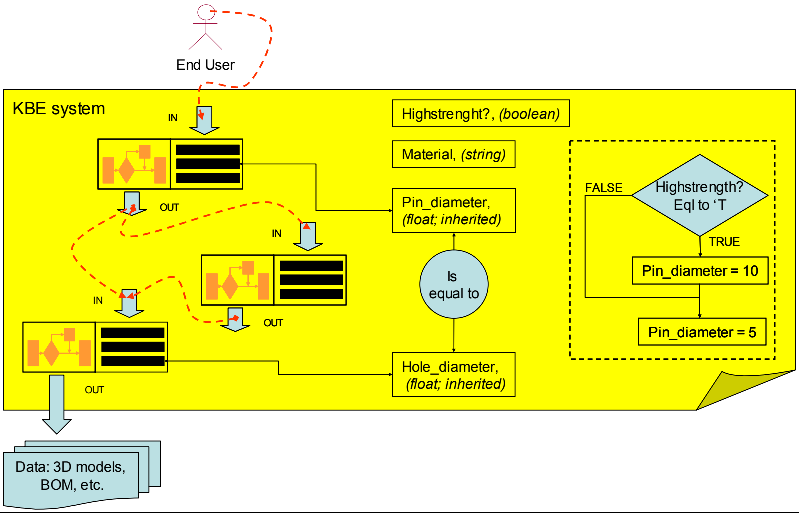
		X		
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

35. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the “KBE services for PLM” metamodel? What is in your domain the level of interest that you would assign to it?

			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the “KBE services for PLM” metamodel.

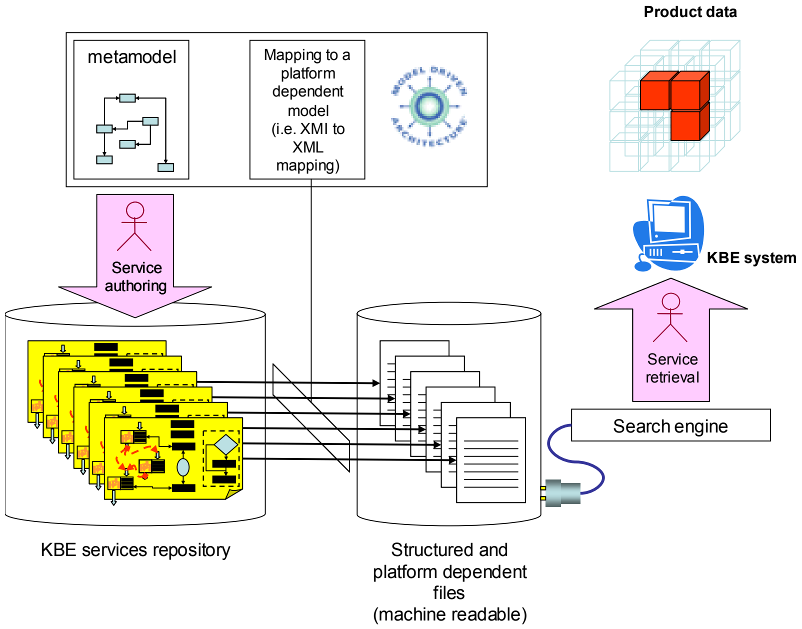
		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

2.3 Use cases for the standard

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] complaint metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

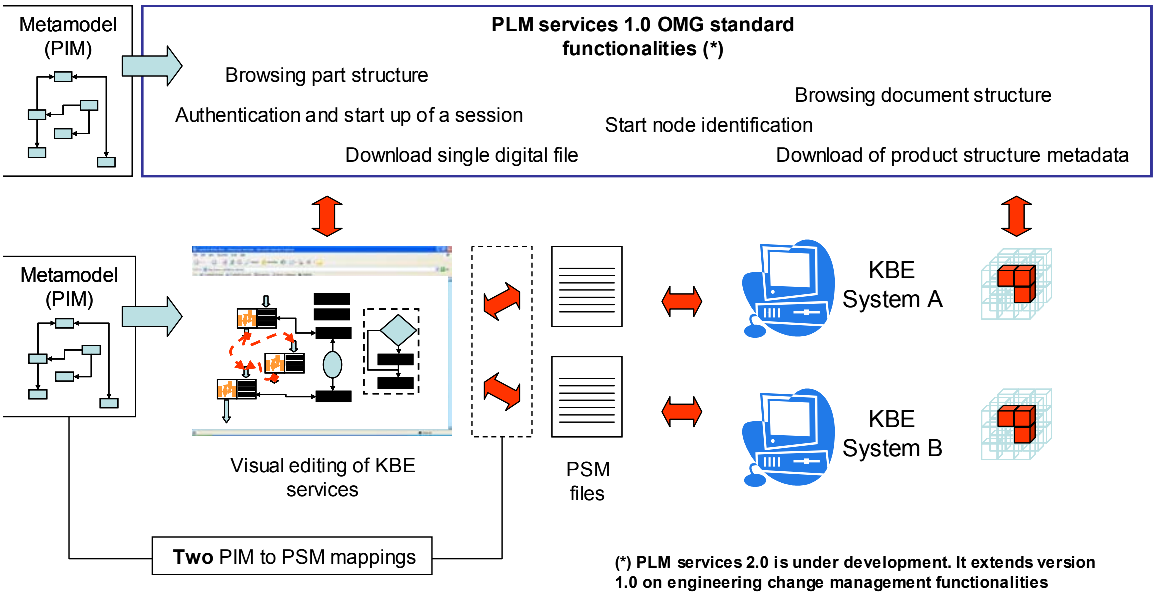
[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

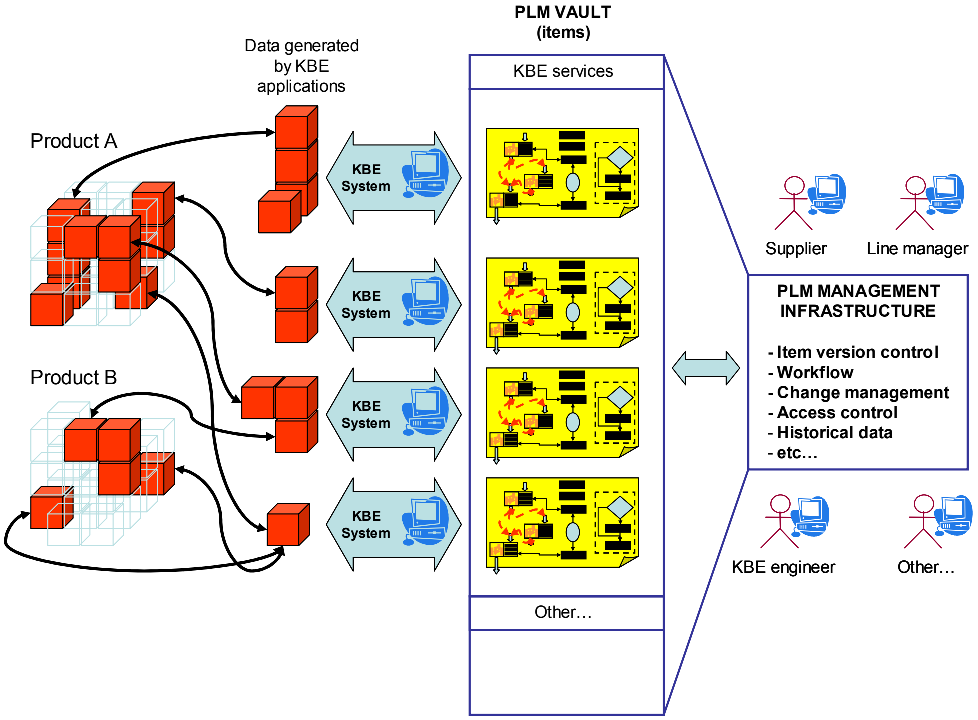
Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor's KBE language).

39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



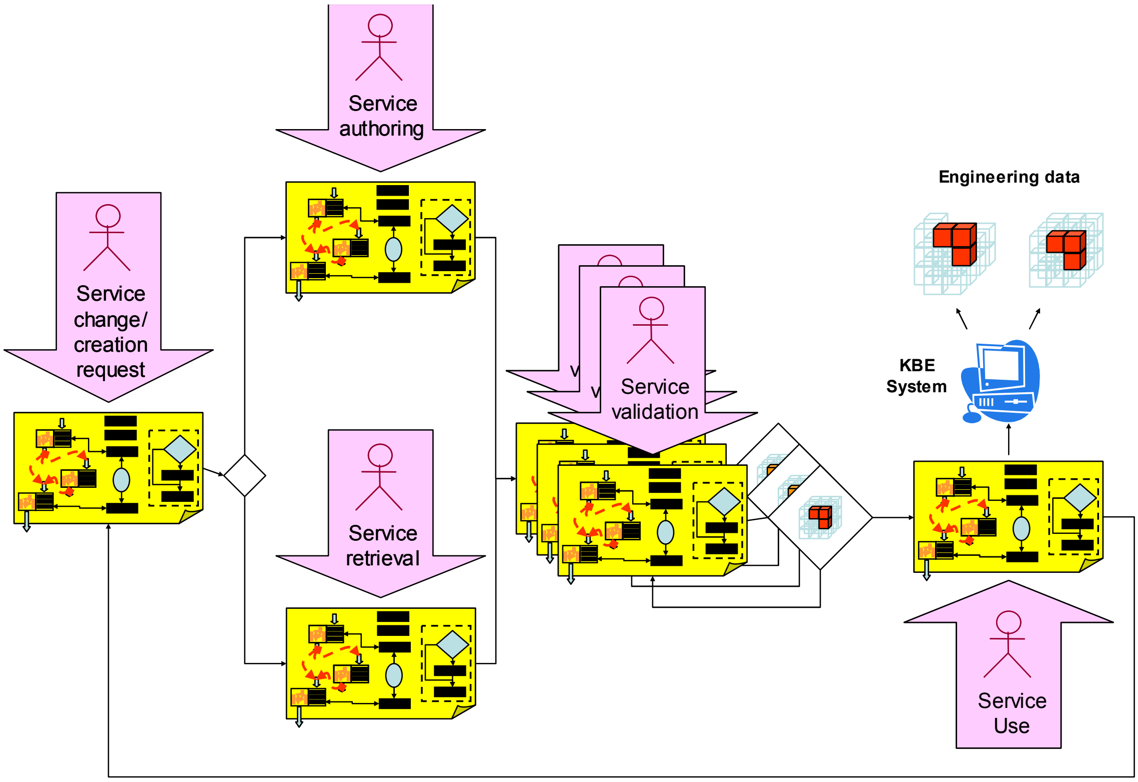
USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 4: standardised KBE services authoring, reuse and maintenance

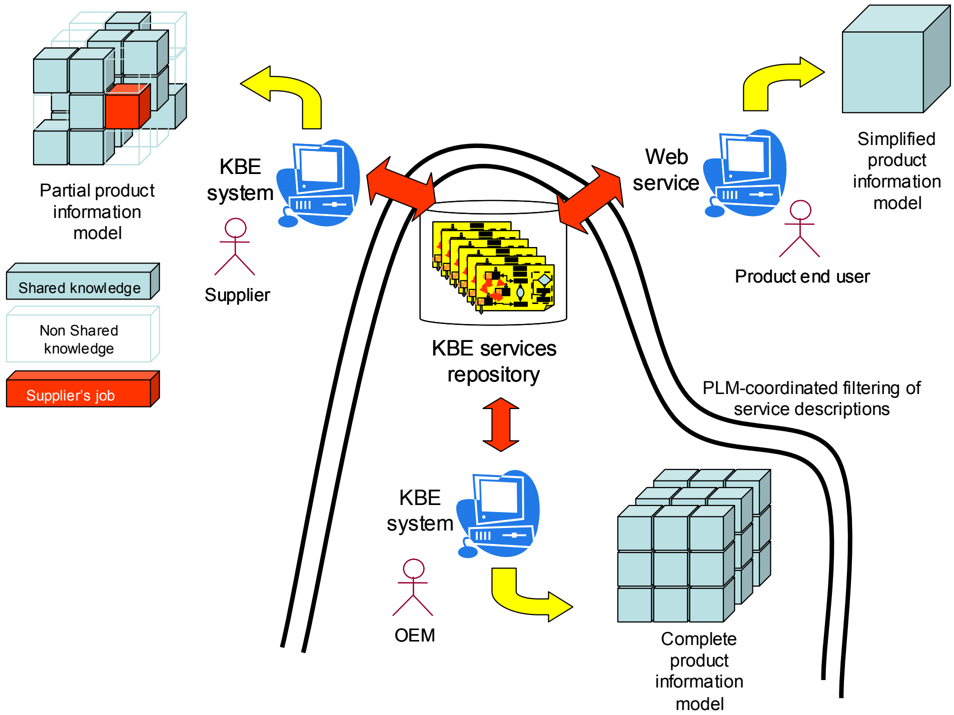


USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.
Comments:				

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?

		X		
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development.	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments").

Comments:

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	X	

Comments:

	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).		X

Comments:
Would like to but work commitments means I do not have the time to be more actively involved.

	YES	NO
46. Would you be interested in influencing the development of the "KBE services for PLM" OMG standard?	X	
Comments:		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	Adrian Murton
Company name:	Airbus UK
Contact address:	Building 09F Airbus UK Filton Bristol
E-mail address:	Adrian.murton@airbus.com

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
X				
Original equipment manufacturer.	Consultancy services company.	Software vendor company.	Research institute.	Other, (add).
Comments:				

2. What is the size of the organisation that you belong to?				
			X	
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees.	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
X		X	
I develop KBE applications.	I use KBE applications.	I provide software related support to KBE developers and users.	Other, (add).
Comments:			

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
X				
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation.	I am part of a PLM software development team.	Other, (add).
Comments:				

2. Technical view

	YES	NO
5. Are you aware of the OMG's Model Driven Architecture and the software standards associated with it?	X	
If affirmative, which ones do you know? MDA, MOF, UML etc		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	X	

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the "KBE services for PLM" RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems. (KBE application from KBE system "A" can be used in KBE system "B")				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process. (KBE applications can be visualised by non KBE experts)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects. (KBE applications can be more easily retrieved and re-engineered to be reused in more situations)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications. (KBE applications can be more efficiently adapted to the changes of the knowledge)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications. (KBE applications can be more easily created by assembling existing documented components)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure. (KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services. (KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM. (Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?				
			X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?				
			X	
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term.	It will provide significant benefits to product engineering in the long term.	It will provide significant benefits to product engineering in the short term.
Comments:				

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?				
			X	
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?				
				X
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

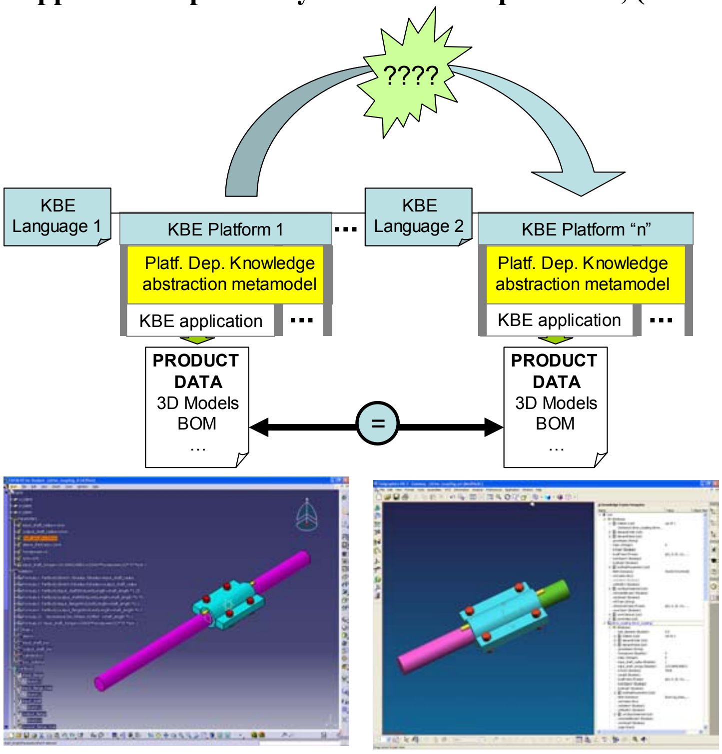
21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?				
			X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?				
			X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.				
				X
Negative impact.	Some positive impact but not in my domain.	Some positive impact in my domain as part of a long term strategy.	High positive impact in my domain but not in my current list of preferences.	High positive impact in my domain. In my current list of preferences.
Comments:				

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

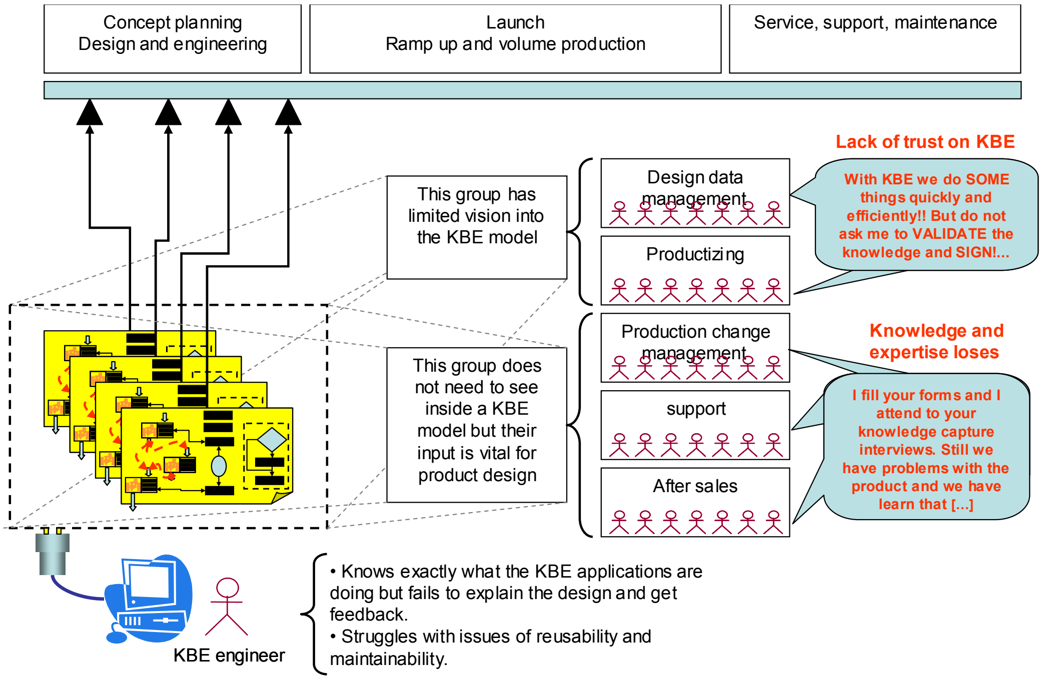
			X	
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

25. Evaluate the appropriateness of providing solutions to the issue.

		X		
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

			X	
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

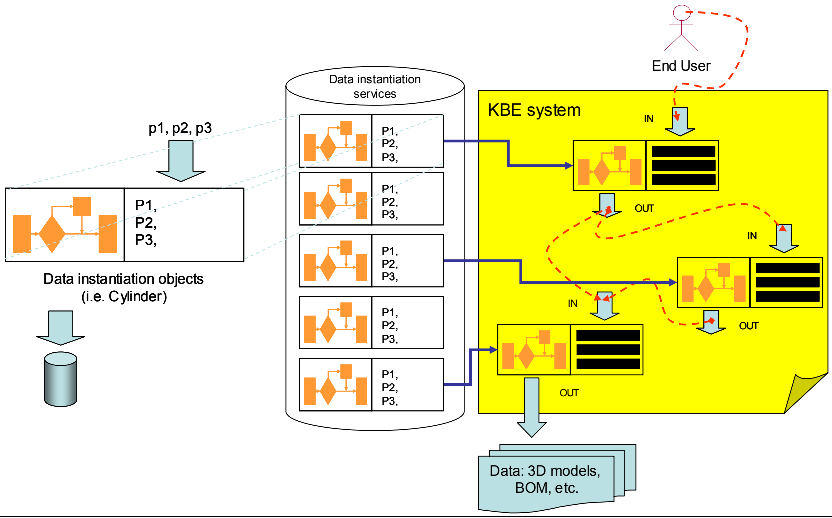
27. Evaluate the appropriateness of providing solutions to the issue.

			X	
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

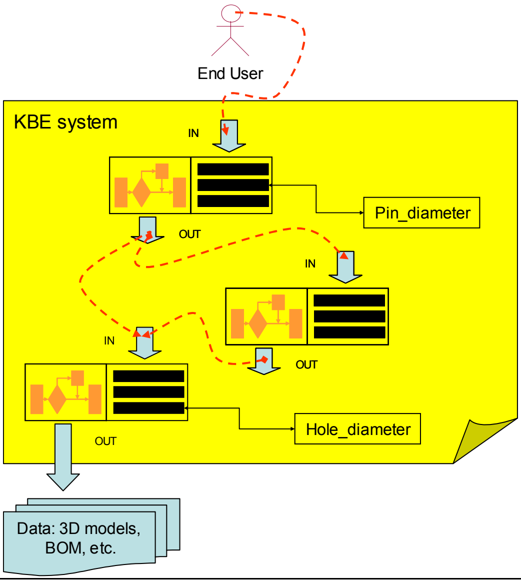
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

29. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

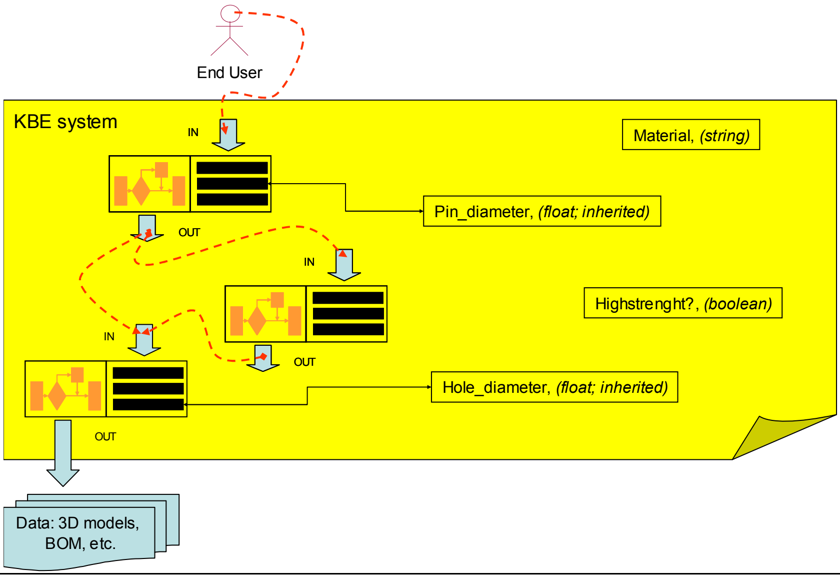
			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

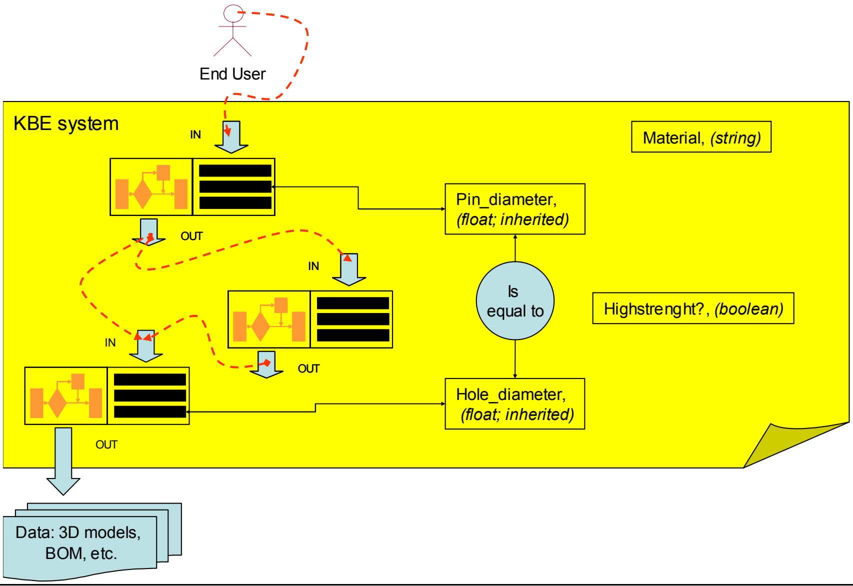
33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

Reuse STEP APs

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

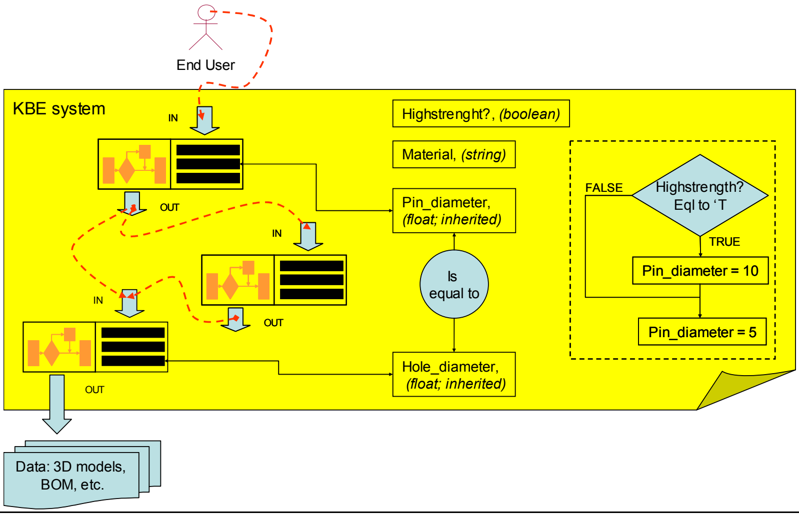
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

35. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

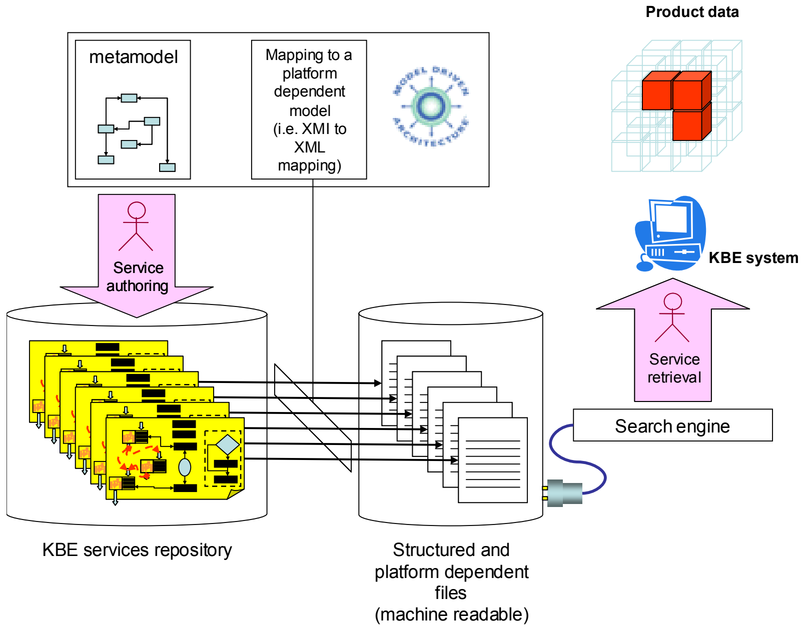
			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

2.3 Use cases for the standard

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] complaint metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

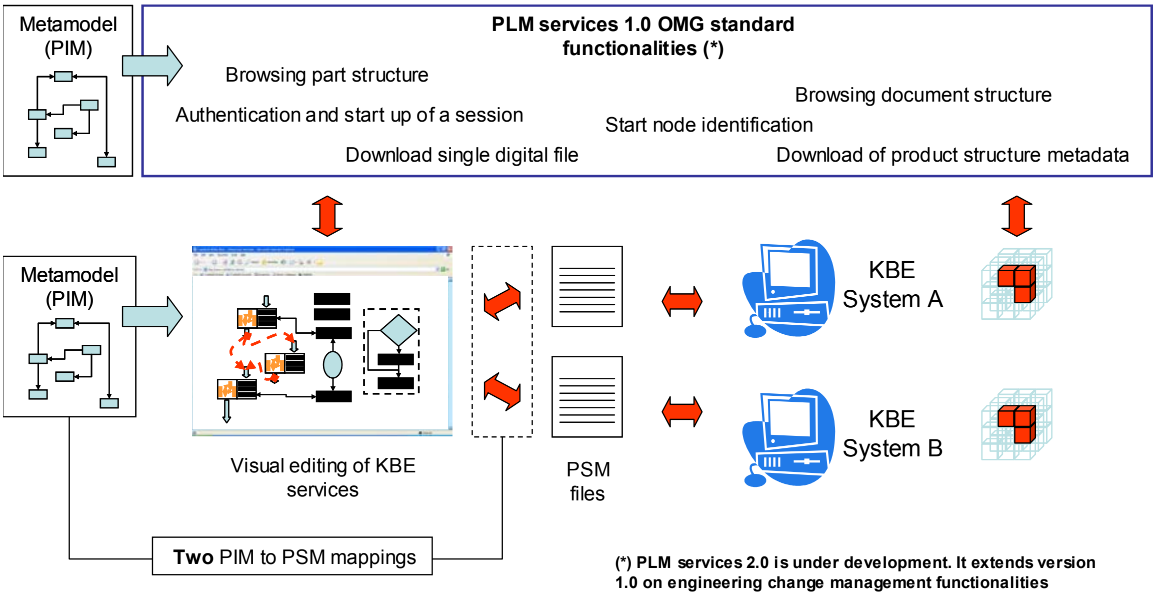
[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor's KBE language).

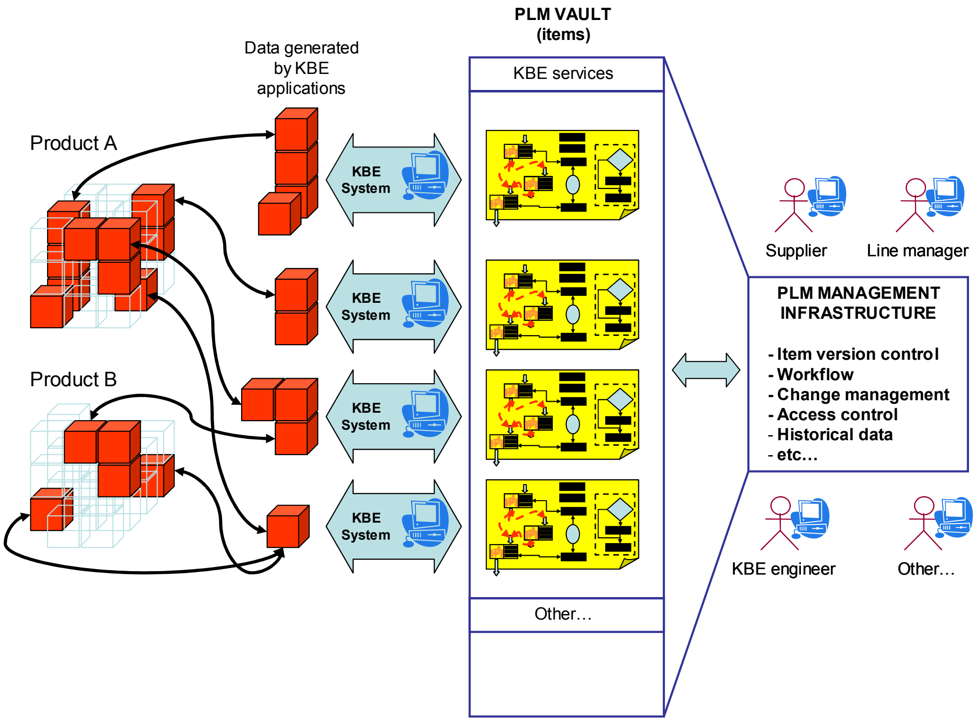
39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

(Not sure I really understood this one!)

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



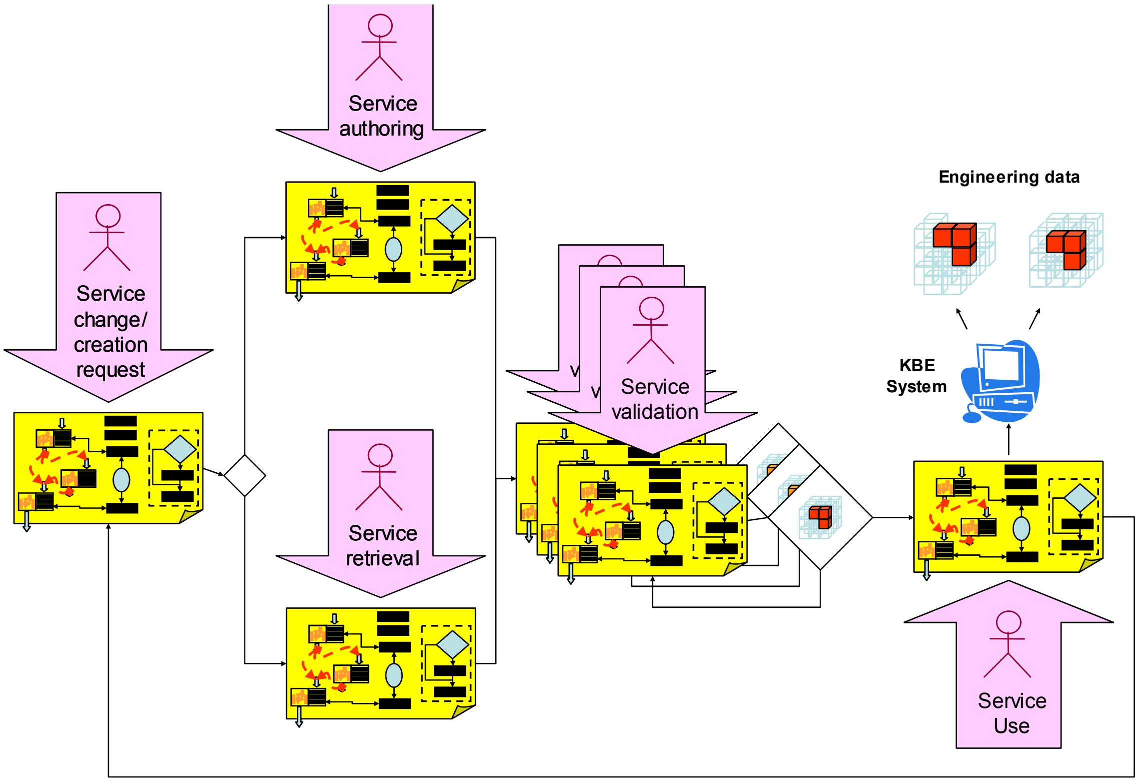
USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

				X
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 4: standardised KBE services authoring, reuse and maintenance



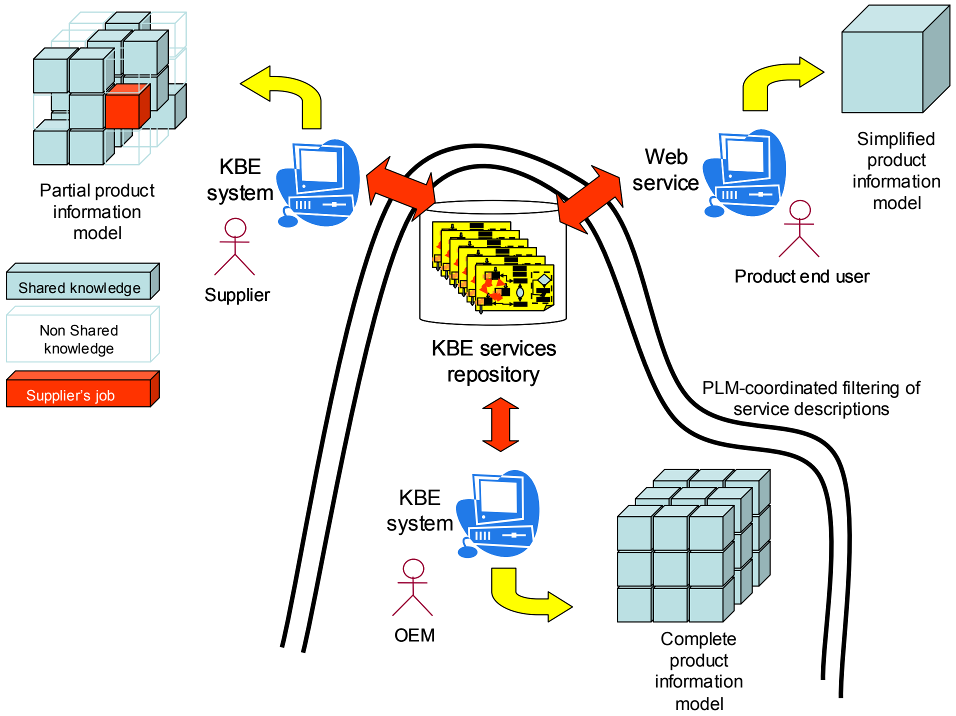
USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

				X
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?				
		X		
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development.	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments").
Comments:				

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	X	
Comments:		

	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).		X
Comments:		

	YES	NO
46. Would you be interested in influencing the development of the “KBE services for PLM” OMG standard?	X	
Comments:		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	John M. Switlik
Company name:	Boeing (Retired)
Contact address:	10116 E Shadybrook St Wichita, KS 67206
E-mail address:	John.m.switlik@ieee.org

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
Original equipment manufacturer. x	Consultancy services company. x	Software vendor company.	Research institute.	Other, (add).

Comments:
I'm completing this questionnaire from two viewpoints.

I recently retired from Boeing where I was an Associate Technical Fellow in the Knowledge Base Systems Group with an emphasis on Product Definition and Build. This organization started in the late 80s using ICAD, StoneRule, and other products.

My continued interest is in the successful application of KBE.

2. What is the size of the organisation that you belong to?				
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees. x	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
I develop KBE applications. x	I use KBE applications.	I provide software related support to KBE developers and users.	Other, (add).

Comments:

We developed for platforms on all the tiers (mainframe, workstation, and PC).

In terms of achievement, our group made SEI CMMI Level 5 in 2004. This may have been a first for a KBE development group.

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation. x	I am part of a PLM software development team.	Other, (add).

Comments:

Our systems interfaced with PLM.

2. Technical view

	YES	NO
5. Are you aware of the OMG's Model Driven Architecture and the software standards associated with it?	x	
If affirmative, which ones do you know? Have used UML, XML, and CORBA.		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	x	x

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the "KBE services for PLM" RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems. (KBE application from KBE system "A" can be used in KBE system "B")				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Part of this may be accomplished by limiting the tool set (homogeneity) used by development teams. However, given a heterogeneous world, interoperability will be important, provided that security concerns are addressed and managed.				

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process. (KBE applications can be visualised by non KBE experts)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.
Comments: There are a couple of prime issues that concern this issue, though these two are not the only issues. 1. The preservation and protection of intellectual property (competitive advantage) has to be on the forefront. 2. Complexity concerns are going to arise. At a recent vendor meeting, I heard users complain about increasing run times. As functionality gets pushed below the floor, we need to raise visibility of time and resource requirements in a robust fashion.				

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects.
(KBE applications can be more easily retrieved and re-engineered to be reused in more situations)

Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

This has always been a difficult issue, and the concerns of Item 8 apply here too.

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications.
(KBE applications can be more efficiently adapted to the changes of the knowledge)

Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

PLM is a top-down view. Maintenance at this level will differ from that of CAx (the bottom up). From where I sit, KBE has to bridge both views.

A key issue might be the ability to adequately support end-user computing, in that the domain experts ought to have a closer look at the application's particulars than has normally been the case.

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications.
(KBE applications can be more easily created by assembling existing documented components)

Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

This is a given. A related issue will be support for distributed processing across servers.

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure.
(KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)

Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

This would be a very interesting from several angles, such as reuse, distributed computing (say, grid-like), and IP protection.

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services.
(KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)

Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

This ought to facilitate re-use even within an organization. However, it has applicability also as the potential basis for a real strong supply chain management scheme.

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM.
(Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).

Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. x	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

One issue would be preventing, or a least inhibiting (not enabling), reverse engineering. One wonders if a new type of service based upon distributed (and secured) hosts will be necessary. That is, execute and present results without allowing accessible to the executable. Is that the idea?

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. X	Highly relevant issue in my domain. Part of my short term strategy.
Comments: There are two aspects of knowledge change: domain specific and software. These are not entirely separable; however the latter already has management mechanisms in place which ought to be reused.				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. X	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Yes, everyone is looking for this, however can it be made computable (as least, capable of simulation)?				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?				
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term. x	It will contribute significantly in the short term.
Comments: Given the push to standard products, KBE might be considered a given (over and above parametric modelling) in that the necessary framework is flavoured toward decision support.				

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?				
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term. x	It will provide significant benefits to product engineering in the long term. x	It will provide significant benefits to product engineering in the short term.
Comments: It was within Boeing, provided that the security issues could be resolved.				

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?				
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term. X	It will add significant value in the short term.
Comments: Yes. Everyone seems to be trying to figure out what KBE is exactly. The OMG work will help with some clarification. That KBE is required within CAX (embedded and not) is my concern.				

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?

No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term. x	It will add significant value in the short term.

Comments:

In part, as there is the CAx aspect of KBE that needs attention, too.

21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?

No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term. x	It will contribute significantly in the short term.

Comments:

Is there an effort to introduce KBE as a regular part of the Engineering curriculum?

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?

No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term. x	It will contribute significantly in the short term.

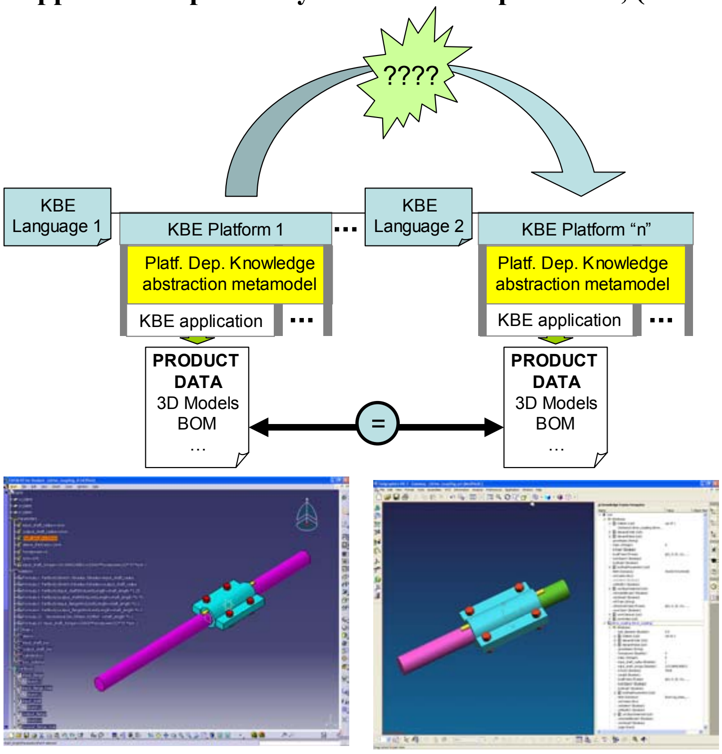
Comments:

Yes. However, be aware that there are more advanced (meaning, less deterministic) variations on the KBE theme that will need to be addressed as well.

23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.				
Negative impact.	Some positive impact but not in my domain.	Some positive impact in my domain as part of a long term strategy. x	High positive impact in my domain but not in my current list of preferences.	High positive impact in my domain. In my current list of preferences.
Comments:				

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail. x	This is a very important issue in my domain. Solutions for this need to be put in place.

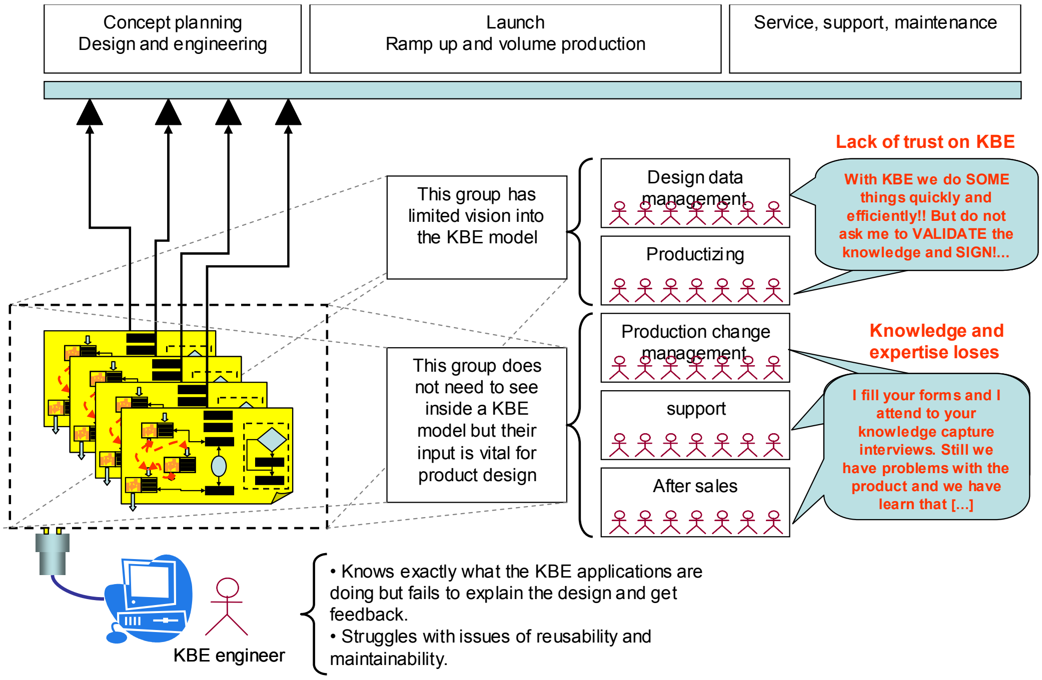
25. Evaluate the appropriateness of providing solutions to the issue.

It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected. x	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

Depends upon the amount and type of heterogeneity that is present. However, a type of interchange that uses 'web semantics' might help handle the disparity. Has the OMG seen progress in this area?

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions. x	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

27. Evaluate the appropriateness of providing solutions to the issue.

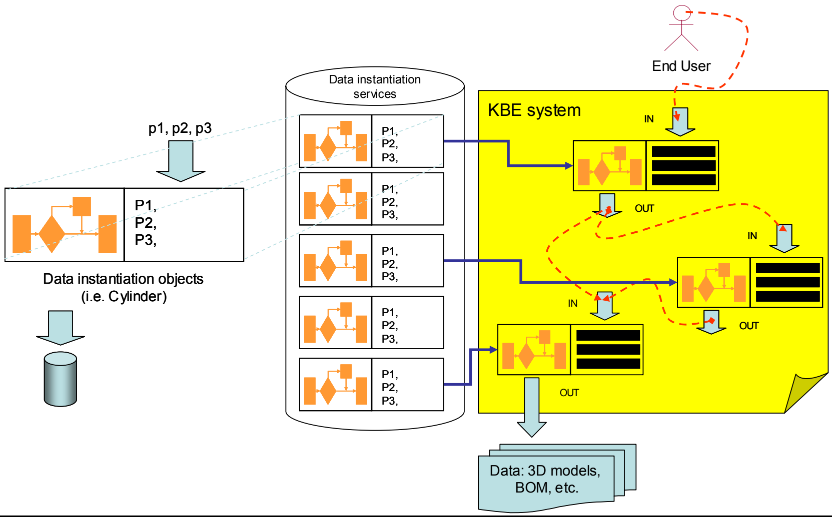
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected. x	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

Part of the problem resides in interchanges between experts in different domains. This has been an ongoing problem with many types of solutions tried (design-build teams, etc.). PLM is bringing in another approach that might help bridge some of the ontological issues. Yet, the definition of a true Engineering Knowledge Language (EKL) has an appeal.

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel. x	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

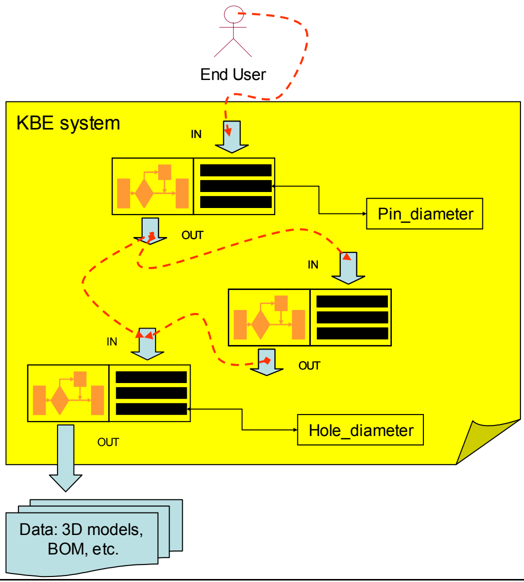
29. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality. x	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

It has to be broader and support 'functional views' (or roles) to boot.

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel. x	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

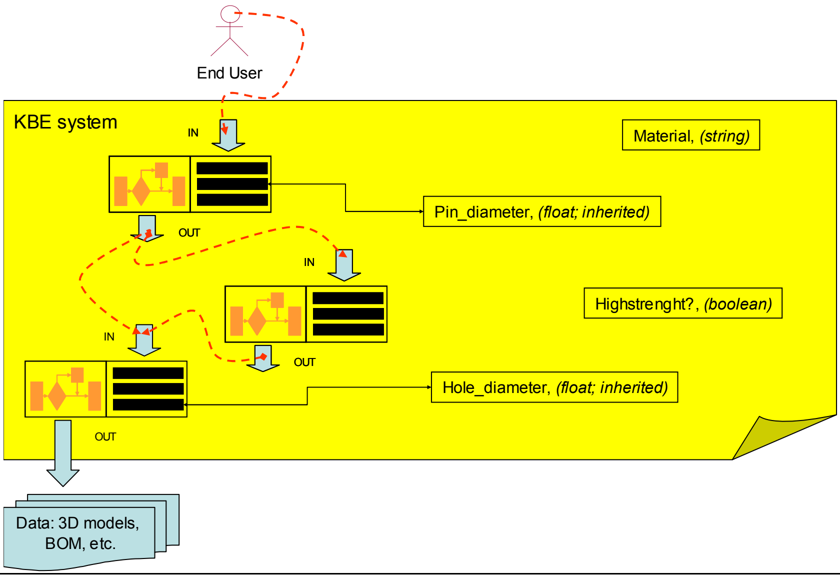
31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality. x	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

What about checking? That is, KBE and PLM may drive the world top-down. But, there are results from independent processes that will roll up. Some of these will be from automated methods (not necessarily believable a priori). Other will be from human-oriented methods, that very well ought to be reviewed (even if the review process itself is pushed to the lower level – lean concept).

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail. x	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

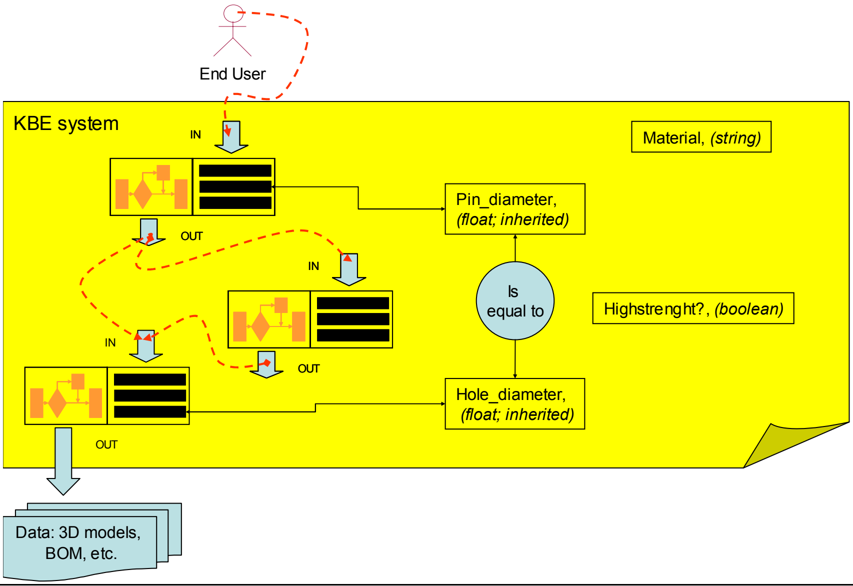
33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality. X	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

Again, 'functional' specs ought to play here especially as they map to analytics.

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail. x	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

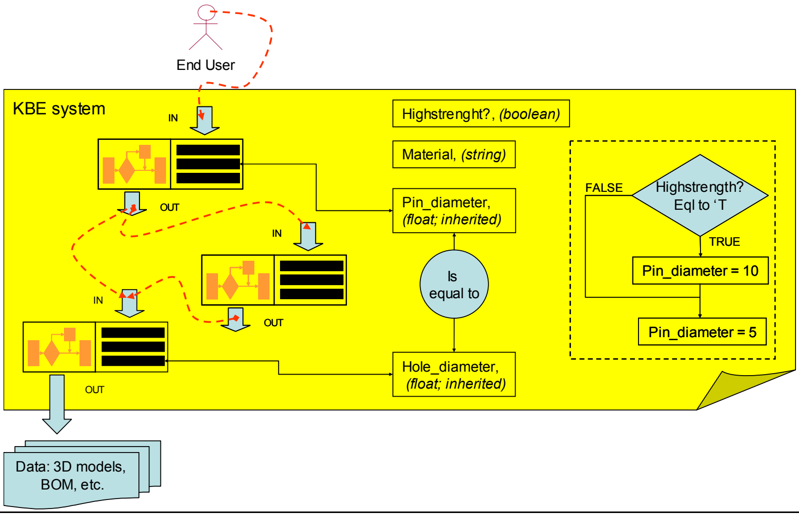
35. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality. x	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

See Comments for 33/34.

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel. X	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality. x	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

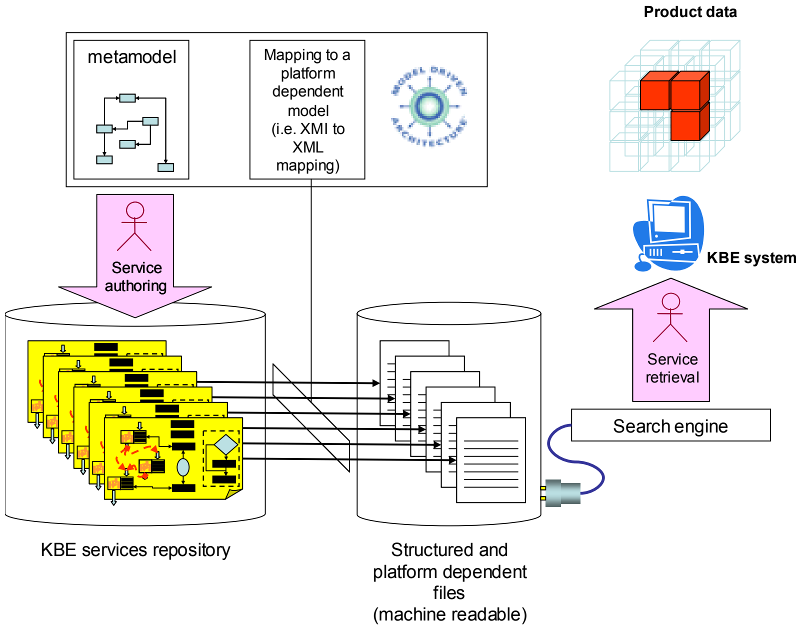
Comments:

Needs to address heterogeneous systems in conjunction with other standardization efforts.

2.3 Use cases for the standard

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] **compliant** metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

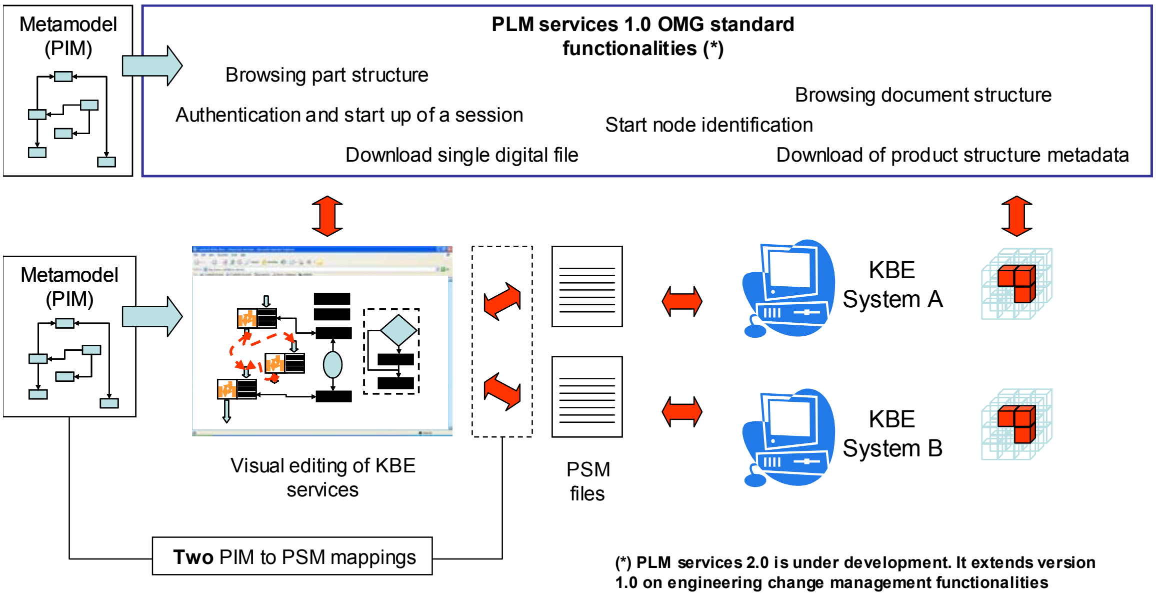
38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy. x

Comments:

Related to #27, the need for an EKL as well. Is MDA sufficient? Or will it provide an extensive (and extensible) framework for handling roles and behaviours?

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor's KBE language).

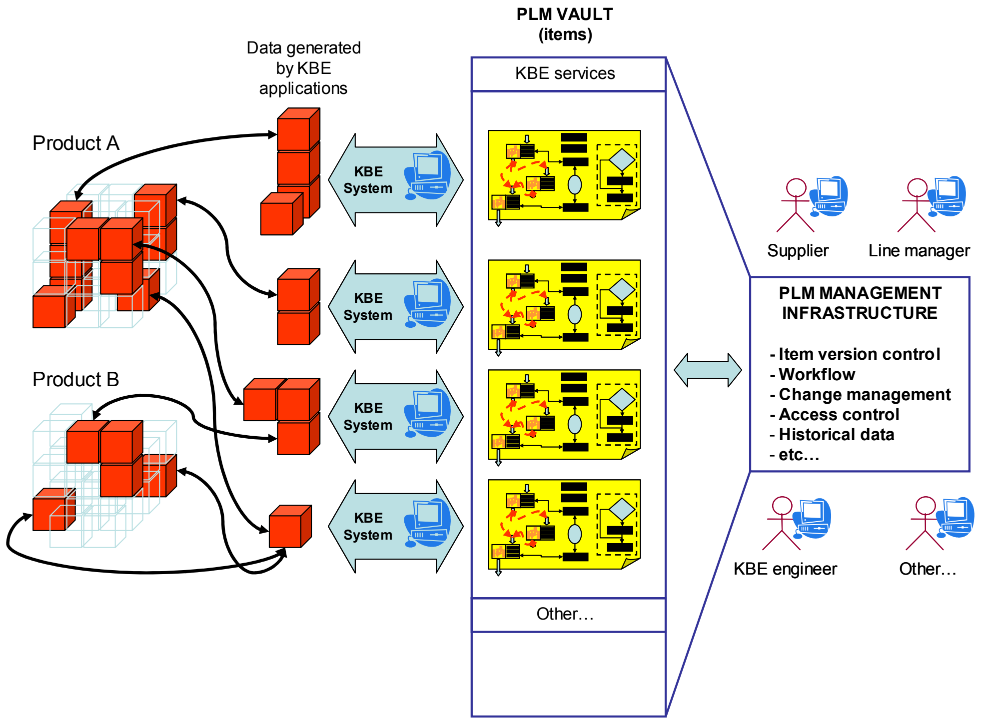
39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy. x

Comments:

The EKL/MDA approach would need a workbench. What are the constraints that will be placed upon implementation of this workbench (OS, language, …)?

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

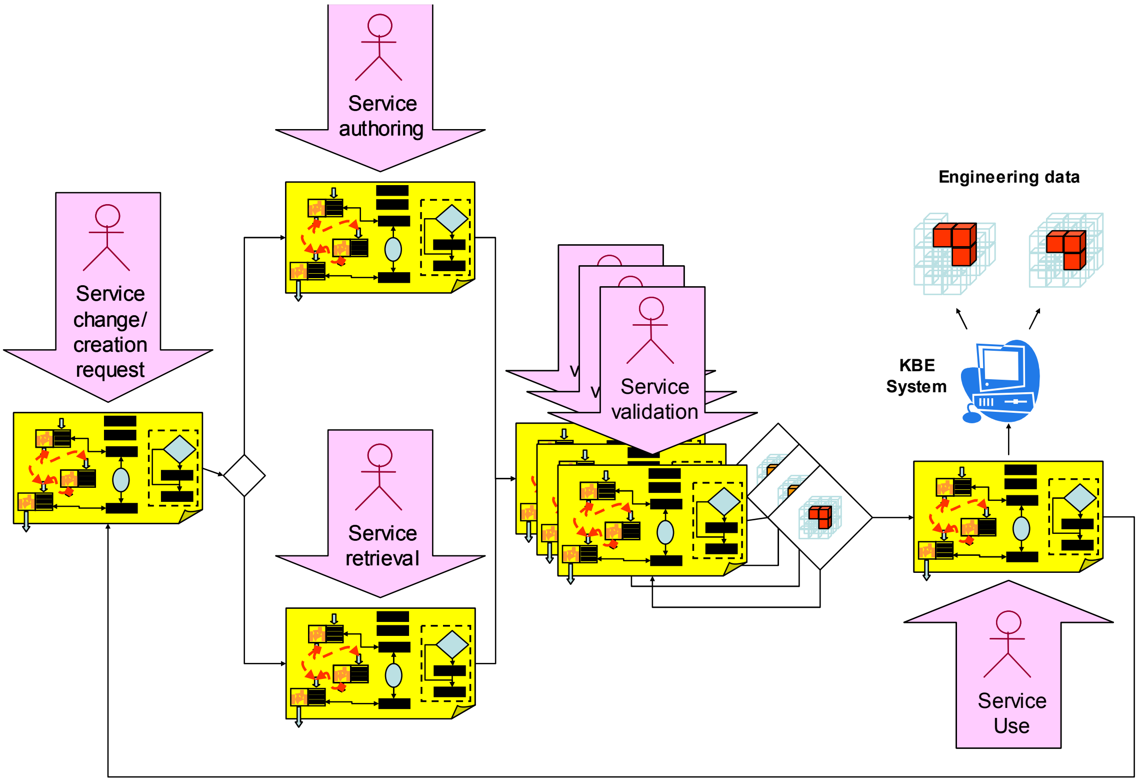
40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy. x

Comments:

From this it sounds like KBE may be evolving to be the principal integrative platform within PLM. It this is true then there are many aspects to this problem that will need to be addressed, such as the particulars of PLM components, the interchange problems between these components, etc.

Use case 4: standardised KBE services authoring, reuse and maintenance



USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

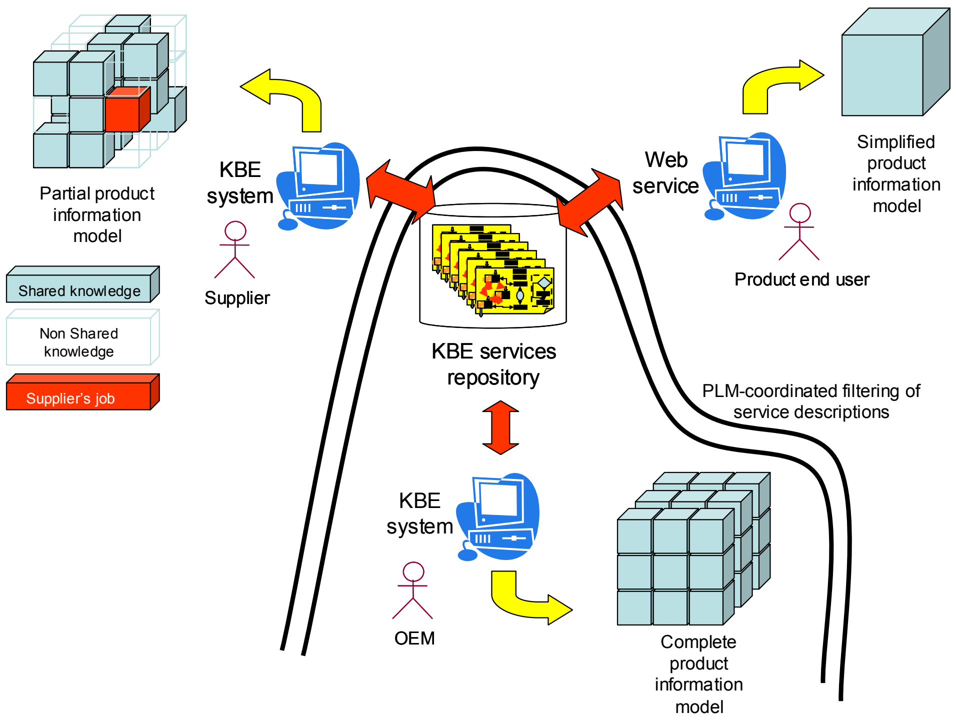
41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy. x

Comments:

This is a continual theme (not unlike Case 3). A push to 'tailored' is a top-down initiative. The reality is local modifications. Witness the appeal of personalization. In this context, though, we may be talking ontological variants that are subtle albeit that we want them to be simple (such as taking an emphasis that just talks product differentiation – example: changing a label/form item versus some not-so-trivial modification of functionality). It's not an easy problem.

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy. X

Comments:

It's good to see the 'online catalogue' concept as it applies to controlling IP exposure. However, I wonder if what we need is more than a 'catalogue' in that it ought to support decisions as well as compute (support optimization, shaping, etc.).

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?				
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development. x	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments").
Comments:				

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	x	
Comments:		

	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).		x
Comments:		

	YES	NO
46. Would you be interested in influencing the development of the "KBE services for PLM" OMG standard?	x	
Comments:		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	Harshal Trivedi
Company name:	INCAT Ltd. (A Tata Technologies Company)
Contact address:	Prospect Way, London Luton Airport, Luton, Bedfordshire LU2 9QH U.K.
E-mail address:	Harshal.Trivedi@tatatechnologies.com

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
	X			
Original equipment manufacturer.	Consultancy services company.	Software vendor company.	Research institute.	Other, (add).
Comments:				

2. What is the size of the organisation that you belong to?				
			X	
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees.	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
X			
I develop KBE applications.	I use KBE applications.	I provide software related support to KBE developers and users.	Other, (add).
Comments:			

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
		X		
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation.	I am part of a PLM software development team.	Other, (add).
Comments:				

2. Technical view

	YES	NO
5. Are you aware of the OMG's Model Driven Architecture and the software standards associated with it?	X	
If affirmative, which ones do you know? MDA , STEP etc.		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	X	

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the "KBE services for PLM" RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems. (KBE application from KBE system "A" can be used in KBE system "B")				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process. (KBE applications can be visualised by non KBE experts)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects.
(KBE applications can be more easily retrieved and re-engineered to be reused in more situations)

		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications.
(KBE applications can be more efficiently adapted to the changes of the knowledge)

				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications.
(KBE applications can be more easily created by assembling existing documented components)

				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.

Comments:

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure. (KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services. (KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)				
	X			
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM. (Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?				
			X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?				
			X	
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term.	It will provide significant benefits to product engineering in the long term.	It will provide significant benefits to product engineering in the short term.
Comments:				

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?				
			X	
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?				
	X			
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

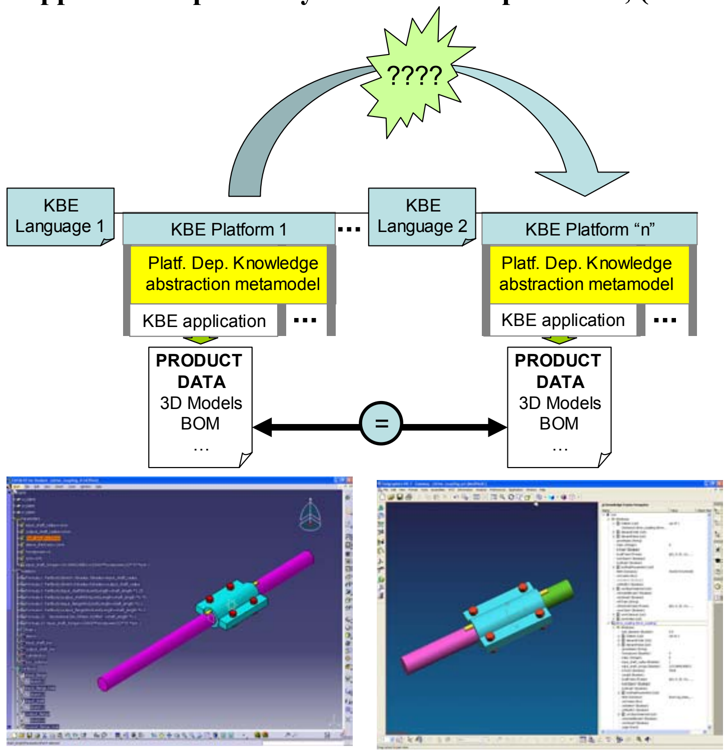
21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?				
			X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?				
	X			
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

<table>
<tr><td colspan="5">23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.</td></tr>
<tr><td></td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Negative impact.</td><td>Some positive impact but not in my domain.</td><td>Some positive impact in my domain as part of a long term strategy.</td><td>High positive impact in my domain but not in my current list of preferences.</td><td>High positive impact in my domain. In my current list of preferences.</td></tr>
<tr><td colspan="5">Comments:</td></tr>
</table>

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

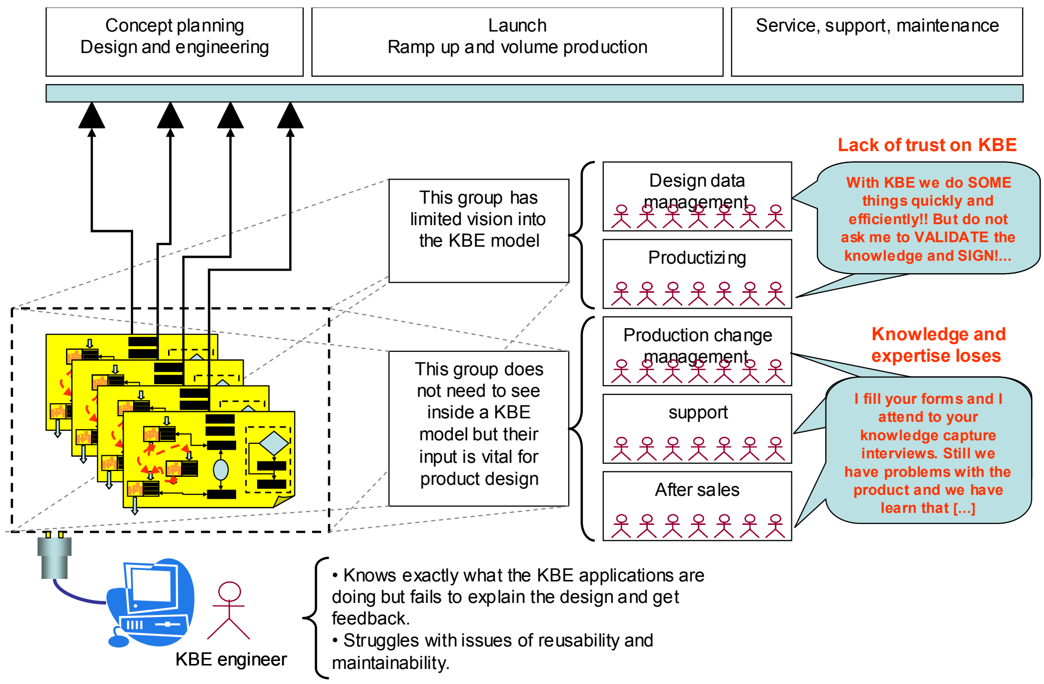
			X	
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

25. Evaluate the appropriateness of providing solutions to the issue.

		X		
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

			X	
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

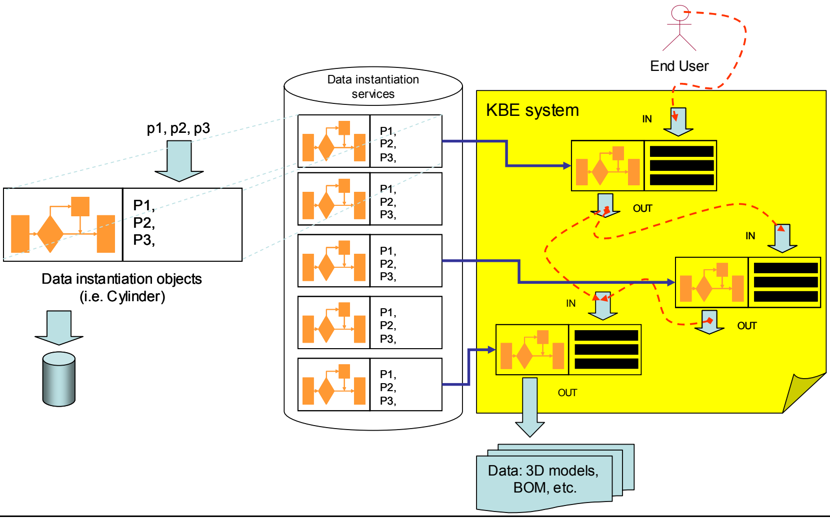
27. Evaluate the appropriateness of providing solutions to the issue.

			X	
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

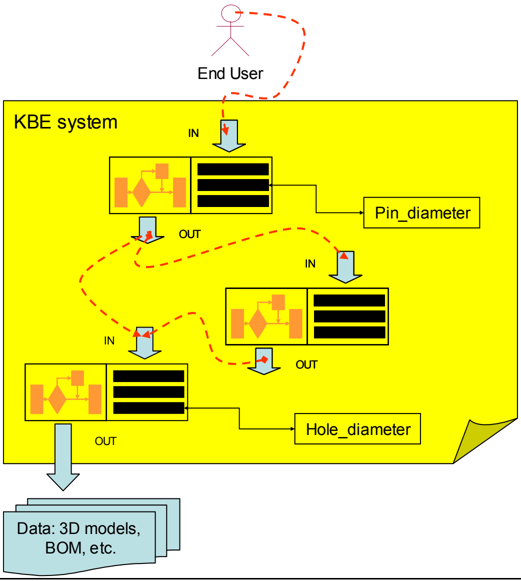
			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

29. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

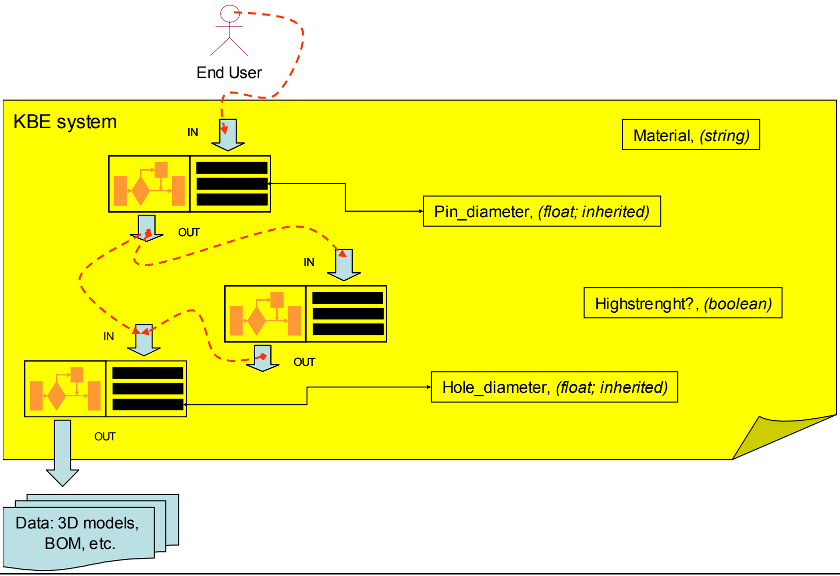
		X		
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

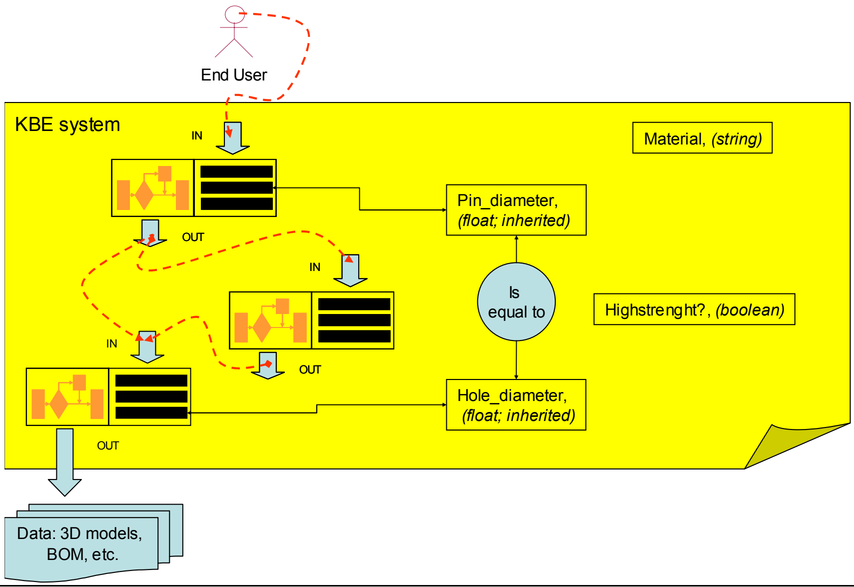
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

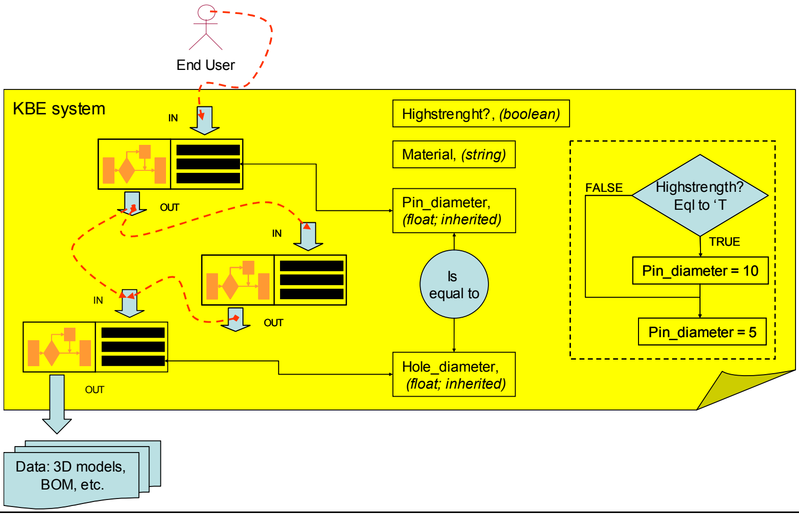
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

35. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the “KBE services for PLM” metamodel? What is in your domain the level of interest that you would assign to it?

			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the “KBE services for PLM” metamodel.

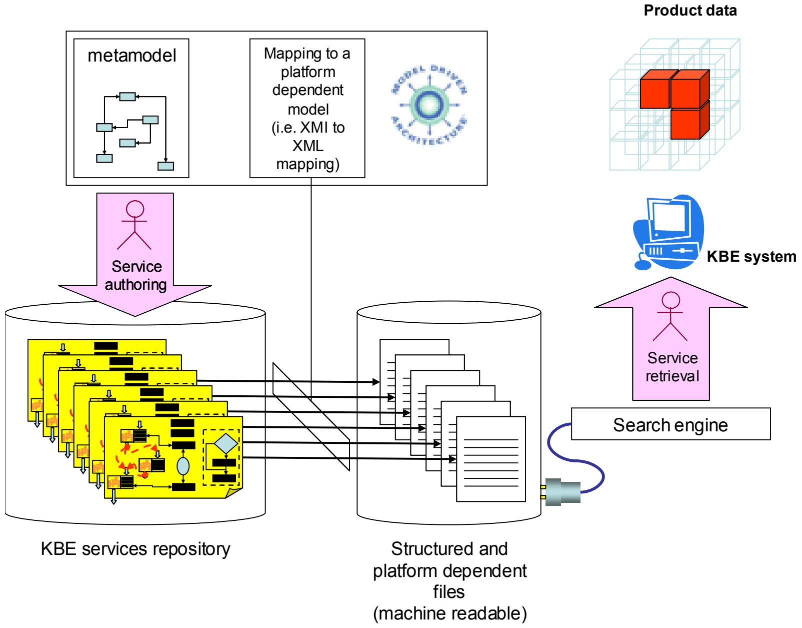
				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

2.3 *Use cases for the standard*

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] compliant metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

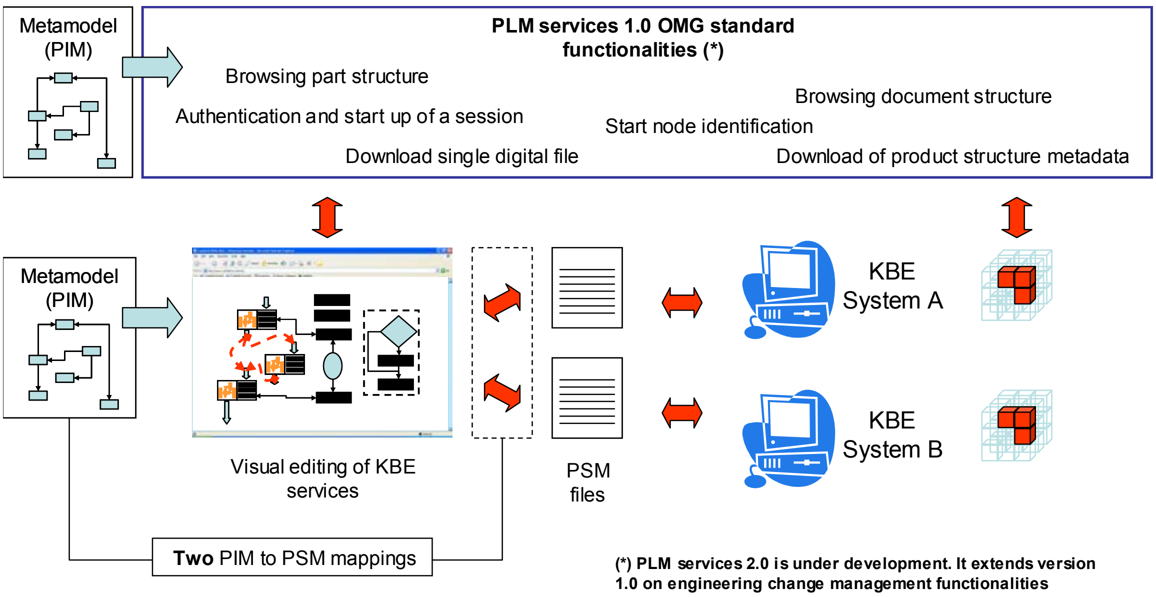
[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
The evolution of metamodel in context of PIM to PSM will depend on the environment in which it is implemented.

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

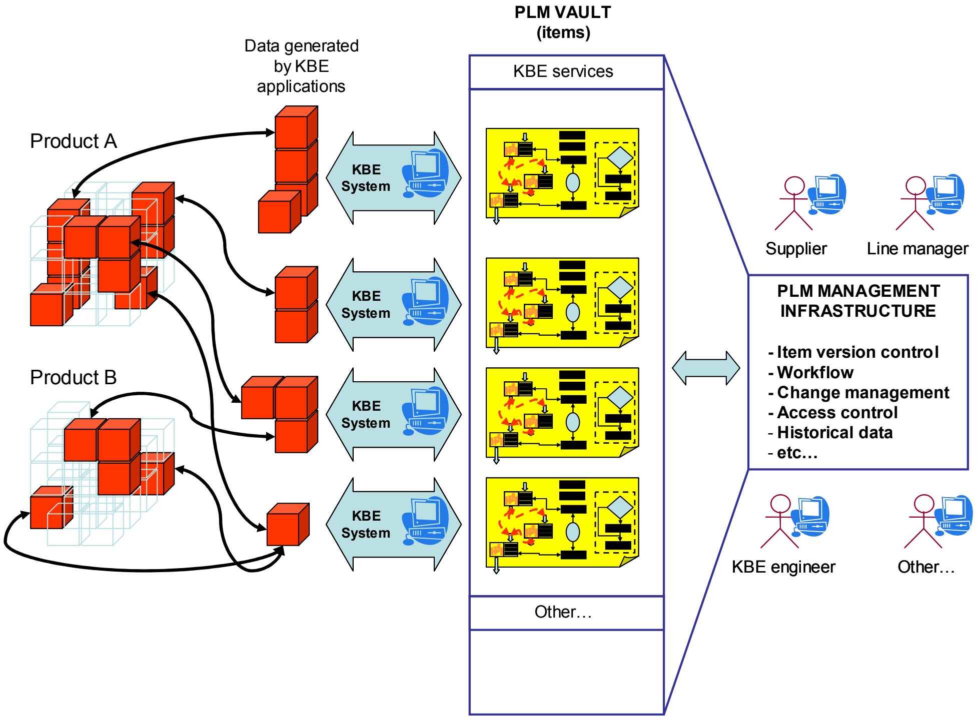
Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor's KBE language).

39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



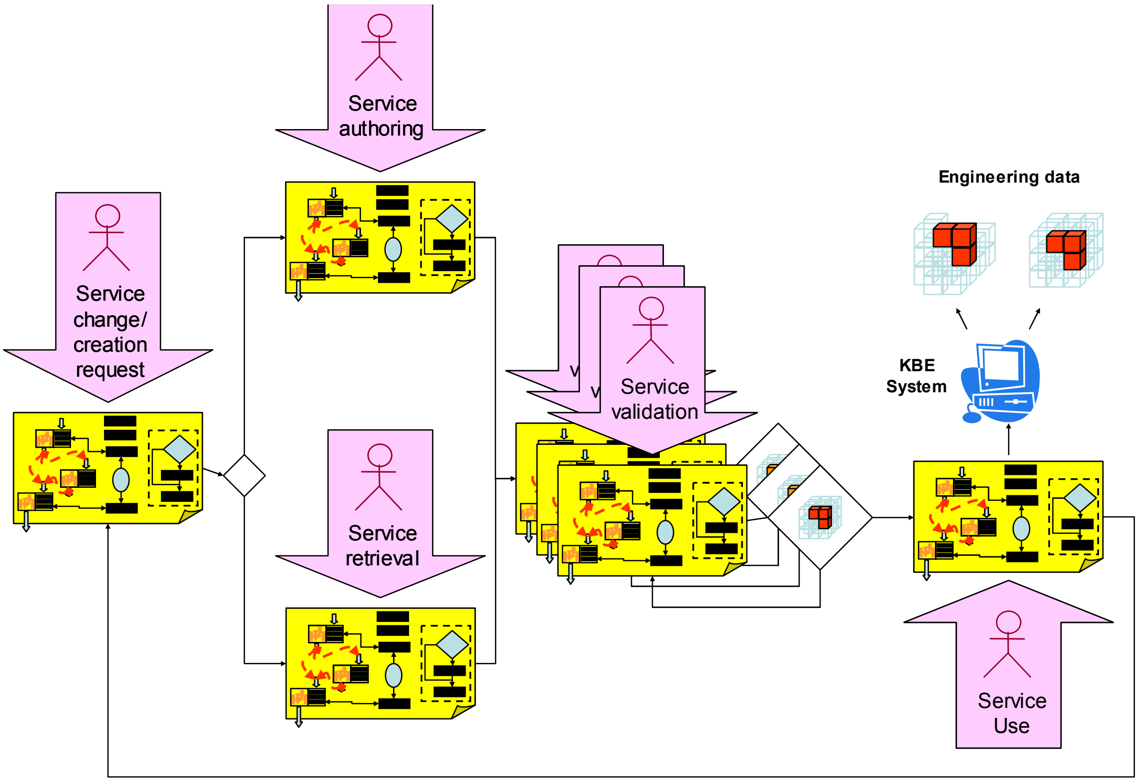
USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 4: standardised KBE services authoring, reuse and maintenance



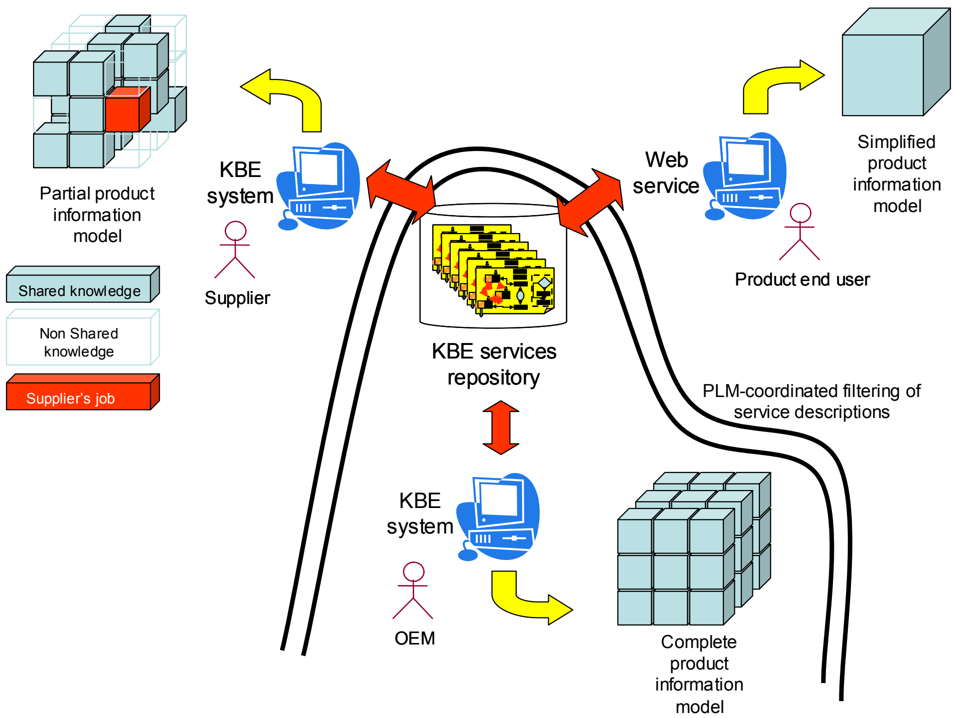
USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

	X			
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?				
		X		
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development.	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments").
Comments:				

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	X	
Comments:		

	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).	X	
Comments:		

	YES	NO
46. Would you be interested in influencing the development of the "KBE services for PLM" OMG standard?	X	
Comments:		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	Brian Prasad
Company name:	Control Systems Division (CSD) Parker Aerospace Parker Hannifin Corporation
Contact address:	Brian Prasad Leader, Knowledge Engineering Team Control Systems Division (CSD) Parker Aerospace Parker Hannifin Corporation 14300 Alton Parkway Irvine, CA 92618-1898, USA Tel: (949) 465 4705 Fax: (949) 465-4330 Email: bprasad@parker.com
E-mail address:	bprasad@parker.com

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
Original equipment manufacturer. XX	Consultancy services company.	Software vendor company.	Research institute.	Other, (add).
Comments:				

2. What is the size of the organisation that you belong to?				
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees. XX	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
I develop KBE applications.	I use KBE applications.	I provide software related support to KBE developers and users. XX	Other, (add).
Comments: We are developing a KBE Application Development Architecture, which are Product and Part Independent. AS far I I know, no one in has done that so far. Since we are using CATIA v5, it is tied to Catia V5 KnowledgeWare language. But it can be implemented on any PLM software platform.			

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation.	I am part of a PLM software development team.	Other, (add).
Comments: I am responsible for defining KBE standards across the CSD Enterprise. My role is as Chief Knowledge Officer.				

2. Technical view

	YES	NO
5. Are you aware of the OMG's Model Driven Architecture and the software standards associated with it?	XX	
If affirmative, which ones do you know? I received a request to lead this effort from OMG director. Some time ago. Your submission to COE Focus Group gave me incentive to write this note.		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	Yes, Very Much so	

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the "KBE services for PLM" RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems. (KBE application from KBE system "A" can be used in KBE system "B")				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments: I believe there should standard communication protocols for managing rules, defining KBE parameters and defining attributes. There should be a standard input_frame protocol for building functions/primitive for an object. There are many things I could mention, but space does not permit me.				

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process. (KBE applications can be visualised by non KBE experts)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments: Very important topic.				

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects. (KBE applications can be more easily retrieved and re-engineered to be reused in more situations)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments:				

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications. (KBE applications can be more efficiently adapted to the changes of the knowledge)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments:				

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications. (KBE applications can be more easily created by assembling existing documented components)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments: I believe modularity provides reuse of the captured objects or knowledge elements.				

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure. (KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments: I agree totally. We are seeing that at Parker.				

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services. (KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: We are very interested in deploying as formalised semantic web services that users can discover and access in order to generate engineering data				

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM. (Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: WE have a KEPT Knowledge Management architecture which are interested in implementing at Parker. But because of any such standards, we are getting very wide /conflicting solutions.				

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy. XX	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy. XX
Comments:				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?				
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term. XX	It will contribute significantly in the short term.
Comments:				

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?				
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term.	It will provide significant benefits to product engineering in the long term. XX	It will provide significant benefits to product engineering in the short term.
Comments:				

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?				
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?				
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

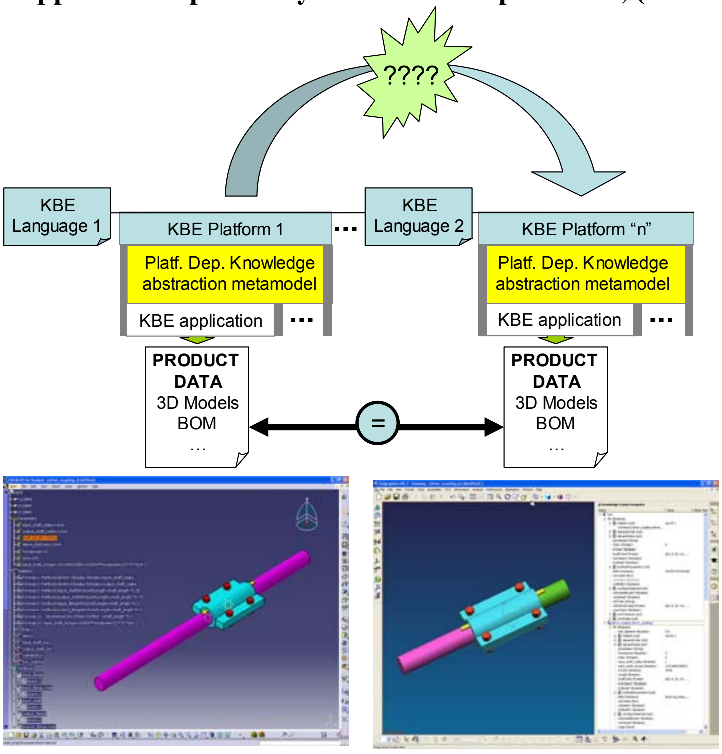
21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?				
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?				
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.				
Negative impact.	Some positive impact but not in my domain.	Some positive impact in my domain as part of a long term strategy.	High positive impact in my domain but not in my current list of preferences.	High positive impact in my domain. In my current list of preferences.
Comments: Very much needed. Past Due before the vendors start creating their own proprietary knowledge exchange protocols.				

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

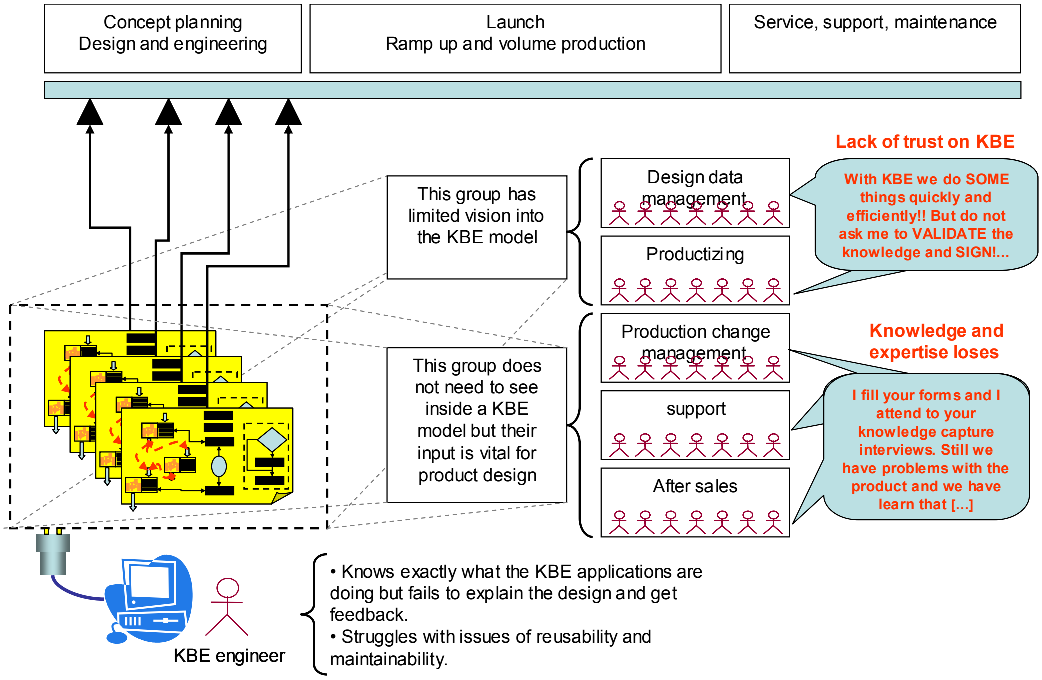
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place. XX

25. Evaluate the appropriateness of providing solutions to the issue.

It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it. XX

Comments:

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place. XX

27. Evaluate the appropriateness of providing solutions to the issue.

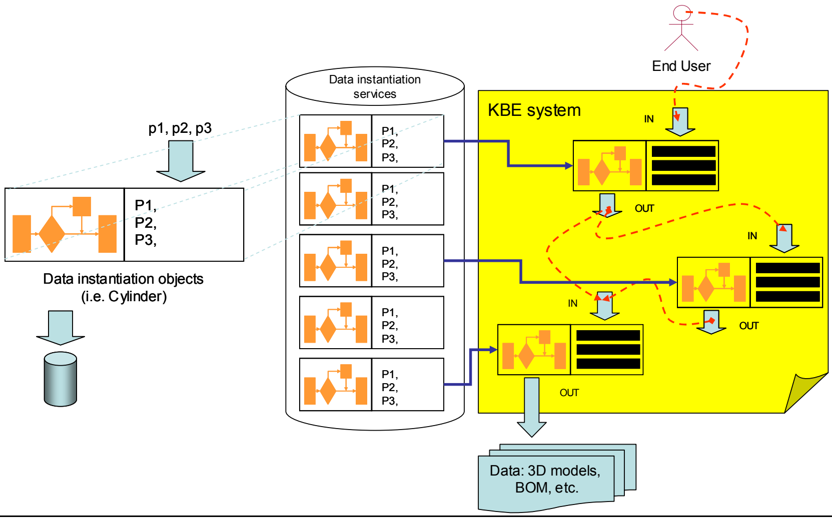
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it. XX

Comments:

I have implemented a standardized process for capturing the knowledge, architecture for which is product independent.
The individual parts are product dependent.

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

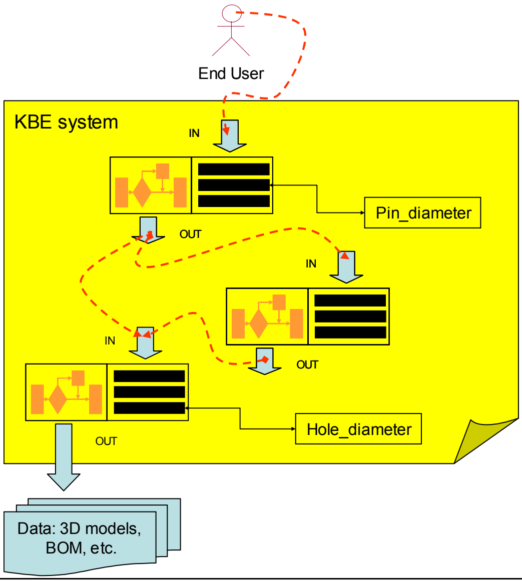
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail. XXX	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

29. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality. XX	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided. XX

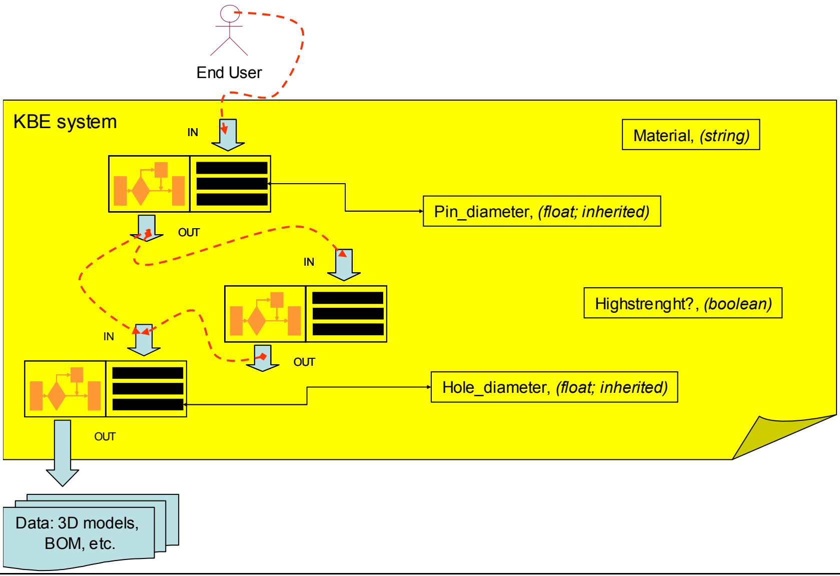
31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality. XX

Comments:

We are using a method to exchange parameters across multiple parts. This technique is part independent. We must find such protocols of exchanging information across parts and objects.

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided. XX

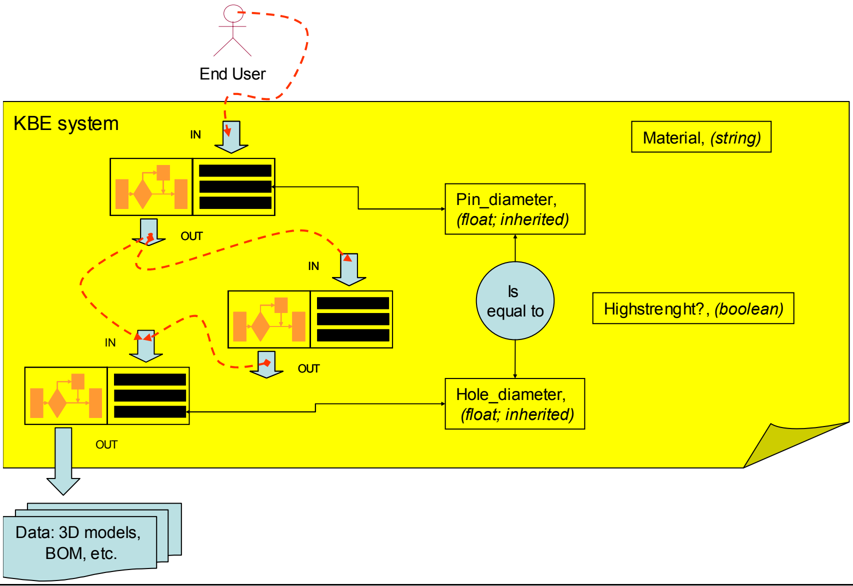
33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality. XX

Comments:

CATIA V5 KBE tool provides this level of abstractions and provides a method for identification of types of attributes that contain certain "integer", real" or Boolean values.

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided. XX

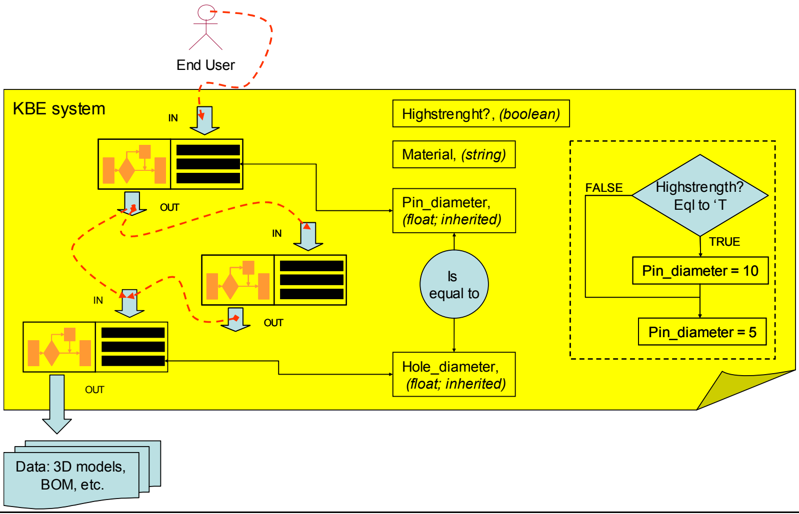
35. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality. XX

Comments:

CATIA V5 Knowlegeware tools provide it at multiple places. In Formulae, in KWA Rules, in Tables, and in creation of KWE rules

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

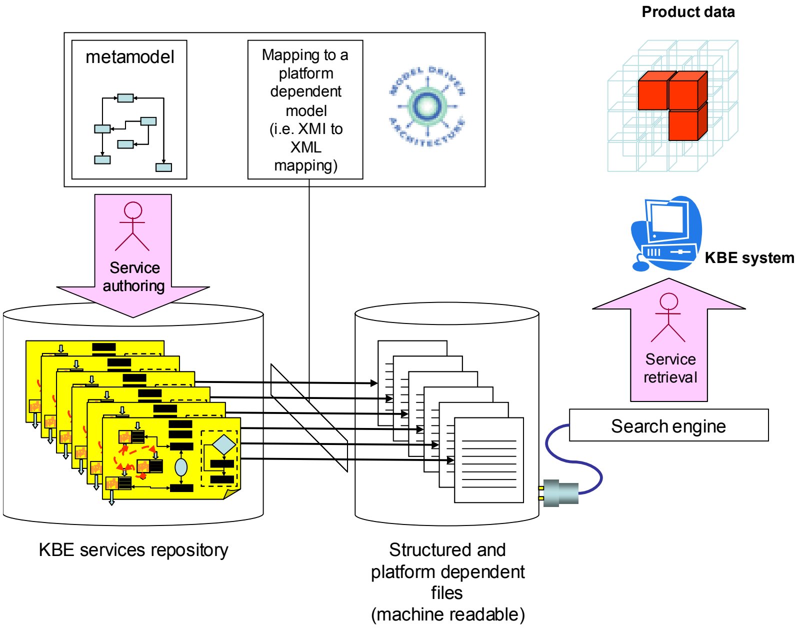
Comments:

CATIA V5 does this via an external parameters. However when parts name changes, it breaks the associated parameters'' links.
We need to think of passing attributes without breaking the links. Plug in and Plug out concept, if parts are removed,. Still you could reconfigure the assembly without any link being broken.

2.3 Use cases for the standard

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] complaint metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

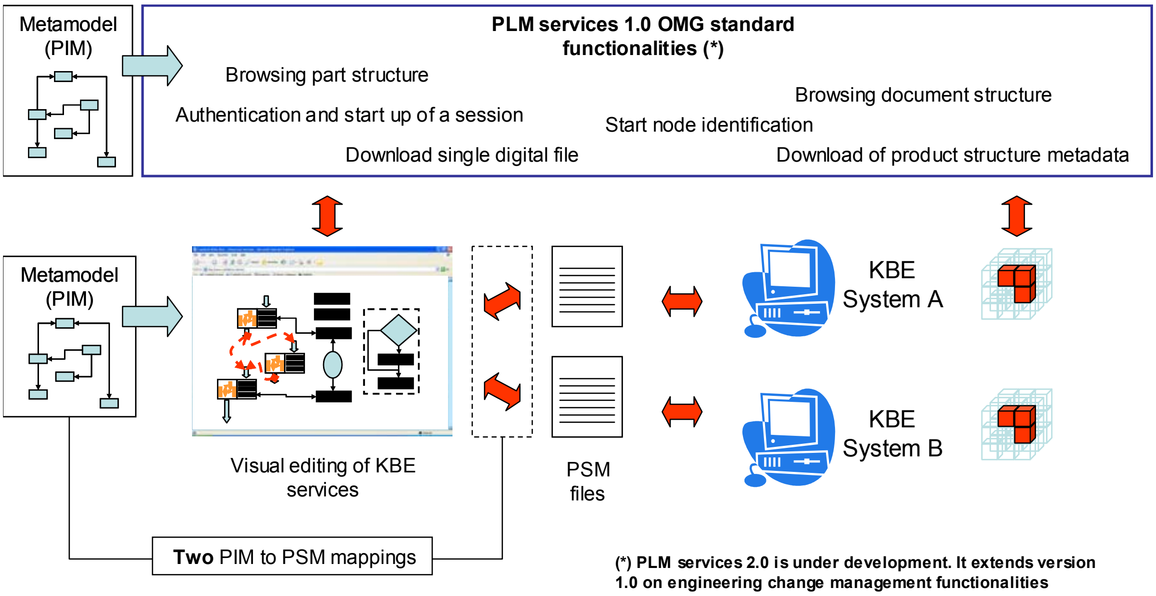
38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

It is too early to look into this at this time.

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

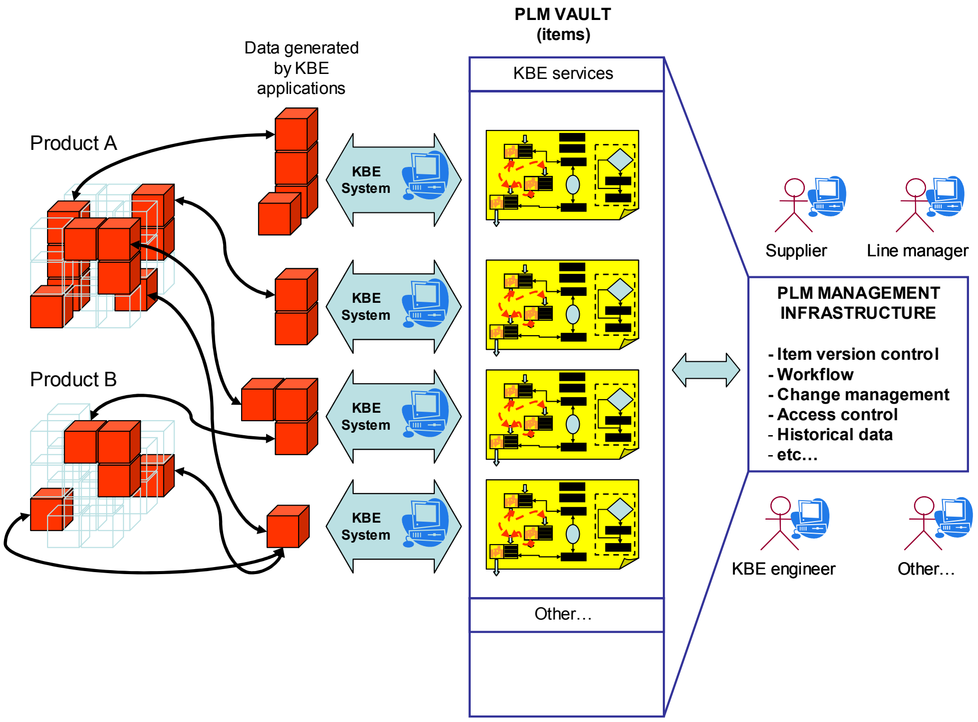
Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor's KBE language).

39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:
Too specific to a metamodel.

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

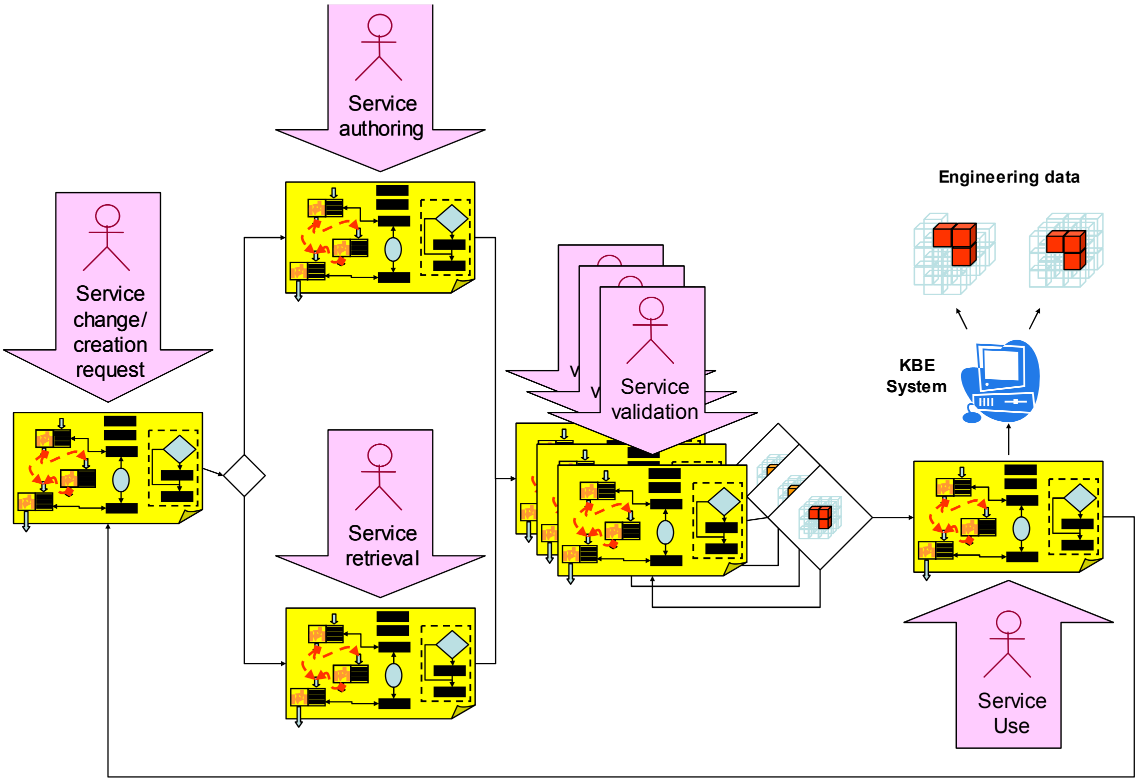
40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Not only individual parts, but Rules and relations should be managed as well.

Use case 4: standardised KBE services authoring, reuse and maintenance



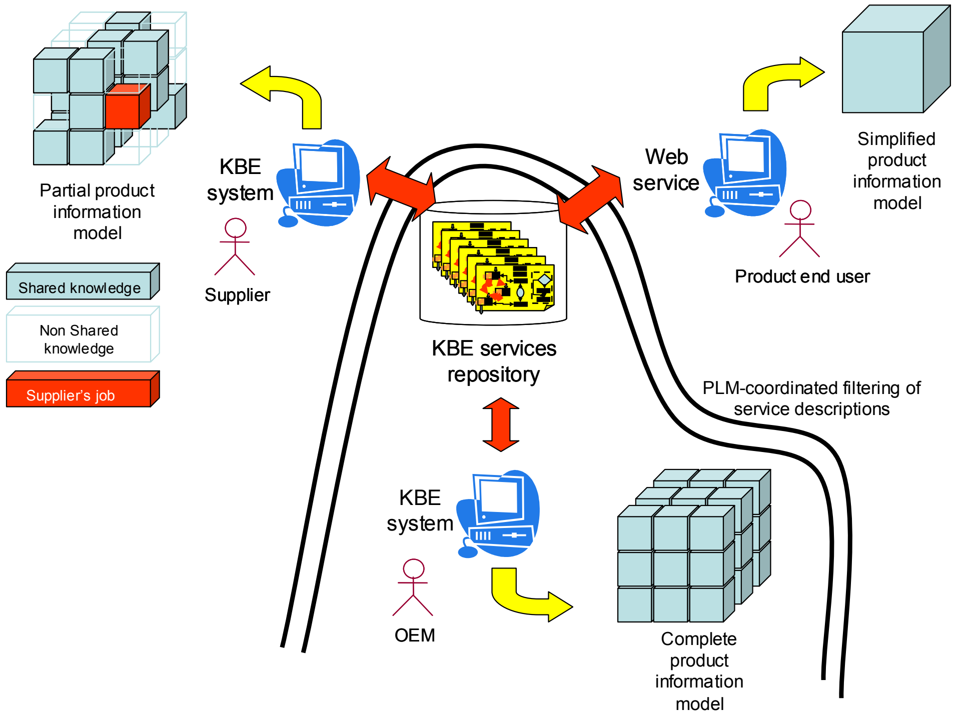
USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy. XX	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy. XX	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?				
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development.	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments") XX.
Comments: I think it would be next differentiator for companies to compete in the world marketplace (who has beetr KBE knowledgebase and how they are leveraging for maximizing product excellence.)				

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	X	
Comments:		

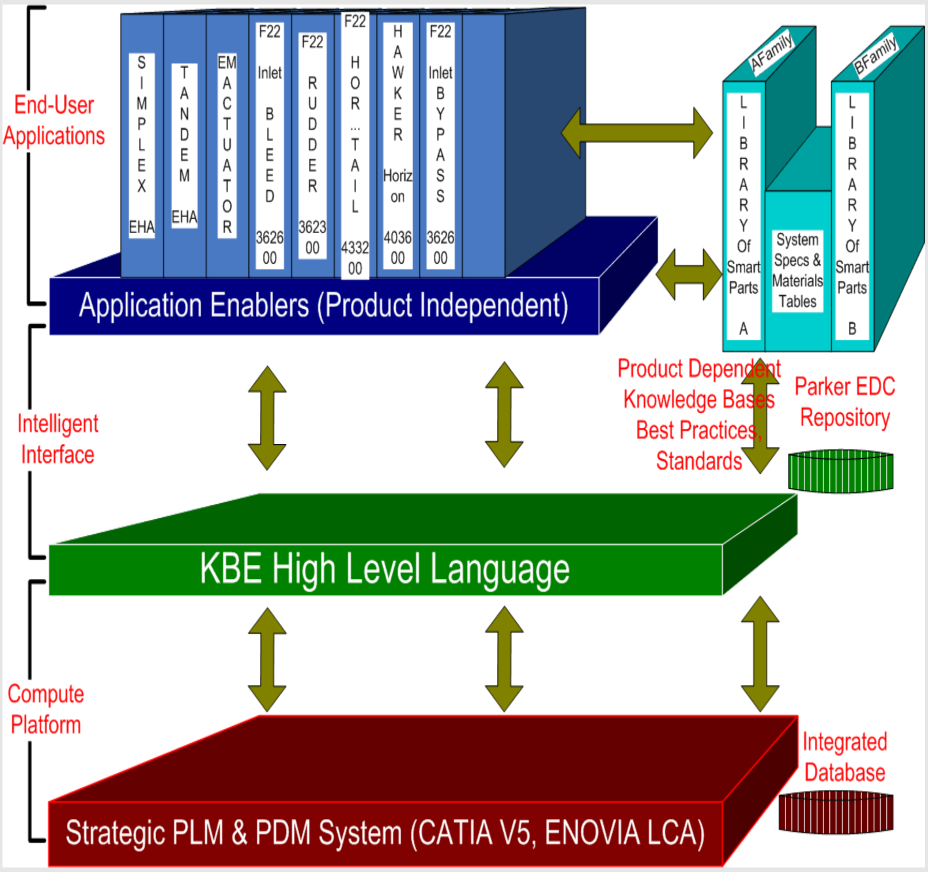
	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).	XX	
Comments: I do not have a lot of time. But could provide few use scenarios, if incurring cost is shared by OMG or any sponsoring agencies.		

	YES	NO
46. Would you be interested in influencing the development of the "KBE services for PLM" OMG standard?	XX	
Comments: If it does not involve too much time and it is funded by governing agencies.		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

Charter **– Develop a general-purpose Knowledge-Driven DA ArchitectureTM and a generative "KDA Wizard System." The first application is an Actuator Configurator inside CATIA v5. The KDA's decision-based process automatically determines which solution meets the customer requirements in least cost, weight, and time investments. Using this system, Parker engineers can configure a family of Hydraulic Actuators (both Tandem and Simplex family) automatically from customer specifications directly inside CATIA V5—a tool most engineers at TEC are quite familiar with.**



KBE services for PLM

OMG's Request for proposal document: dtc/2005-09-11
Feedback questionnaire

Table of contents

Respondent contact details

Name:	Helen Lockett
Company name:	Cranfield University
Contact address:	School Of Engineering Cranfield University Cranfield Bedford MK43 0AL
E-mail address:	H.Lockett@cranfield.ac.uk

Information about the questionnaire

The OMG has recently issued a request for proposal (RFP) soliciting Model Driven Architecture (*MDA*™) standards for Knowledge-Based Engineering (KBE) software services within Product Lifecycle Management (PLM) systems.

A number of end users and vendors of both KBE and PLM systems have participated in the development of the RFP.

This questionnaire is intended to acquire feedback on the "KBE services for PLM" RFP. Its ultimate objective is to evaluate the appropriateness of the RFP and to support the coordination of further activities around the standardisation process.

Information shared in this questionnaire is to be treated with confidentiality. Results on the analysis of the data gathered will be shared with the participants ensuring that particular opinions and names are omitted unless there is explicit authorisation from respondents.

We kindly encourage the participation in this activity and the dissemination of the questionnaire to other colleagues that might provide valuable input to the analysis.

Instructions to obtain this questionnaire

This questionnaire is stored as an OMG document in the OMG's document server. The URL to access the questionnaire is:
http://www.omg.org/cgi-bin/doc?mantis/2005-10-01

The questionnaire has been created using Microsoft Word 2002 (10.5522.4219) SP-2. Enquiries to receive the questionnaire on alternative file formats can be made using the details supplied on the "contact information" section of this document.

Instructions to answer the questionnaire

- Questions should be answered on the grey colored cells of the tables provided.
- Questions should be answered by adding an "x" character under the question statement.
- Unless stated in the question (by the questionnaire) or by a comment (by the respondent), questions have one possible answer.
- Most of the questions include additional grey boxes labelled as "comments". Use these boxes if you need to add comments concerned to the question statement.
- At the end of the questionnaire there is additional space to add other comments if you want to do so.

Instructions to submit the questionnaire

We encourage the submission of the questionnaire by email as an attached file to the email address supplied in the "contact information" section of this document.

Other alternatives to submit the questionnaire are listed as follows:

- **Post:** You can send a hard copy of the questionnaire to the post address supplied in the "contact information" section of this document.
- **E-mail without file attachments:** You can transcript the answers of the questionnaire into an email message, (a "plain text" template can be provided on demand via email).
- **Fax:** You can transcript the answers into a document that can be faxed to us, (a word document template can be provided on demand via email).
- **Telephone:** You can arrange a teleconference with us via email so we can transcript your answers into an empty questionnaire.

Contact information

Any question regarding the questionnaire can be made using the following contact details:

Pablo Bermell-Garcia
Department of Enterprise Integration
Cranfield University,
Bedford, MK430AL,
United Kingdom
p.bermell@cranfield.ac.uk
Tel: +44 1234 75 4194
Fax: +44 1234 750 852

Useful information sources to answer the questionnaire

The issued "KBE services for PLM" RFP can be found in:
http://www.omg.org/cgi-bin/doc?dtc/05-09-11
(Specific information about the RFP is in chapter 6 of the document).
Further information on the OMG can be found in:
http://www.omg.org
Information on the OMG "*PLM services*" standard can be found in:
http://www.prostep.org/en/events/workshops/archiv/plmservices.htm
http://www.prostep.org/en/projektgruppen/pdm-if/plmservices.htm

Although effort has been put to make the questionnaire easy to understand, some technical terminology related to OMG modelling standards is used. On the other hand, we encourage responders to read the RFP document issued by the OMG in order to fully realise the rationale of the questionnaire. Please refer to the links provided. Apart from this, do not hesitate to contact us for getting support in filling the questionnaire.

1. Company profile

The "company profile" section is intended to explore the relationships to PLM and KBE technologies in your own organisation context.

1. Which of these categories describes better the role of the organisation that you belong to? (More than one option can be marked).				
			X	X
Original equipment manufacturer.	Consultancy services company.	Software vendor company.	Research institute.	Other, (add). University
Comments:				

2. What is the size of the organisation that you belong to?				
		X		
Less than 500 employees.	Less than 1000 employees.	Less than 2000 employees.	More than 2000 employees.	Unknown.

3. Which of these categories describes better your role in relation to KBE technology? (More than one option can be marked).			
X	X		
I develop KBE applications.	I use KBE applications.	I provide software related support to KBE developers and users.	Other, (add).
Comments:			

4. Which of these categories describes better your role in relation to PLM technology? (More than one option can be marked).				
X	X	X		
I am part of the team responsible to implement PLM technology in my organisation.	I am an administrator of the PLM solution running at my organisation.	I am a user of the PLM solution running in my organisation.	I am part of a PLM software development team.	Other, (add).
Comments:				

2. Technical view

	YES	NO
5. Are you aware of the OMG's Model Driven Architecture and the software standards associated with it?	X	
If affirmative, which ones do you know? UML		

2.1 View on the convergence of PLM and KBE technology

	YES	NO
6. Is the convergence of KBE and PLM part of your vision of future product realisation technologies?	X	

The following questions describe 10 issues to be supported by the convergence of PLM and KBE technology. The text between the parentheses is aimed to clarify each issue description. We ask you to evaluate their relevance in your domain. Notice that these are generic issues and not all of them are covered by the "KBE services for PLM" RFP.

7. PLM/KBE convergence should provide support for interoperability between KBE systems. (KBE application from KBE system "A" can be used in KBE system "B")				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: Although not in my short term strategy this is an issue that I have worked on in the past and expect to have to work on again in the future				

8. PLM/KBE convergence should provide support for increasing the transparency of KBE applications functionalities and the information entities that they process. (KBE applications can be visualised by non KBE experts)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

9. PLM/KBE convergence should provide support for increasing the reuse of existing KBE applications across domains and projects. (KBE applications can be more easily retrieved and re-engineered to be reused in more situations)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

10. PLM/KBE convergence should provide support for increasing the efficiency in maintaining and updating KBE applications. (KBE applications can be more efficiently adapted to the changes of the knowledge)				
			X	
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

11. PLM/KBE convergence should provide support for modularity in the development of KBE applications. (KBE applications can be more easily created by assembling existing documented components)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

12. PLM/KBE convergence should provide support for the management of service-oriented KBE infrastructure. (KBE applications can be deployed as services across the network enabling them to be discovered and reused more intensively)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: In my opinion this aspect is part of the wider PLM role, and not as important within the KBE services.				

13. PLM/KBE convergence should provide support for KBE applications to generate engineering data through semantic web services. (KBE applications can be deployed as formalised semantic web services that users can discover and access in order to generate engineering data)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments: See question 12				

14. PLM/KBE convergence should provide support for the management of intellectual property stored in PLM. (Engineering knowledge stored in the PLM infrastructure is used as an input for KBE applications and vice-versa).				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

15. PLM/KBE convergence should provide support for engineering change management of KBE applications in PLM. (KBE application engineering change requests can be supported by PLM engineering change management infrastructure)				
		X		
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

16. PLM/KBE convergence should provide support for more formal knowledge representation methods both in PLM and KBE. (KBE systems and PLM solutions allow the deployment of formal conceptual models and advanced inference/reasoning mechanisms)				
				X
Not a relevant issue.	Some relevance but not in my domain.	Some relevance in my domain. Part of my long-term strategy.	Highly relevant issue in my domain. Not in my short term strategy.	Highly relevant issue in my domain. Part of my short term strategy.
Comments:				

2.2 View on the RFP

This section asks for specific feedback on the issued RFP. The questions here concentrate on: a) the perceived impact of the standard; b) the relevance of the issues presented in the RFP and; c) the perceived value of the KBE services functionalities to be represented in the standard.

a) Perceived impact of the standard

17. Will the existence of standardised KBE services definition contribute to wider use of the technology?				
			X	
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

18. Will the ability to interoperate between KBE systems be beneficial for your product engineering activities?				
			X	
No, it will not represent any benefit.	It will provide some benefits to product engineering in the long term.	It will provide some benefits to product engineering in the short term.	It will provide significant benefits to product engineering in the long term.	It will provide significant benefits to product engineering in the short term.
Comments:				

19. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of PLM technology?				
			X	
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

20. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard represent an added value for the use of KBE technology?				
	X			
No, it will not add value.	It will add some value in the long term.	It will add some value in the short term.	It will add significant value in the long term.	It will add significant value in the short term.
Comments:				

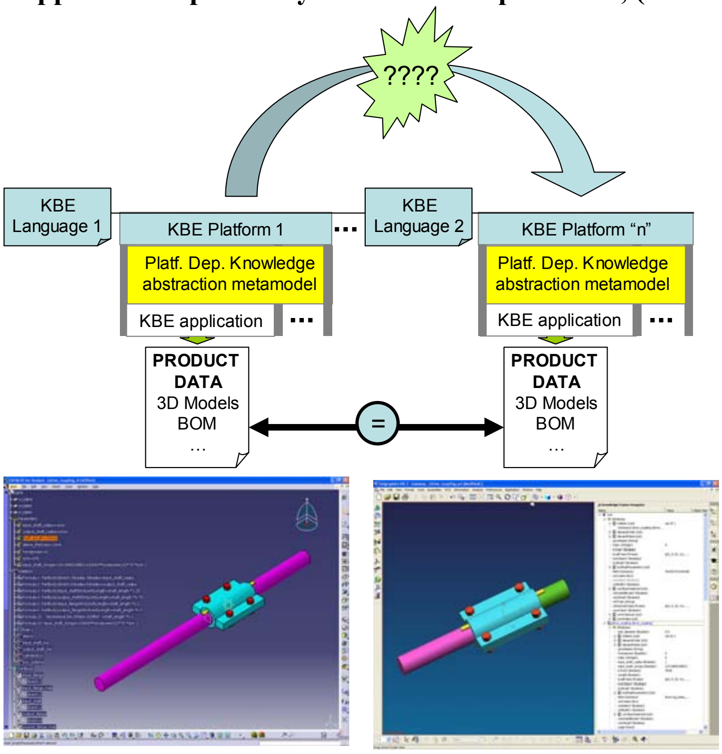
21. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient KBE deployment within engineering organisations?				
	X			
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

22. Considering the support to be provided by the standard for managing KBE services within PLM. Will the adoption of the standard contribute to more efficient sharing reuse and maintenance of the knowledge existing in KBE applications?				
				X
No, it will not contribute.	It will make some contribution in the long term.	It will make some contribution in the short term.	It will contribute significantly in the long term.	It will contribute significantly in the short term.
Comments:				

23. Evaluate the overall impact that the adoption of the standard shall have in your KBE and PLM activities.				
			X	
Negative impact.	Some positive impact but not in my domain.	Some positive impact in my domain as part of a long term strategy.	High positive impact in my domain but not in my current list of preferences.	High positive impact in my domain. In my current list of preferences.
Comments:				

b) Relevance of the issues presented in the RFP

Issue 1: need to support interoperability between KBE platforms, (see 6.1.3 on the RFP).



24. Do you recognise the existence of this issue? What level of importance would you assign to it?

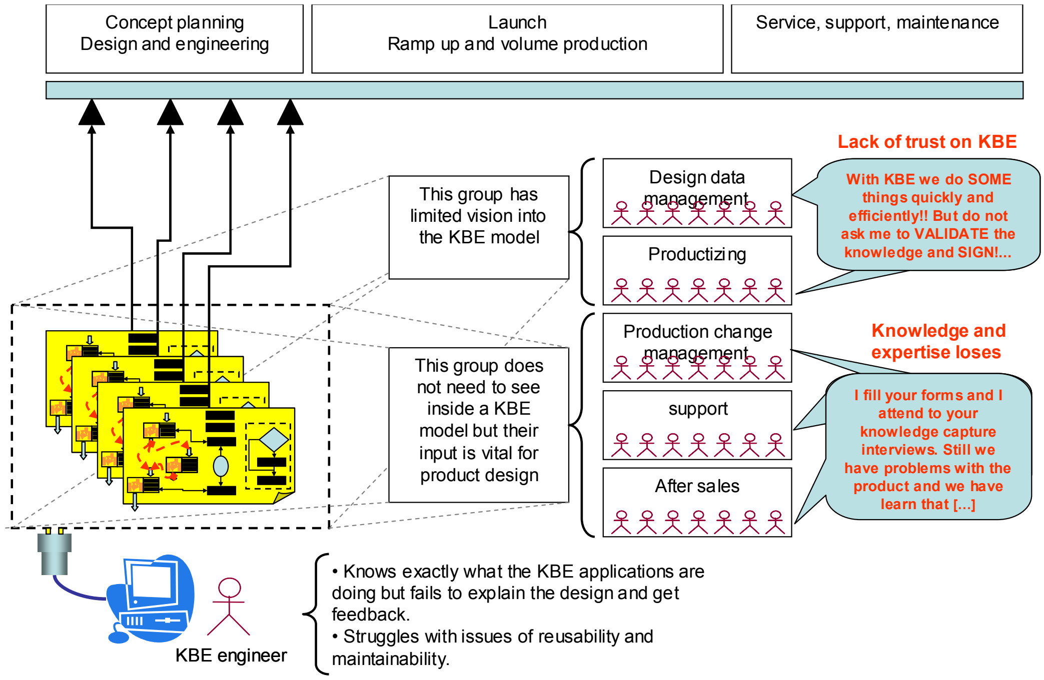
				X
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

25. Evaluate the appropriateness of providing solutions to the issue.

			X	
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:
I find this question difficult to answer – in my view it is a difficult issue to solve, but the benefits should make it worth the effort.

Issue 2: limitations on the ability to deploy KBE in a collaborative way and the lack of connection between KBE and other parts of the business, (see 6.1.4 on the RFP).



26. Do you recognise the existence of this issue? What level of importance would you assign to it?

			X	
The issue is not important in my domain.	The issue has some importance in my domain. There is not much interest on providing solutions.	This issue has some importance in my domain. There is some interest on providing solutions.	This is an important issue in my domain. Solutions for this need to be studied in detail.	This is a very important issue in my domain. Solutions for this need to be put in place.

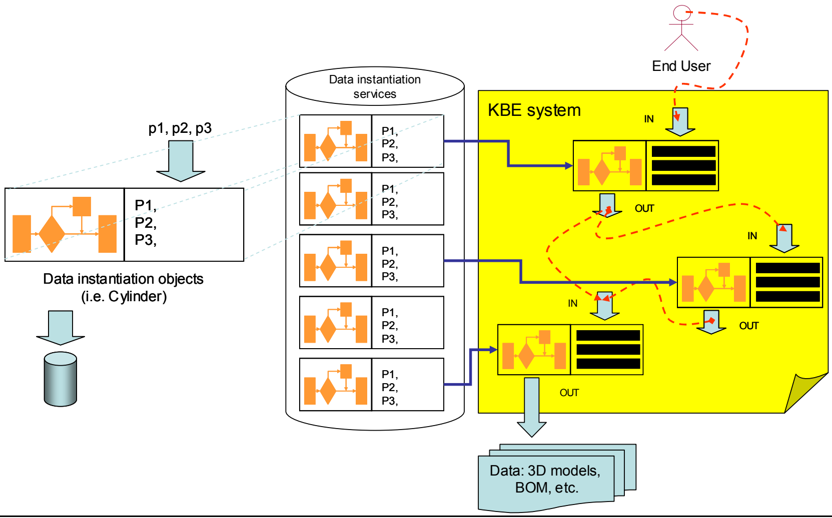
27. Evaluate the appropriateness of providing solutions to the issue.

			X	
It would be too much complicated to provide solutions for this issue.	It is a complicated issue to solve. Little return on investment is expected.	It is a complicated issue to solve. Limited return on investment is expected.	It is relatively easy to solve the issue. Enough return on investment is expected.	It is not a complicated issue to solve. It is very worthwhile to solve it.

Comments:
I find this question difficult to answer. The problem would be difficult to resolve effectively, but it is worthy of investigation.

c) Perceived value of the KBE services functionalities to be represented in the standard

KBE services functionality: Access to geometry and topology information.



28. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

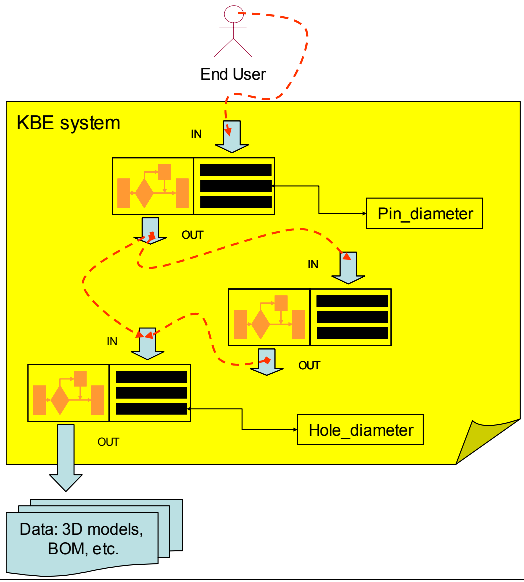
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

29. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Assignment of domain-dependent design information to attributes of engineering data



30. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

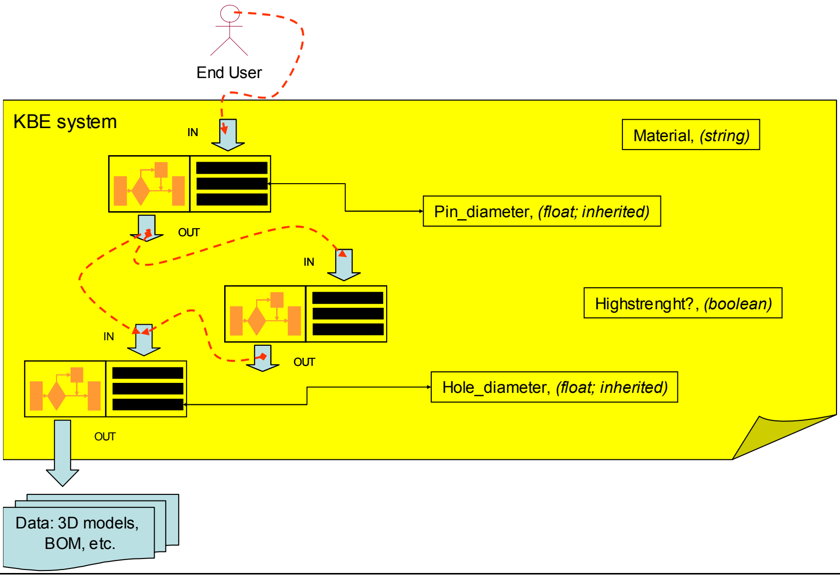
			X	
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

31. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Create domain-dependent engineering attributes



32. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

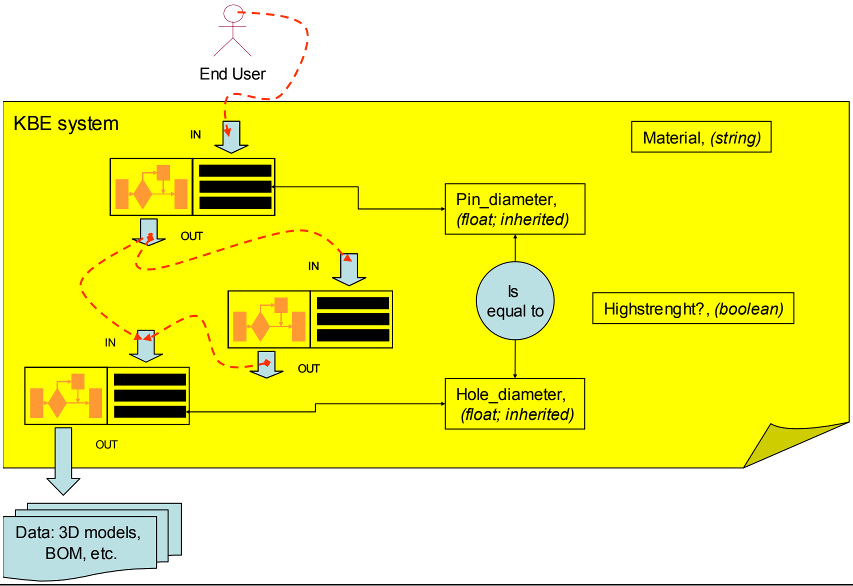
		X		
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

33. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

		X		
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define relationships between engineering attributes



34. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

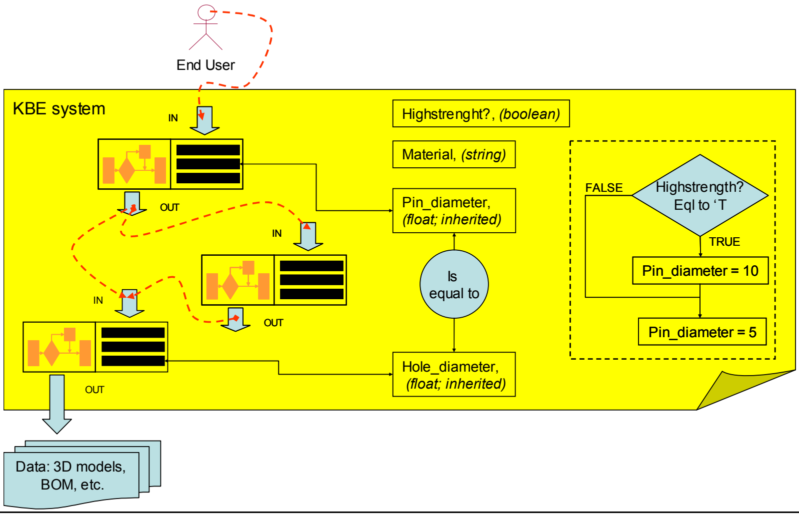
				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

35. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

			X	
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

KBE services functionality: Define engineering rules that control the generation of engineering data



36. Do you recognise the need to represent this functionality in the "KBE services for PLM" metamodel? What is in your domain the level of interest that you would assign to it?

				X
The functionality is not important in my domain.	The functionality has some importance in my domain. There is not so much interest in supporting it on the metamodel.	This functionality has some importance in my domain. There is some interest in supporting it on the metamodel.	This is an important functionality in my domain. Support for it in the metamodel need to be studied in detail.	This is a very important functionality in my domain. Support for it in the metamodel need to be provided.

37. Evaluate the appropriateness of supporting this functionality on the "KBE services for PLM" metamodel.

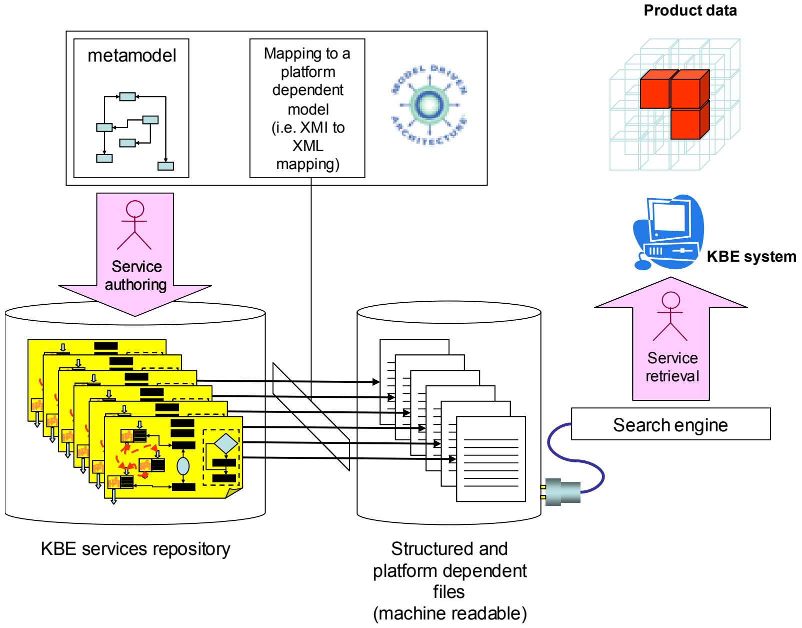
				X
It would be too much complicated to support this functionality in the metamodel.	It is complicated to support this functionality in the metamodel. Little benefits can be expected from the representation of this functionality.	It is complicated to support this functionality in the metamodel. Limited benefits can be expected from the representation of this functionality.	It is relatively easy to support this functionality in the metamodel. Enough benefits can be expected from the representation of this functionality.	It is easy to support this functionality in the metamodel. High benefits can be expected from the representation of this functionality.

Comments:

2.3 Use cases for the standard

This section introduces a number of use cases to illustrate possible scenarios in which KBE service definitions can be deployed and integrated with PLM technology.

Use case 1: retrieval and reuse of *MDA* standardised KBE services to support engineering data generation



USE CASE DESCRIPTION: Using the *MDA* approach, a MOF[1] complaint metamodel of KBE services contains the basic modelling infrastructure to produce KBE services. In the *MDA* context such metamodel is known as the *Platform Independent Model* (PIM). The *MDA* approach also includes the definition of mappings to transform service descriptions into *Platform Specific Models* (PSM). The PSMs generated from this mapping are the platform specific KBE languages, but also other languages such as XML[2] or WSDL[3] can be PSMs. Using the *MDA* approach, the knowledge stored in KBE applications can be systematically structured. Thus, more effective service retrieval using search engines is supported.

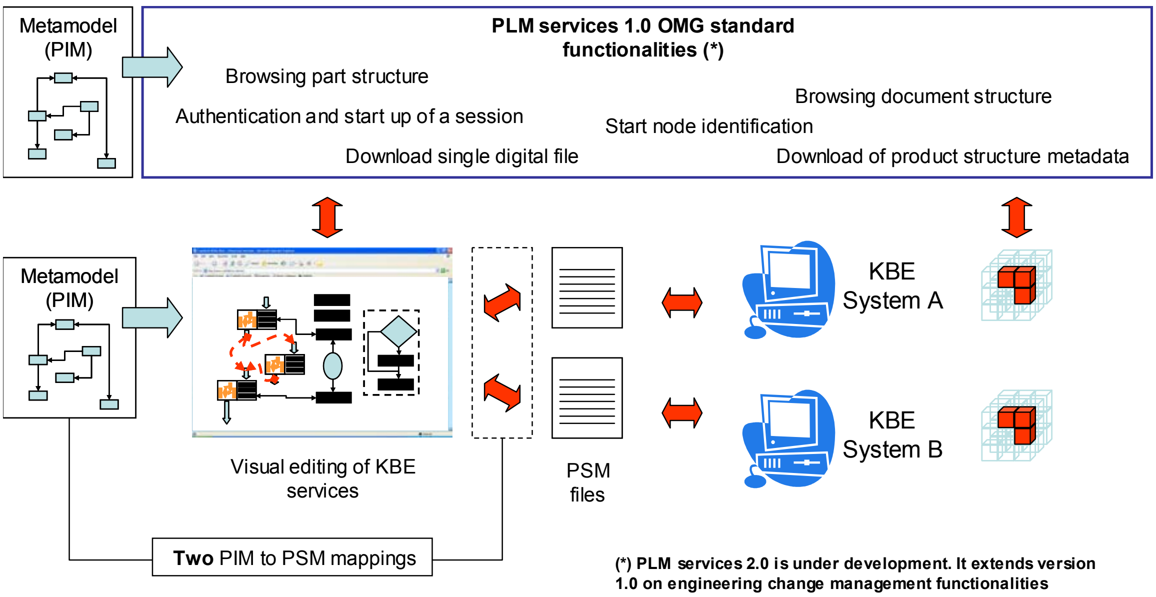
[1] Meta Object Facility ™; [2] Extensible Markup Language; [3] Web Services Description Language.

38. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 2: visual composition and analysis of KBE services under the PLM management infrastructure



USE CASE DESCRIPTION: The metamodel resulting from the standard is applied in this use case to define the modelling primitives on a visual editor for KBE services. Using a PSM mapping the editor can write a file on platform specific KBE languages to allow different KBE system to generate the data. This entire infrastructure is managed by using the functionalities supported by the *PLM services* standard.

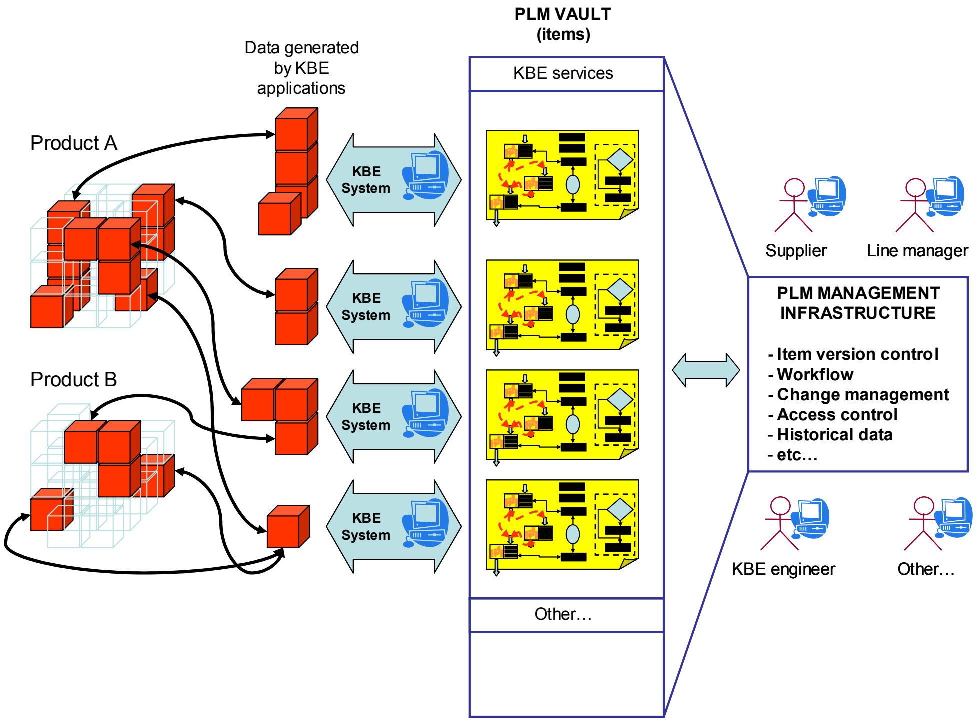
Notice that MDA standards include the metamodel and also the mapping rules necessary to transform PIMs into the PSMs, (i.e. specific vendor’s KBE language).

39. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 3: standardised KBE services as PLM items to support reusability across engineering projects



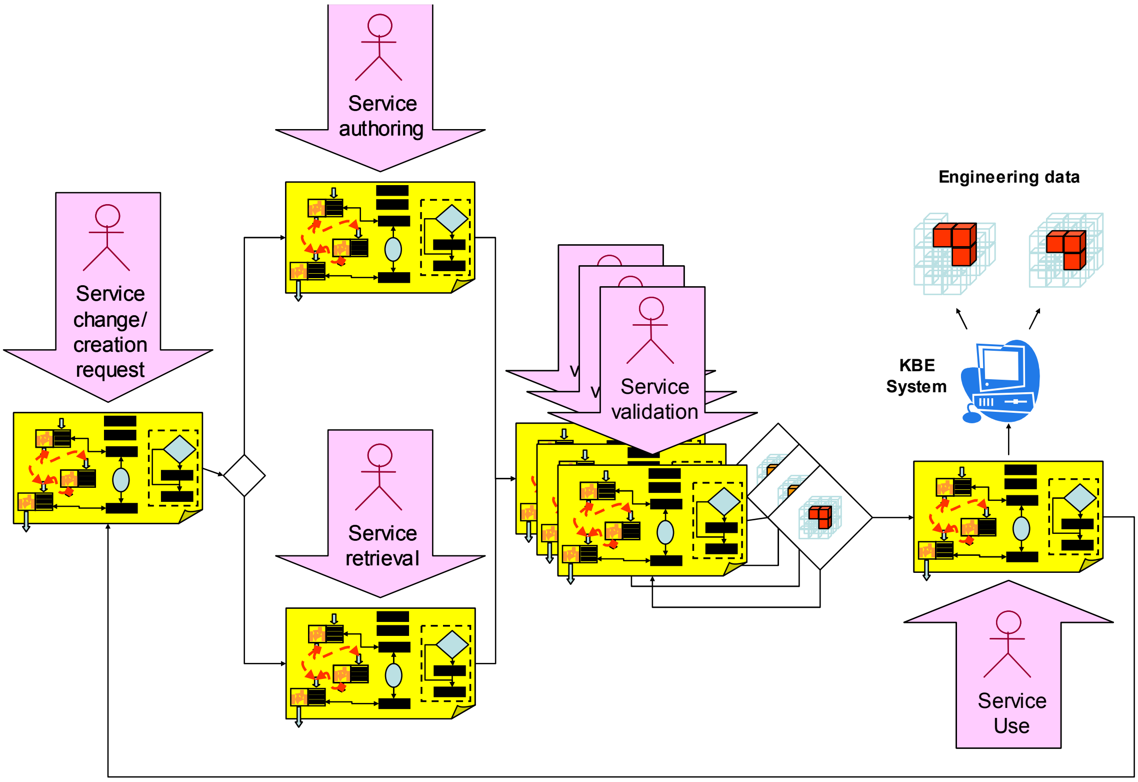
USE CASE DESCRIPTION: KBE service descriptions are applied in this use case as PLM-managed items. Reusability is supported here by the increased transparency of the KBE services descriptions across diverse types of PLM users, (i.e. Suppliers, line managers, KBE engineers, etc.). PLM coordinated access to the knowledge in KBE services augments the chances of detect errors in them and reusing them across projects.

40. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 4: standardised KBE services authoring, reuse and maintenance



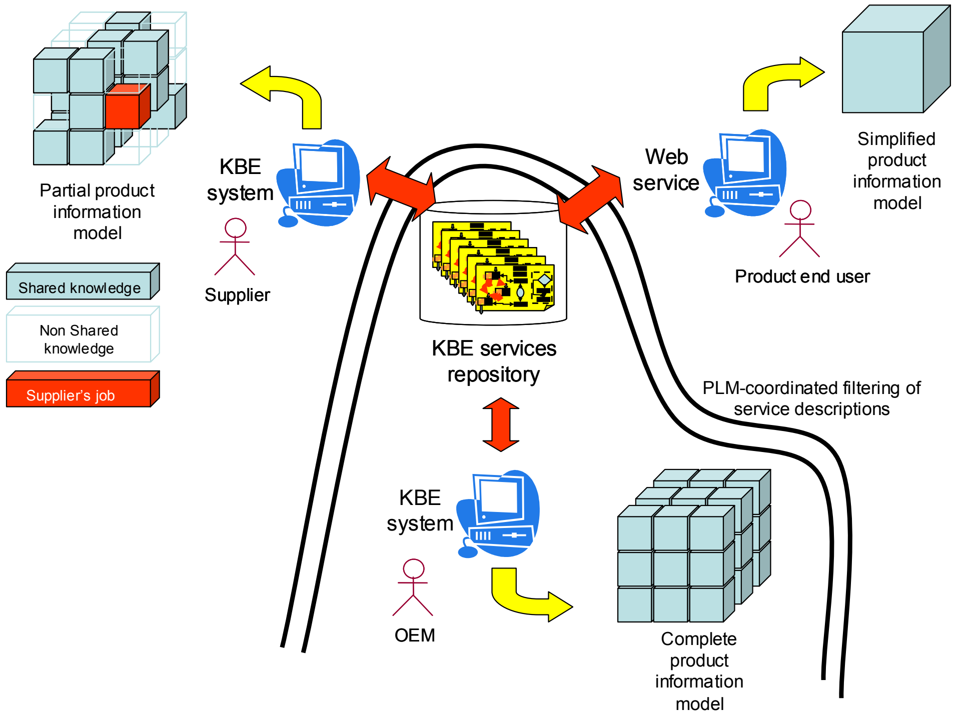
USE CASE DESCRIPTION: This use case describes a simplified model of the KBE services lifecycle. The KBE services for PLM standard shall support the management of the work necessary to deploy KBE infrastructure. PLM functionalities such as data access control and engineering change management are used here to manage the tasks associated with the lifecycle of KBE services (arrows).

41. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

			X	
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

Use case 5: PLM-based management of standardised KBE services for product customers and B2B relationships



USE CASE DESCRIPTION: This use case illustrates the application of the KBE services for PLM standard to support "tailored" exchange of knowledge according to corporate policies. PLM-coordinated access and configuration control of KBE services is used here to filter the knowledge that can be accessed by different actors outside the organisation. For example, a supplier involved in a particular job receives a KBE services description that includes rules and constraints affecting its job while hiding other knowledge entities. Another example is a product end user that access to a web service which only discloses the necessary knowledge to configure a product and the simplified geometry of the product (i.e. an online catalogue).

42. Evaluate the relevance of the use case according to the KBE/PLM integration needs in your domain

		X		
The use case is not applicable in my domain.	The use case has some relevance but not in my domain.	The use case has some relevance in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is not part of my short term strategy.	Highly relevant use case in my domain. Supporting the use case is part of my short term strategy.

Comments:

3. Interest on PLM/KBE integration research activities

This section is intended to explore the interest across the PLM/KBE community to pursue further actions in the "KBE services for PLM" standardisation process.

43. Would you be interested to participate on research activities around KBE/PLM integration? In that case, what would be your preferences?				
		X		
Not interested on PLM/KBE integration research.	I am interested in promoting research activities towards better PLM/KBE integration but not necessarily involving the standard development.	I am interested in promoting research activities towards better PLM/KBE integration whose result is transferred to the standard development.	I am interested in promoting research activities focused specifically in the development of the standard.	I am interested in promoting research activities towards better PLM/KBE integration but not in these particular ones. (Please specify on "comments").
Comments:				

	YES	NO
44. Would you be interested in attending to a workshop to discuss and plan research activities on PLM/KBE integration?	X	
Comments:		

	YES	NO
45. Would you be interested in becoming part of the submission team for the "KBE services for PLM" OMG standard? (Notice that only "contributing", "domain" and "platform" OMG members can become standard submitters).		
Comments: Maybe!		

	YES	NO
46. Would you be interested in influencing the development of the "KBE services for PLM" OMG standard?	X	
Comments:		

4. Additional comments

Use this section if you want to add additional comments or observations about the issued RFP or any other of the topics covered here.

Overall I found this questionnaire quite challenging to complete! On the positive side it persuaded me to read the RFP more carefully than I would otherwise have done, but in many cases I found it difficult to discriminate between the various functionality aspects presented in the questionnaire. The language used to describe the use cases is rather difficult to follow.

Overall I see this proposal as very important to future developments in, and interoperability between KBE tools within a PLM environment.

Appendix C

RDF CODE FOR THE STRUCTURE METAMODEL

```
<?xml version='1.0' encoding='UTF-8'?>
<!DOCTYPE rdf:RDF [
	 <!ENTITY rdf 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'>
	 <!ENTITY a 'http://protege.stanford.edu/system#'>
	 <!ENTITY rdf_ 'http://protege.stanford.edu/rdf'>
	 <!ENTITY rdfs 'http://www.w3.org/2000/01/rdf-schema#'>
]>
<rdf:RDF xmlns:rdf="&rdf;"
	 xmlns:rdf_="&rdf_;"
	 xmlns:a="&a;"
	 xmlns:rdfs="&rdfs;">
<rdfs:Class rdf:about="&rdf_;ATT_DECL_DEF"
	 rdfs:label="ATT DECL DEF">
	<rdfs:subClassOf rdf:resource="&rdf_;INTERNAL_DECLARATION"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Class-App-lifecycle-relation-label"
	 rdfs:label="Class-App-lifecycle-relation-label">
	<rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;Class-Class-COL-conn"
	 rdfs:label="Class-Class-COL-conn">
	<rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Class-Class-COL-conn-label"
	 rdfs:label="Class-Class-COL-conn-label">
	<rdfs:domain rdf:resource="&rdf_;Class-Class-COL-conn"/>
	<rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Class-Class-lifecycle-relation-label"
	 rdfs:label="Class-Class-lifecycle-relation-label">
	<rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;Class-InsSpec-COL-conn"
	 rdfs:label="Class-InsSpec-COL-conn">
	<rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Class-InsSpec-COL-conn-label"
	 rdfs:label="Class-InsSpec-COL-conn-label">
	<rdfs:domain rdf:resource="&rdf_;Class-InsSpec-COL-conn"/>
	<rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Class-lifecycle-model"
	 rdfs:label="Class-lifecycle-model">
	<rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Class-lifecycle-relations"
	 rdfs:label="Class-lifecycle-relations">
	<rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Component-lifecycle-model"
	 rdfs:label="Component-lifecycle-model">
	<rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Component-lifecycle-relations"
	 rdfs:label="Component-lifecycle-relations">
	<rdfs:range rdf:resource="&a;_directed_binary_relation"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Creation_date"
	 rdfs:label="Creation date">
	<rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Defines_multiple_instances"
	 rdfs:label="Defines_multiple_instances">
	<rdfs:domain rdf:resource="&rdf_;INSTANTIATION_DEF"/>
	<rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;ExtOp-KComp-rel"
	 rdfs:label="ExtOp-KComp-rel">
	<rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;ExtOp-KComp-rel-label"
	 rdfs:label="ExtOp-KComp-rel-label">
	<rdfs:domain rdf:resource="&rdf_;ExtOp-KComp-rel"/>
	<rdfs:range rdf:resource="&rdfs;Literal"/>
```

```
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;INPUT_DECL_DEF"
         rdfs:label="INPUT DECL DEF">
        <rdfs:subClassOf rdf:resource="&rdf_;INTERNAL_DECLARATION"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;INSTANCE-SPEC"
         rdfs:label="INSTANCE-SPEC">
        <rdfs:subClassOf rdf:resource="&rdf_;INSTANTIATION_BINDING"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;INSTANTIATION_BINDING"
         rdfs:label="INSTANTIATION BINDING">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;INSTANTIATION_DEF"
         rdfs:label="INSTANTIATION DEF">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;INTERNAL_DECLARATION"
         rdfs:label="INTERNAL DECLARATION">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Instance_name"
         rdfs:label="Instance_name">
        <rdfs:domain rdf:resource="&rdf_;INSTANTIATION_DEF"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;KBE-OBJECT"
         rdfs:label="KBE-OBJECT">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE-OBJECT-SPEC"
         rdfs:label="KBE-OBJECT-SPEC">
        <rdfs:subClassOf rdf:resource="&rdf_;INSTANTIATION_BINDING"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;KBE-resource-lifecycle-model"
         rdfs:label="KBE-resource-lifecycle-model">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE-resource-structure-model-relations"
         rdfs:label="KBE-resource-structure-model-relations">
        <rdfs:domain rdf:resource="&rdf_;KBE_RESOURCE"/>
        <rdfs:range rdf:resource="&a;_directed_binary_relation"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;KBESYS_OBJECT"
         rdfs:label="KBESYS OBJECT">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_COMPONENT"
         rdfs:label="KBE COMPONENT">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_COMPONENT_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_COMPONENT_STRUCTURE"
         rdfs:label="KBE COMPONENT STRUCTURE">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_COMPONENT_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_COMPONENT_VIEW"
         rdfs:label="KBE COMPONENT VIEW">
        <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_DEFINITIONS_VIEW"
         rdfs:label="KBE DEFINITIONS VIEW">
        <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_EXTERNAL_OPERATION"
         rdfs:label="KBE EXTERNAL OPERATION">
        <rdfs:subClassOf rdf:resource="&rdf_;KBE_COMPONENT_VIEW"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_OBJECT_VIEW"
         rdfs:label="KBE OBJECT VIEW">
        <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_RESOURCE"
         rdfs:label="KBE RESOURCE">
        <rdfs:subClassOf rdf:resource="&rdfs;Resource"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;KBE_SYSTEM_PRIMITIVE"
         rdfs:label="KBE SYSTEM PRIMITIVE">
```

```
        <rdfs:subClassOf rdf:resource="&rdf_;KBESYS_OBJECT"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;KBE_classes_involved"
         rdfs:label="KBE classes involved">
        <rdfs:range rdf:resource="&rdf_;KBE-OBJECT"/>
        <rdfs:domain rdf:resource="&rdf_;KBE_COMPONENT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_component_name"
         rdfs:label="KBE component name">
        <rdfs:domain rdf:resource="&rdf_;KBE_COMPONENT"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_component_relations"
         rdfs:label="KBE component relations">
        <rdfs:domain rdf:resource="&rdf_;KBE_COMPONENT_STRUCTURE"/>
        <rdfs:range rdf:resource="&a;_directed_binary_relation"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_components_model"
         rdfs:label="KBE components model">
        <rdfs:domain rdf:resource="&rdf_;KBE_COMPONENT_STRUCTURE"/>
        <rdfs:range rdf:resource="&rdf_;KBE_COMPONENT_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_object_name"
         rdfs:label="KBE_object_name">
        <rdfs:domain rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_resource_lifecycle_model"
         rdfs:label="KBE resource lifecycle model">
        <rdfs:range rdf:resource="&rdf_;KBE_RESOURCE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_resource_lifecycle_relations"
         rdfs:label="KBE resource lifecycle relations">
        <rdfs:range rdf:resource="&rdf_;Kres-Kres-rel"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_resource_name"
         rdfs:label="KBE resource name">
        <rdfs:domain rdf:resource="&rdf_;KBE_RESOURCE"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;KBE_system_name"
         rdfs:label="KBE system name">
        <rdfs:domain rdf:resource="&rdf_;KBE_SYSTEM_PRIMITIVE"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;KComp-ExtOp-rel"
         rdfs:label="KComp-ExtOp-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;KComp-ExtOp-rel-label"
         rdfs:label="KComp-ExtOp-rel-label">
        <rdfs:domain rdf:resource="&rdf_;KComp-ExtOp-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;KComp-KCom-rel"
         rdfs:label="KComp-KCom-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;KComp-KCom-rel-label"
         rdfs:label="KComp-KCom-rel-label">
        <rdfs:domain rdf:resource="&rdf_;KComp-KCom-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;KComp-KComp-rel"
         rdfs:label="KComp-KComp-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;KComp-KComp-rel-label"
         rdfs:label="KComp-KComp-rel-label">
        <rdfs:domain rdf:resource="&rdf_;KComp-KComp-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;KComp-KRes-rel"
         rdfs:label="KComp-KRes-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;KComp-KRes-rel-label"
```

```
         rdfs:label="KComp-KRes-rel-label">
        <rdfs:domain rdf:resource="&rdf_;KComp-KRes-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;Kres-Kres-rel"
         rdfs:label="Kres-Kres-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Kres-Kres-rel-label"
         rdfs:label="Kres-Kres-rel-label">
        <rdfs:domain rdf:resource="&rdf_;Kres-Kres-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;Note-entity-rel"
         rdfs:label="Note-entity-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;Owner"
         rdfs:label="Owner">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;UCl-Ucl-rel-label"
         rdfs:label="UCl-Ucl-rel-label">
        <rdfs:domain rdf:resource="&rdf_;userClass-UserClass-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Uc-Sc-label"
         rdfs:label="Uc-Sc-label">
        <rdfs:domain rdf:resource="&rdf_;userClass-InsSpec-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;UsC-UsC-rel-label"
         rdfs:label="UsC-UsC-rel-label">
        <rdfs:domain rdf:resource="&rdf_;insSpec-userClass-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;Validators"
         rdfs:label="Validators">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;comments"
         rdfs:label="comments">
        <rdfs:domain rdf:resource="&rdf_;KBE_COMPONENT"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;contains_Rule"
         rdfs:label="contains_Rule">
        <rdfs:domain rdf:resource="&rdf_;ATT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;INPUT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;INSTANCE-SPEC"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;datatype-name"
         rdfs:label="datatype-name">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;definition_involved"
         rdfs:label="definition involved">
        <rdfs:range rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
        <rdfs:domain rdf:resource="&rdf_;KBE_EXTERNAL_OPERATION"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;definitions_involved"
         rdfs:label="definitions involved">
        <rdfs:range rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;document"
         rdfs:label="document">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;documentation"
         rdfs:label="documentation">
        <rdfs:domain rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;eng-description"
         rdfs:label="eng-description">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
```

```
</rdf:Property>
<rdf:Property rdf:about="&rdf_;eng-rationale-model"
         rdfs:label="eng-rationale-model">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;extended_info"
         rdfs:label="extended info">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has-REUSED-ext-def"
         rdfs:label="has-REUSED-ext-def">
        <rdfs:domain rdf:resource="&rdf_;ATT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;INPUT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;INSTANCE-SPEC"/>
        <rdfs:range rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has-collected-external-definition"
         rdfs:label="has-collected-external-definition">
        <rdfs:domain rdf:resource="&rdf_;ATT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;INPUT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;INSTANCE-SPEC"/>
        <rdfs:range rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has-content-model"
         rdfs:label="has-content-model">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has-defpart-inst-inp"
         rdfs:label="has-defpart-inst-inp">
        <rdfs:range rdf:resource="&rdf_;KBE-OBJECT-SPEC"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_DataType"
         rdfs:label="has_DataType">
        <rdfs:domain rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_KBE-component-structure"
         rdfs:label="has_KBE-component-structure">
        <rdfs:range rdf:resource="&rdf_;KBE_COMPONENT_STRUCTURE"/>
        <rdfs:domain rdf:resource="&rdf_;KBE_RESOURCE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_KBE_construct"
         rdfs:label="has_KBE_construct">
        <rdfs:domain rdf:resource="&rdf_;KBE_RESOURCE"/>
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_attribute_definition"
         rdfs:label="has_attribute_definition">
        <rdfs:range rdf:resource="&rdf_;ATT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_component_lifecycle"
         rdfs:label="has_component_lifecycle">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_declared_input"
         rdfs:label="has_declared_input">
        <rdfs:range rdf:resource="&rdf_;INPUT_DECL_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_inst_spec"
         rdfs:label="has_inst_spec">
        <rdfs:range rdf:resource="&rdf_;INSTANCE-SPEC"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_instance_spec"
         rdfs:label="has_instance_spec">
        <rdfs:range rdf:resource="&rdf_;INSTANCE-SPEC"/>
        <rdfs:domain rdf:resource="&rdf_;INSTANTIATION_DEF"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_instantiation_def"
         rdfs:label="has_instantiation_def">
        <rdfs:range rdf:resource="&rdf_;INSTANTIATION_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_object_instantiation"
         rdfs:label="has_object_instantiation">
        <rdfs:domain rdf:resource="&rdf_;INSTANTIATION_DEF"/>
```

```
        <rdfs:range rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_object_lifecycle"
         rdfs:label="has_object_lifecycle">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_object_spec"
         rdfs:label="has_object_spec">
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
        <rdfs:range rdf:resource="&rdf_;KBE-OBJECT-SPEC"/>
        <rdfs:domain rdf:resource="&rdf_;KBE_SYSTEM_PRIMITIVE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_rationale_model"
         rdfs:label="has_rationale_model">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_reused_external_definition"
         rdfs:label="has_reused_external_definition">
        <rdfs:range rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_state_documentation"
         rdfs:label="has_state_documentation">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;has_user_inputs"
         rdfs:label="has_user_inputs">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;input_name"
         rdfs:label="input_name">
        <rdfs:domain rdf:resource="&rdf_;INSTANTIATION_BINDING"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;insSpec-userClass-rel"
         rdfs:label="insSpec-userClass-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;ins_term"
         rdfs:label="ins_term">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;inverse_of_has_declared_inputs"
         rdfs:label="inverse_of_has_declared_inputs">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is-component-metadata-of"
         rdfs:label="is-component-metadata-of">
        <rdfs:range rdf:resource="&rdf_;KBE_COMPONENT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is-content-model-of-class"
         rdfs:label="is-content-model-of-class">
        <rdfs:range rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is-resource-metadata-of"
         rdfs:label="is-resource-metadata-of">
        <rdfs:range rdf:resource="&rdf_;KBE_RESOURCE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_DataType_of"
         rdfs:label="is_DataType_of">
        <rdfs:range rdf:resource="&rdf_;KBE_DEFINITIONS_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_a_declared_input_of"
         rdfs:label="is_a_declared_input_of">
        <rdfs:domain rdf:resource="&rdf_;INPUT_DECL_DEF"/>
        <rdfs:range rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_attribute_definition_of"
         rdfs:label="is_attribute_definition_of">
        <rdfs:domain rdf:resource="&rdf_;ATT_DECL_DEF"/>
        <rdfs:range rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_component_structure_of_KBE_resource"
         rdfs:label="is_component_structure_of_KBE resource">
        <rdfs:domain rdf:resource="&rdf_;KBE_COMPONENT_STRUCTURE"/>
        <rdfs:range rdf:resource="&rdf_;KBE_RESOURCE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_instance_spec_of"
```

```
         rdfs:label="is_instance_spec_of">
        <rdfs:domain rdf:resource="&rdf_;INSTANCE-SPEC"/>
        <rdfs:range rdf:resource="&rdf_;INSTANTIATION_DEF"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_instantiation_def_of"
         rdfs:label="is_instantiation_def_of">
        <rdfs:domain rdf:resource="&rdf_;INSTANTIATION_DEF"/>
        <rdfs:range rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_metadata_of_CLASS"
         rdfs:label="is_metadata_of_CLASS">
        <rdfs:range rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_object_for_instantiation_in"
         rdfs:label="is_object_for_instantiation_in">
        <rdfs:range rdf:resource="&rdf_;INSTANTIATION_DEF"/>
        <rdfs:domain rdf:resource="&rdf_;KBE_SYSTEM_PRIMITIVE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_object_spec_of"
         rdfs:label="is_object_spec_of">
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT-SPEC"/>
        <rdfs:range rdf:resource="&rdf_;KBE_OBJECT_VIEW"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_part_of_KBE_resource"
         rdfs:label="is_part_of_KBE_resource">
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
        <rdfs:range rdf:resource="&rdf_;KBE_RESOURCE"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;is_state_doc_in_eng-state"
         rdfs:label="is_state_doc_in_eng-state">
        <rdfs:range rdf:resource="&rdfs;Resource"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;kbeSt-kbeSt-rel-label"
         rdfs:label="kbeSt-kbeSt-rel-label">
        <rdfs:domain rdf:resource="&rdf_;rationale-kbeSt-kbeSt-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;message_name"
         rdfs:label="message name">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;note"
         rdfs:label="note">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;note-ent-rel-label"
         rdfs:label="note-ent-rel-label">
        <rdfs:domain rdf:resource="&rdf_;Note-entity-rel"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;operation_label"
         rdfs:label="operation label">
        <rdfs:domain rdf:resource="&rdf_;KBE_EXTERNAL_OPERATION"/>
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;queryBody"
         rdfs:label="queryBody">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;queryName"
         rdfs:label="queryName">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;rationale-kbeSt-kbeSt-rel"
         rdfs:label="rationale-kbeSt-kbeSt-rel">
        <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;receives-definitions-from-object"
         rdfs:label="receives-definitions-from-object">
        <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
        <rdfs:range rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;resulting_object_name"
         rdfs:label="resulting_object_name">
        <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;status"
```

```
        rdfs:label="status">
       <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;supplied_by_other_class"
        rdfs:label="supplied by other class">
       <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;supplier-class"
        rdfs:label="supplier-class">
       <rdfs:range rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;supplies-definitions-to-object"
        rdfs:label="supplies-definitions-to-object">
       <rdfs:domain rdf:resource="&rdf_;KBE-OBJECT"/>
       <rdfs:range rdf:resource="&rdf_;KBE-OBJECT"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;system-class-name"
        rdfs:label="system-class-name">
       <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&rdf_;term"
        rdfs:label="term">
       <rdfs:domain rdf:resource="&rdf_;INTERNAL_DECLARATION"/>
       <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdfs:Class rdf:about="&rdf_;userClass-InsSpec-rel"
        rdfs:label="userClass-InsSpec-rel">
       <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdfs:Class rdf:about="&rdf_;userClass-UserClass-rel"
        rdfs:label="userClass-UserClass-rel">
       <rdfs:subClassOf rdf:resource="&a;_directed_binary_relation"/>
</rdfs:Class>
<rdf:Property rdf:about="&rdf_;value"
        rdfs:label="value">
       <rdfs:domain rdf:resource="&rdf_;INSTANCE-SPEC"/>
       <rdfs:domain rdf:resource="&rdf_;INTERNAL_DECLARATION"/>
       <rdfs:range rdf:resource="&rdfs;Literal"/>
</rdf:Property>
<rdf:Property rdf:about="&a;_from"
        rdfs:label=":FROM"/>
<rdf:Property rdf:about="&a;_to"
        rdfs:label=":TO"/>
</rdf:RDF>
```

Appendix D

VALIDATION MEETINGS CHECKLIST

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: Ismail Deif

Organisation: DS – ENOVIA R+D

Role: Manager – Knowledge Engineering

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	☐	☑
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☐	☑	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	☐	☑
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	☑	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☐	☐	☑
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	☐	☑	☐
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	☑	☐
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	☑	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☐	☑	☐
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☑	☐	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☐	☐	☐	☑	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	☑	☐	☐

1.4 Additional space for comments

Process based representation, especially within ~~components~~ Classes, may be better referred to as data flow representation. It may actually represent the "reference" relationships common to KBE models.

Another process-based representation attempts to outline the steps that the user/engineer goes through while generating a design. From this perspective, there might be far fewer steps in a typical KBE application.

2. METADATA MODEL APLICABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☐	☐	☑	☐
The interactions between objects in a KBE resource	☐	☐	☐	☑	☐	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☑	☐
The patterns of repeated behaviour occurring at runtime	☐	☐	☑	☐	☐	☐
The load on each component at runtime	☑	☐	☐	☐	☐	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	☐	☑
The data structures used in the KBE resource	☐	☐	☐	☑	☐	☐
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☐	☑	☐
Adding or changing the functionality of the KBE resource	☐	☐	☐	☐	☑	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	☑	☐	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☐	☑	☐
Investigating runtime interactions in the KBE resource	☐	☐	☐	☑	☐	☐
Investigating how much a KBE code artefact is used	☐	☐	☑	☐	☐	☐
Investigating patterns in the KBE resource execution	☐	☑	☐	☐	☐	☐
Assessing the quality of the KBE resource design	☐	☐	☐	☑	☐	☐
Understanding the domain of the KBE resource	☐	☐	☐	☑	☐	☐

2.3 Additional space for comments

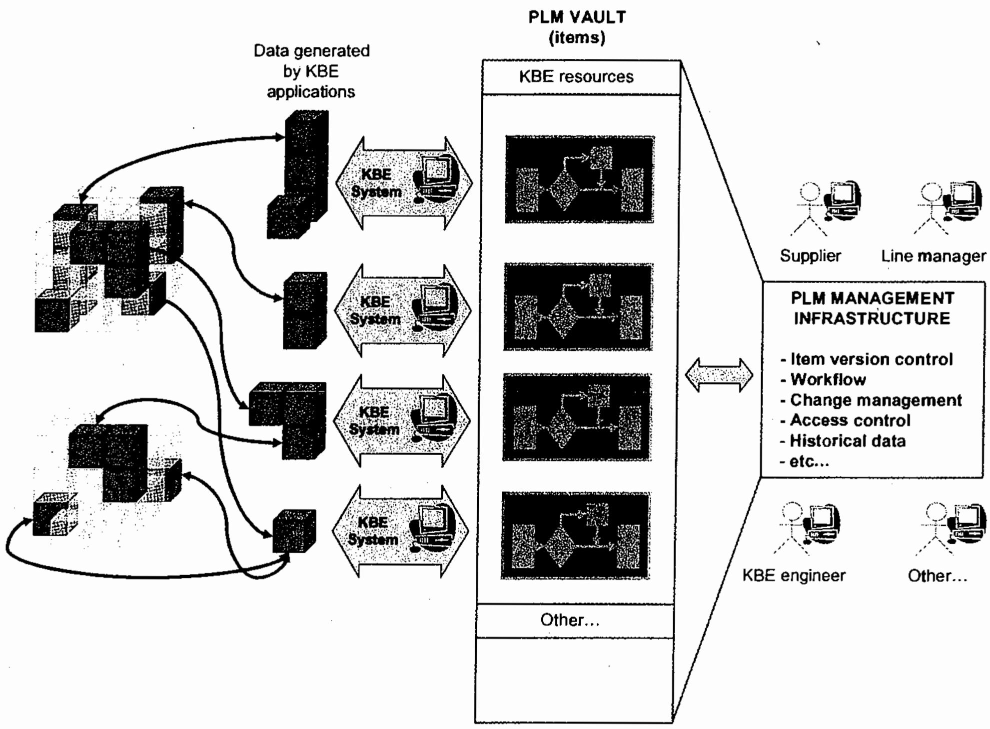
Runtime analysis is probably a very different thing. But there should be relationships between the structure, the functionality and patterns of resource execution and/or loads on components.
But the present metadata does not suppor that.

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
	↓	↓	↓	↓	↓	↓
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	☑	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☑	☐
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☑	☐
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☑	☐	☐

2.5 Additional space for comments

We are very seriously looking at similar concepts.

2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects



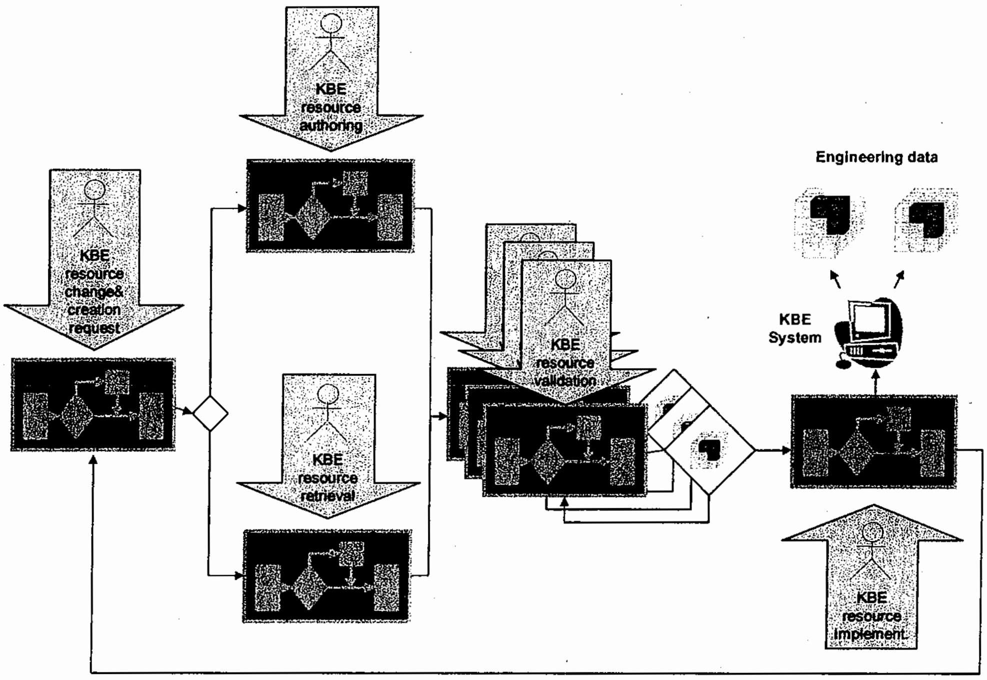
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☑	☐

2.7 Additional space for comments

Knowledge storage, management and reuse require the metadata and annotation shown.

~~These~~
Perhaps this use case and the next should be combined? Not sure, but both are requirements of knowledge management

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☑	☐

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	☐	☑	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☐	☐	☑
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☐	☑
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☐	☑	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	☐	☑	☐
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	☐	☑
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☑	☐	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	☐	☑	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☑	☐	☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☐	☑	☐
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☐	☐	☑	☐
As a support tool for the training of future KBE engineers.	☐	☐	☐	☑	☐	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☑	☐	☐
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☐	☑	☐	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☑	☐	☐	☐

3.3 Additional space for comments

No doubt that this formalization approach helps to better:
- document
- manage
- handle
- develop

KBE knowledge elements.
By better visualizing and understanding KBE components, they can be more easily updated, re-used, etc...
But eventually, there will be an explosion of knowledge elements, both vertically + horizontally. Only a PLM system can manage all of this successfully.

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: Mike Twelves

Organisation: CORUS AUTOMOTIVE ENGINEERING

Role: __________

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	X	☐
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☐	X	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	☐	X
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	X	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☐	X	☐
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	☐	☐	X
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	X	☐
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	X	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	X	☐	☐
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☐	X	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works. How they may visualise it working	☐	☐	☐	☐	X	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	☐	X	☐

1.4 Additional space for comments

2. METADATA MODEL APLICABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☐	☐	☒	☐
The interactions between objects in a KBE resource	☐	☐	☐	☐	☒	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☐	☒
The patterns of repeated behaviour occurring at runtime	☐	☒	☐	☐	☐	☐
The load on each component at runtime	☐	☒	☐	☐	☐	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	☐	☒
The data structures used in the KBE resource	☐	☐	☒	☐	☐	☐
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☐	☒	☐
Adding or changing the functionality of the KBE resource	☐	☐	☒	☐	☐	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	☐	☒	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☐	☒	☐
Investigating runtime interactions in the KBE resource	☐	☒	☐	☐	☐	☐
Investigating how much a KBE code artefact is used	☐	☒	☐	☐	☐	☐
Investigating patterns in the KBE resource execution	☐	☒	☐	☐	☐	☐
Assessing the quality of the KBE resource design	☐	☐	☐	☐	☒	☐
Understanding the domain of the KBE resource	☐	☐	☐	☐	☐	☒

2.3 Additional space for comments

Dependancies - within an application ✓
within a groop of applications ?

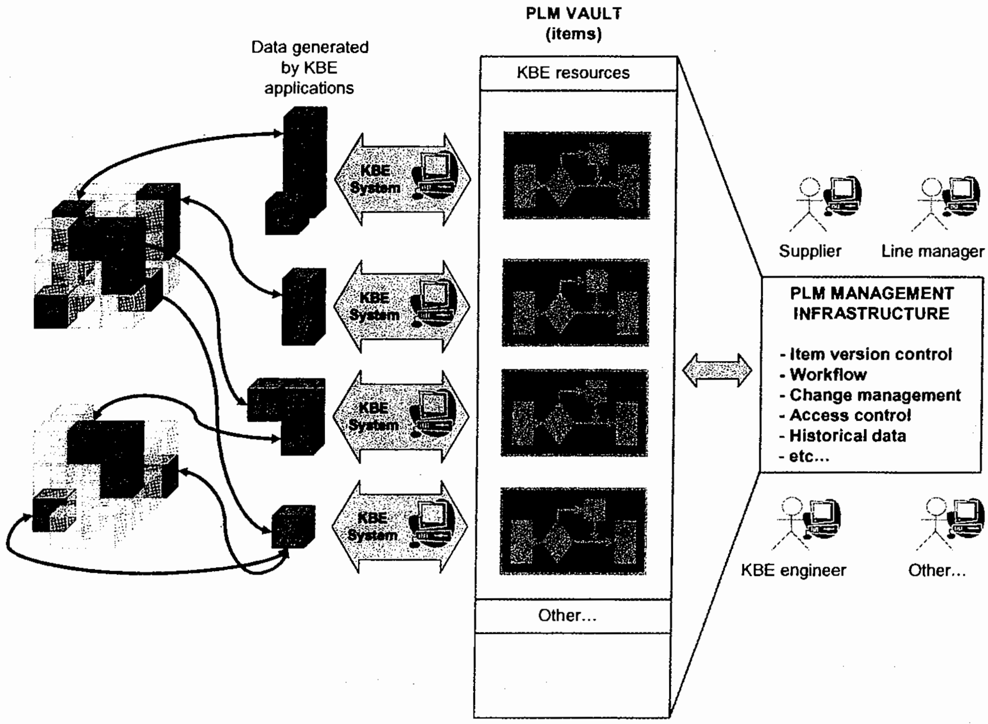
2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	☒	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☒	☐
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☒	☐
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☐	☒	☐

2.5 Additional space for comments

Metadata and change?

Move from keeping code up to date to keeping meta-data up to date. In most cases keeping meta-data up to date is an overhead. Smart ways to auto-update meta data would ensure (potential) benefits are fully leveraged.

2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects

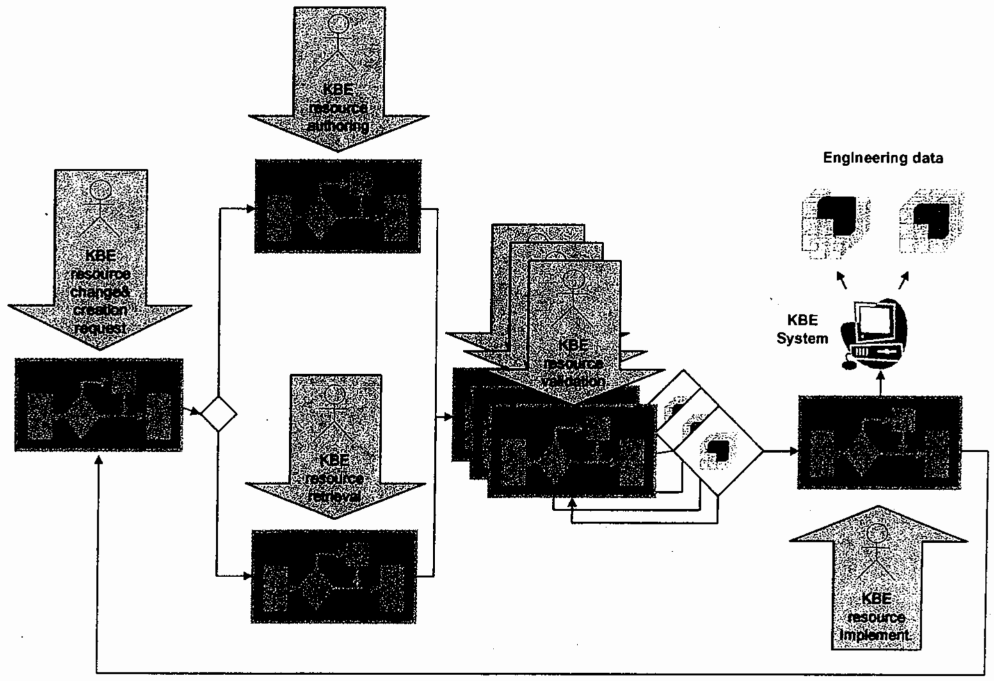


	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☒	☐

2.7 Additional space for comments

In the case of CAD-based KBE yes. For other elements of KBE not sure. Maybe a more general representation is here Service Oriented Architecture with a virtualisation layer between user & service

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☒	☐

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	☒	☐	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☐	☐	☒
PLM technology can be used as a KBE resource repository.	☒	☐	☐	☐	☐	☒
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☒	☐	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	☐	☒	☐
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	☒	☐
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☐	☐	☒
As a language to remotely specify KBE operations or services.	☐	☐	☐	☐	☐	☒
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☒	☐	☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☒	☐	☐
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☐	☐	☒	☐
As a support tool for the training of future KBE engineers.	☐	☐	☐	☐	☒	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☐	☒	☐
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☒	☐	☐	☐	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☐	☐	☒	☐

3.3 Additional space for comments

Big Challenge is to apply this for business benefit

- Need to get something back for putting data (effort) in

Big Opportunity is driving developme (code writing) from the Meta Model

- Auto update of meta model
- Consistent coding technique (KBE for KBE)

Scalability? Impact of changes not only in one application but across a range of applications.

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: Sean Yu

Organisation: Dassault Systems

Role: Software Engineer @ Knowledge Engineering Group

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	☐	☑
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☑	☑	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	☑	☐
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	☑	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☑	☐	☐
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	☑	☐	☐
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	☑	☐
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	☑	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☑	☐	☐
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☐	☑	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☐	☐	☐	☑	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	☐	☑	☐

1.4 Additional space for comments

- To build a meta model for integration between KBE & PLM is very valuable for enterprise information management as well as business intelligence.

- I'm really exited to see such approaches as ontology, metamodel and semantic interoperation.

2. METADATA MODEL APLICABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☐	☐	☐	☑
The interactions between objects in a KBE resource	☐	☐	☐	☐	☐	☑
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☐	☑
The patterns of repeated behaviour occurring at runtime	☐	☐	☐	☐	☐	☑
The load on each component at runtime	☐	☐	☐	☐	☑	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	☐	☑
The data structures used in the KBE resource	☐	☐	☐	☐	☐	☑
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☐	☐	☑
Adding or changing the functionality of the KBE resource	☐	☐	☐	☐	☐	☑
Investigating the internal structure of a KBE code artefact	☐	☐	☐	☐	☐	☑
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☐	☐	☑
Investigating runtime interactions in the KBE resource	☐	☐	☐	☐	☐	☑
Investigating how much a KBE code artefact is used	☐	☐	☐	☐	☐	☑
Investigating patterns in the KBE resource execution	☐	☐	☐	☐	☑	☐
Assessing the quality of the KBE resource design	☐	☐	☐	☐	☑	☐
Understanding the domain of the KBE resource	☐	☐	☐	☐	☐	☑

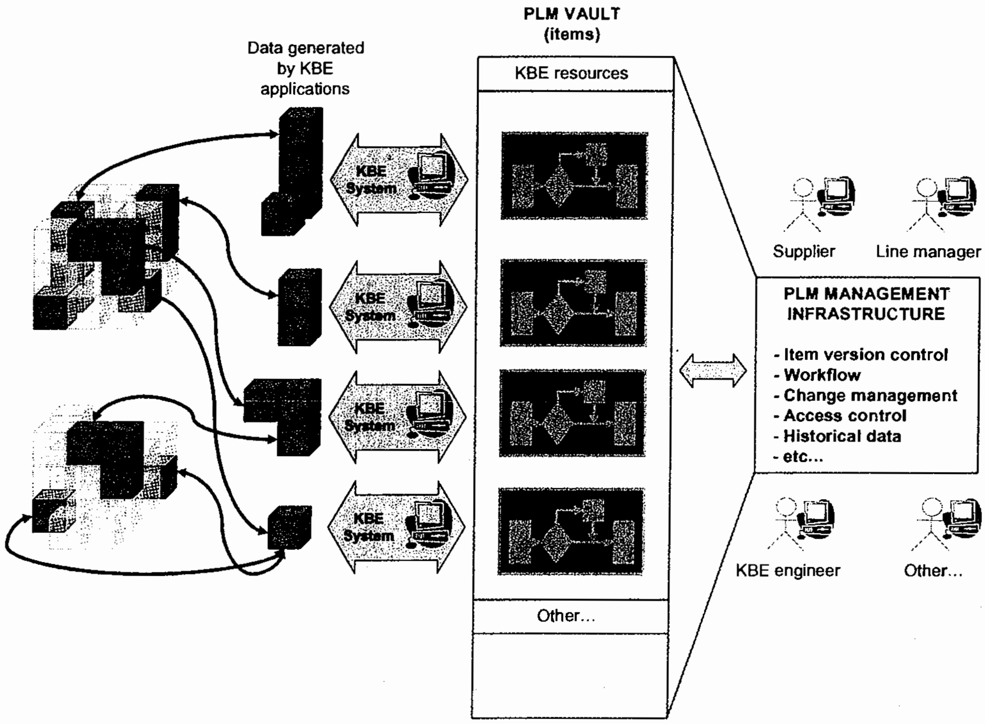
2.3 Additional space for comments

I personally see the need of managing enterprise IP in PLM. KBE as one of the most important way to define engineering IP, definitely has lifecycle on its applications and should be managed by PLM.

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	☑	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☐	☑
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☐	☑
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☐	☐	☑

2.5 Additional space for comments

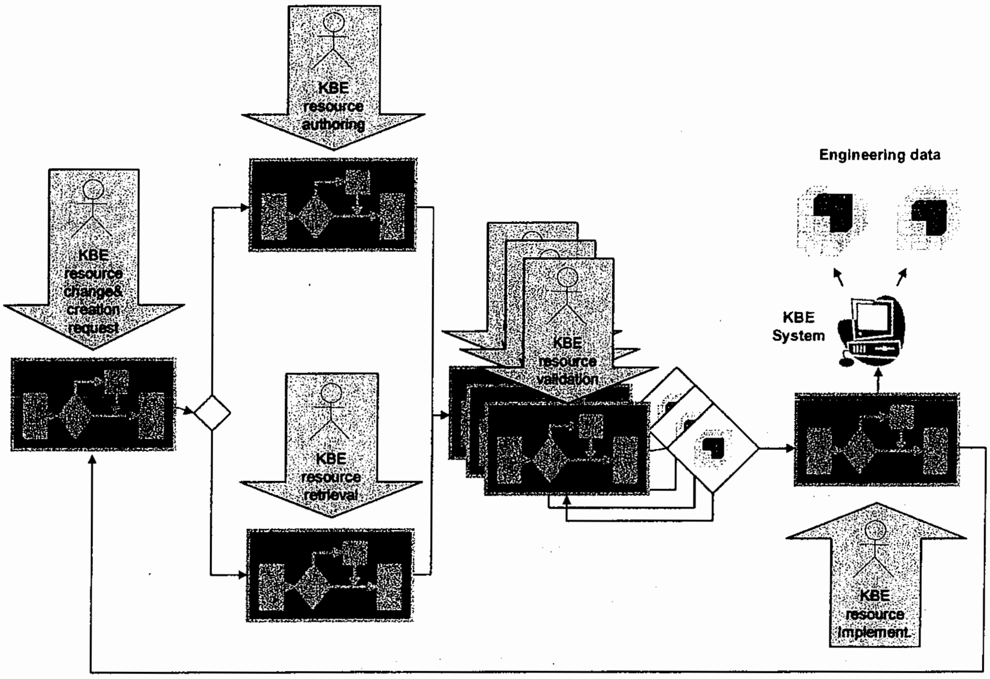
2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☐	☑

2.7 Additional space for comments

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☐	☑

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	☐	☐	☑
The approach improves existing KBE application documentation practices.	☐	☐	☐	☐	☐	☑
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☐	☑
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☐	☐	☑
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	☐	☐	☑
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	☐	☑
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☐	☑	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	☐	☑	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☐	☐	☑
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☐	☐	☑
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☐	☐	☐	☑
As a support tool for the training of future KBE engineers.	☐	☐	☐	☐	☐	☑
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☐	☐	☑
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☐	☐	☐	☑
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☐	☐	☑	☐

3.3 Additional space for comments

Good job!

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: Andy

Organisation:____________________

Role:____________________

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☑	☐	☐
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☐	☑	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☑	☐	☐	☐
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	☑	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☐	☑	☐
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	☐	☑	☐
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☑	☐	☐
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	☑	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☑	☐	☐
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☑	☐	☐	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☑	☐	☐	☐	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	☐	☐	☐

1.4 Additional space for comments

2. METADATA MODEL APLICABILITY

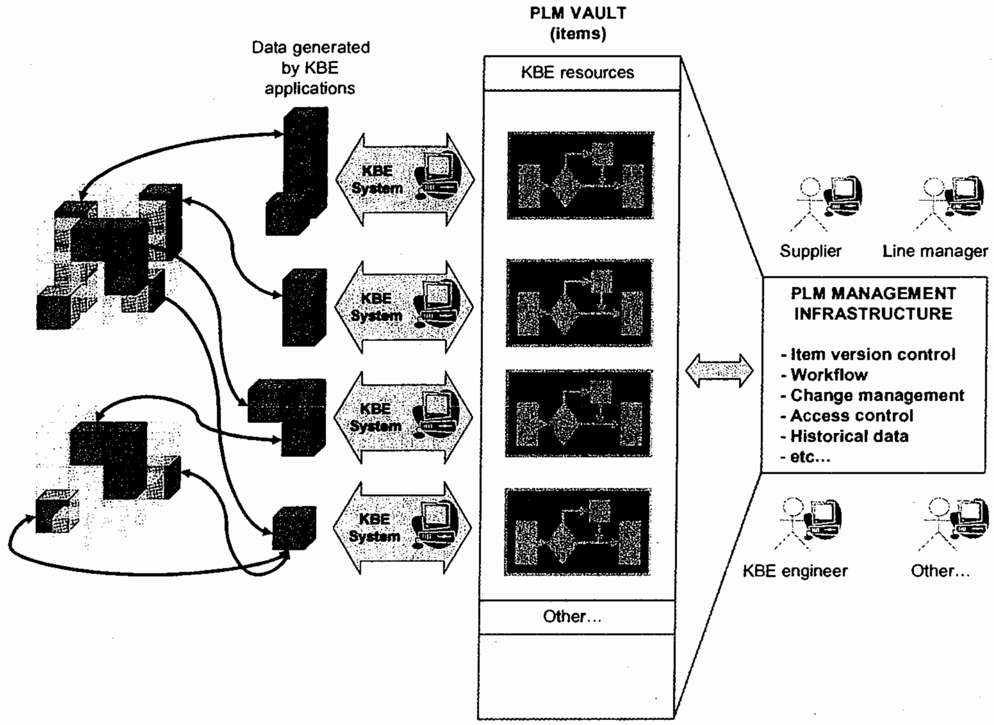
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☑	☐	☐	☐
The interactions between objects in a KBE resource	☐	☐	☑	☐	☐	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☑	☐
The patterns of repeated behaviour occurring at runtime	☐	☑	☐	☐	☐	☐
The load on each component at runtime	☐	☐	☐	☐	☐	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	☐	☐
The data structures used in the KBE resource	☐	☐	☐	☐	☐	☐
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☑	☐	☐	☐	☐
Adding or changing the functionality of the KBE resource	☐	☑	☐	☐	☐	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	☐	☑	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☐	☑	☐
Investigating runtime interactions in the KBE resource	☐	☐	☑	☐	☐	☐
Investigating how much a KBE code artefact is used	☐	☐	☐	☐	☑	☐
Investigating patterns in the KBE resource execution	☐	☑	☐	☐	☐	☐
Assessing the quality of the KBE resource design	☑	☐	☐	☐	☐	☐
Understanding the domain of the KBE resource	☐	☐	☐	☐	☑	☐

2.3 Additional space for comments

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☑	☐	☐	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☑	☐
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☑	☐
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☑	☐	☐	☐	☐

2.5 Additional space for comments

2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects

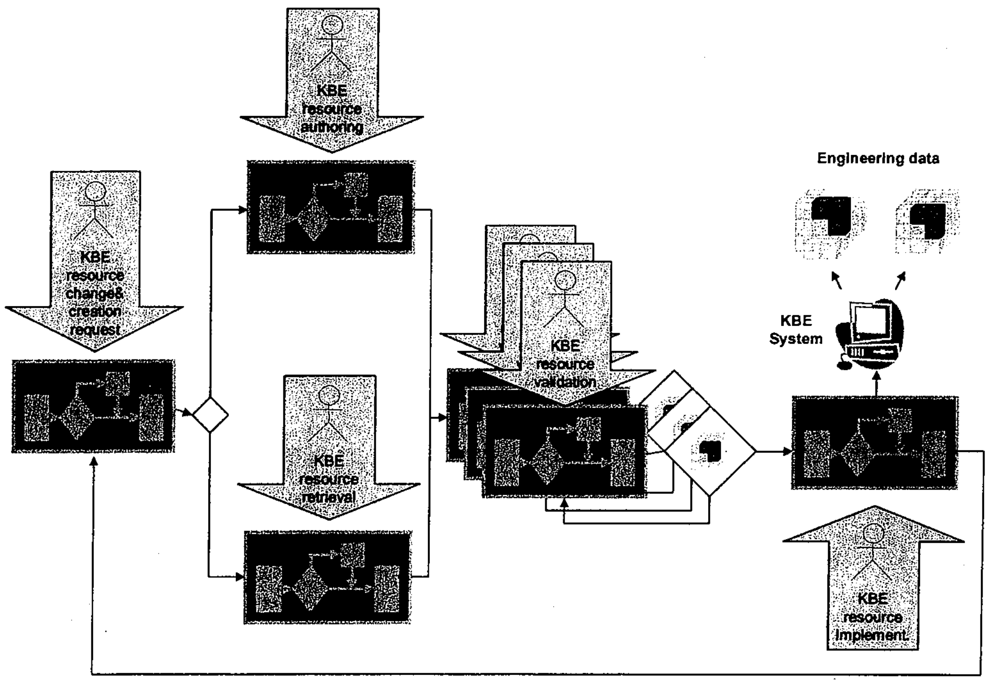


	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☒	☐	☐	☐

2.7 Additional space for comments

The annotation should be at the KBE resources level.

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☐	☐

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☑	☐	☐	☐	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☑	☐	☐
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☐	☑
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☑	☐	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☑	☐	☐	☐
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☑	☐	☐	☐
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☑	☐	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	☑	☐	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☑	☐	☐	☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☑	☐	☐
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☐	☑	☐	☐
As a support tool for the training of future KBE engineers.	☐	☑	☐	☐	☐	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☑	☐	☐	☐	☐	☐
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☐	☑	☐	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☑	☐	☐	☐

3.3 Additional space for comments

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: Hsin-Chi Chang

Organisation: Enovia (KTI)

Role: Software Engineer.

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	☑	☐
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☐	☑	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	☑	☐
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☑	☐	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☐	☑	☐
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☑	☐	☐	☐
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	☑	☐
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☑	☐	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☐	☐	☑
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☐	☑	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☐	☐	☑	☐	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	☐	☑	☐

1.4 Additional space for comments

2. METADATA MODEL APLICABILITY

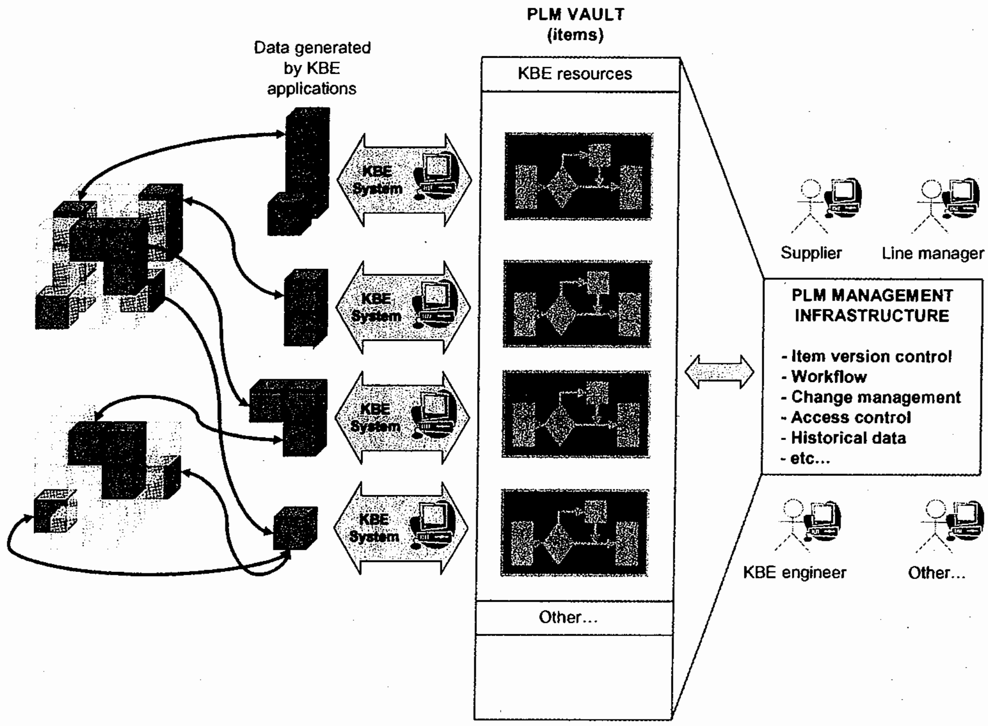
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☐	☐	☑	☐
The interactions between objects in a KBE resource	☐	☐	☐	☑	☐	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☑	☐
The patterns of repeated behaviour occurring at runtime	☐	☐	☐	☐	☐	☐
The load on each component at runtime	☐	☐	☐	☑	☐	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	☑	☐
The data structures used in the KBE resource	☐	☐	☐	☑	☐	☐
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☑	☐	☐
Adding or changing the functionality of the KBE resource	☐	☐	☐	☐	☑	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	☐	☑	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☑	☐	☐
Investigating runtime interactions in the KBE resource	☐	☐	☑	☐	☐	☐
Investigating how much a KBE code artefact is used	☐	☐	☐	☑	☐	☐
Investigating patterns in the KBE resource execution	☐	☐	☐	☐	☐	☑
Assessing the quality of the KBE resource design	☐	☐	☐	☑	☐	☐
Understanding the domain of the KBE resource	☐	☐	☐	☑	☐	☐

2.3 Additional space for comments

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	☑	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☑	☐
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☑	☐
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☑	☐	☐

2.5 Additional space for comments

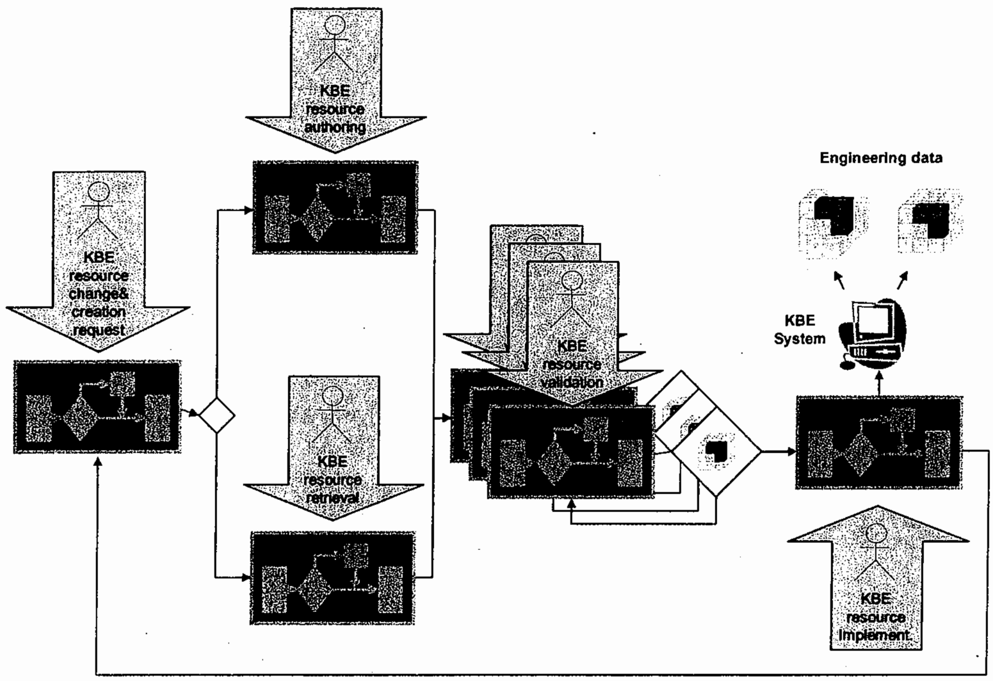
2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☑	☐

2.7 Additional space for comments

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☑	☐	☐

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	☐	☑	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☑	☐	☐
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☐	☑
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☐	☑	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	☐	☑	☐
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	☑	☐
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☑	☐	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	☑	☐	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☐	☑	☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☐	☑	☐
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☑	☐	☐	☐
As a support tool for the training of future KBE engineers.	☐	☐	☐	☐	☑	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☐	☑	☐
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☑	☐	☐	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☑	☐	☐	☐

3.3 Additional space for comments
* KBE user should not know he is using KBE or non-KBE Applica

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: MANOJ VADICHARLA

Organisation: DASSAULT SYSTEMES

Role: Senior Software Engineer

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	☐	☐
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☐	☒	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	☒	☐
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	☒	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☒	☒	☐
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	☐	☐	☒
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	☐	☒
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	☐	☒
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☒	☐	☐
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☐	☒	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☐	☐	☒	☐	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☒	☐	☐	☐

1.4 Additional space for comments

2. METADATA MODEL APLICABILITY

2.1 The KBE resources metadata supports the comprehension of the following aspects:	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The class structure of a KBE resource	☐	☐	☐	☐	☒	☐
The interactions between objects in a KBE resource	☐	☐	☐	☐	☒	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☐	☒
The patterns of repeated behaviour occurring at runtime	☐	☐	☐	☐	☒	☐
The load on each component at runtime	☐	☐	☐	☒	☐	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	☒	☐
The data structures used in the KBE resource	☐	☐	☐	☐	☒	☐

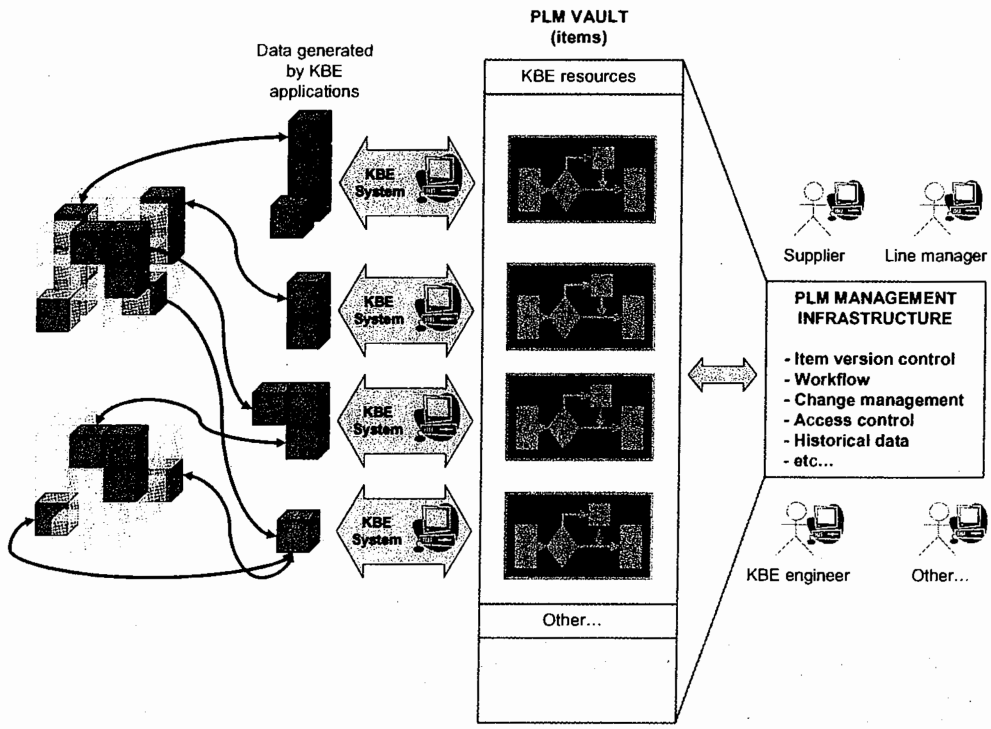
2.2 The KBE resources metadata helps to carry out the following tasks:	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☐	☒	☐
Adding or changing the functionality of the KBE resource	☐	☐	☐	☐	☒	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	☒	☐	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☐	☒	☐
Investigating runtime interactions in the KBE resource	☐	☐	☐	☐	☒	☐
Investigating how much a KBE code artefact is used	☐	☐	☐	☐	☒	☐
Investigating patterns in the KBE resource execution	☐	☐	☐	☐	☒	☐
Assessing the quality of the KBE resource design	☐	☐	☐	☒	☐	☐
Understanding the domain of the KBE resource	☐	☐	☐	☐	☒	☐

2.3 Additional space for comments

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	☒	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☒	☐
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☒	☐
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☐	☐	☒

2.5 Additional space for comments

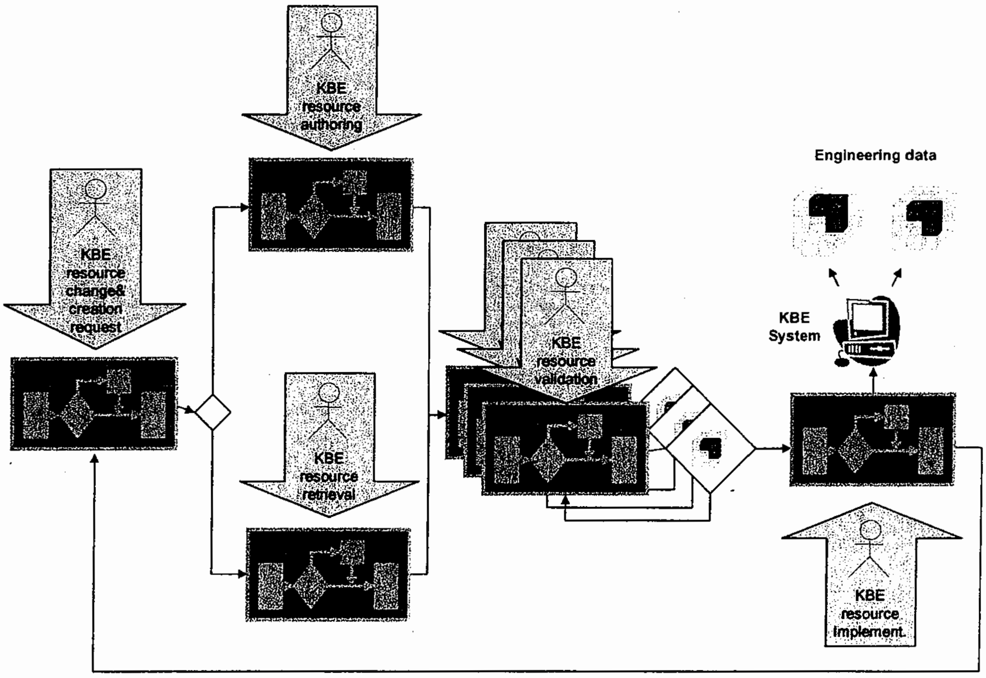
2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☒	☐

2.7 Additional space for comments

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☐	☒

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	☐	☒	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☐	☐	☒
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☒	☐
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☐	☒	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	☐	☒	☐
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	☒	☐
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☒	☐	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	☐	☒	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☐	☒	☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☐	☒	☐
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☐	☐	☒	☐
As a support tool for the training of future KBE engineers.	☐	☐	☐	☐	☒	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☒	☐	☐
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☐	☐	☒	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☐	☐	☒	☐

3.3 Additional space for comments

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: __Adrian Murton________________________________

Organisation:__Airbus UK____________________________

Role:___KBE Product Line Manager_____________________________

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	☐	✓
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	☐	✓	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	✓	☐
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	✓	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☐	☐	✓
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	☐	✓	☐
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	☐	✓
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	✓	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☐	☐	✓
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☐	✓	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☐	☐	✓	☐	☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	☐	✓	☐

1.4 Additional space for comments

2. METADATA MODEL APLICABILITY

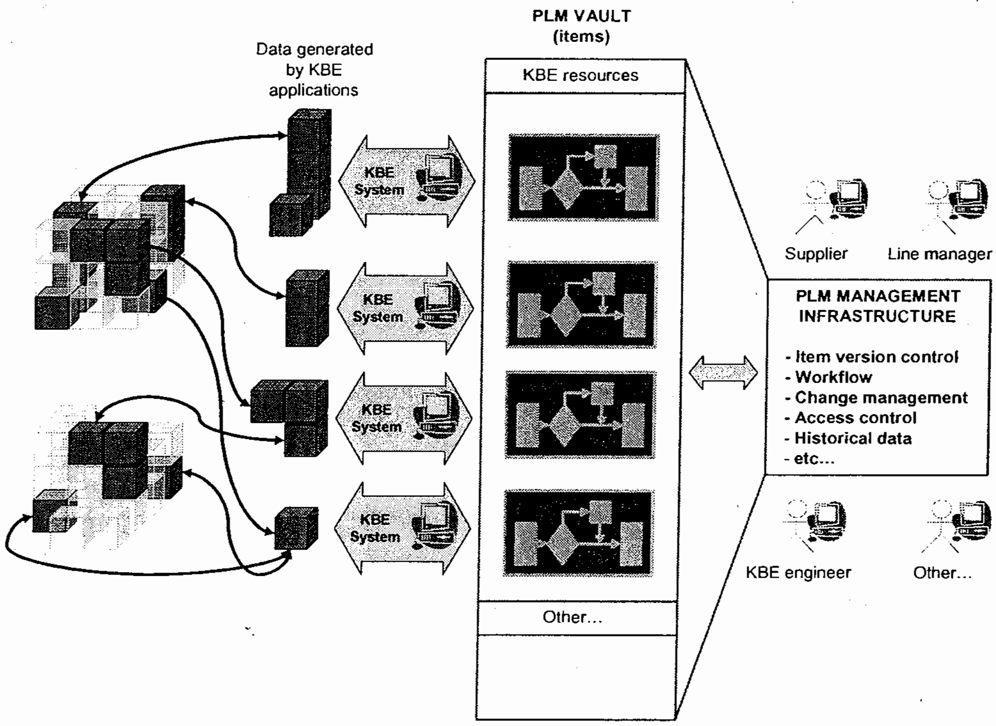
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☐	☐	✓	☐
The interactions between objects in a KBE resource	☐	☐	☐	☐	✓	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☐	✓
The patterns of repeated behaviour occurring at runtime	☐	☐	☐	✓	☐	☐
The load on each component at runtime	☐	☐	☐	✓	☐	☐
The impact of changes in the KBE resource	☐	☐	☐	☐	✓	☐
The data structures used in the KBE resource	☐	☐	☐	☐	✓	☐
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☐	✓	☐
Adding or changing the functionality of the KBE resource	☐	☐	☐	☐	✓	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	✓	☐	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	✓	☐	☐
Investigating runtime interactions in the KBE resource	☐	☐	☐	✓	☐	☐
Investigating how much a KBE code artefact is used	☐	☐	☐	✓	☐	☐
Investigating patterns in the KBE resource execution	☐	☐	☐	✓	☐	☐
Assessing the quality of the KBE resource design	☐	☐	☐	☐	☐	✓
Understanding the domain of the KBE resource	☐	☐	☐	☐	☐	✓

2.3 Additional space for comments

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	✓	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	☐	☐	✓
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☐	✓
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☐	✓	☐

2.5 Additional space for comments

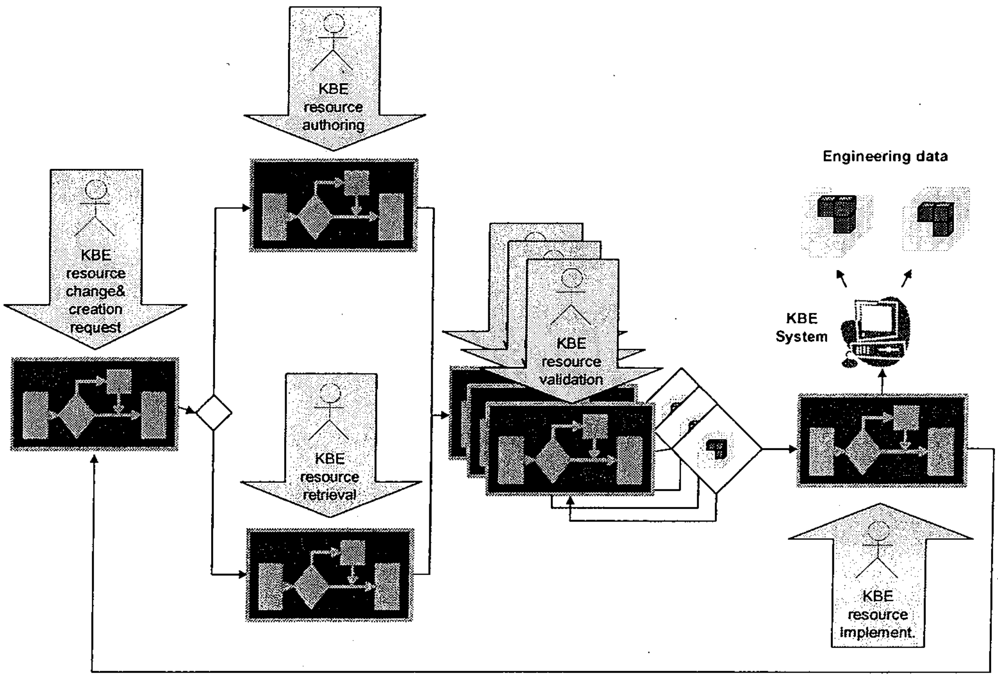
2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☐	✓

2.7 Additional space for comments

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	✓	☐

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	☐	✓	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☐	☐	✓
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☐	✓
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☐	✓	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	☐	☐	✓
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	☐	✓
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☐	✓	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	☐	✓	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☐	✓	☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☐	☐	✓
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	☐	☐	✓	☐
As a support tool for the training of future KBE engineers.	☐	☐	☐	☐	✓	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☐	☐	✓
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☐	☐	✓	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☐	✓	☐	☐

3.3 Additional space for comments

Validation protocol

What is to be assessed: **A metadata model to describe KBE applications as resources in distributed computing environments.**

Procedure

1. Give a description of the metadata model

2. Distribute a validation criteria checklist covering:
- CORRECTNESS OF THE MODEL
- APPLICABILITY FOR KBE/PLM INTEGRATION
- TRANSFERABILITY

3. Discuss and record each of the validation criteria

Name: ______Harshal Trivedi___________________

Organisation:________INCAT Ltd. (A Tata Technologies Company)

Role:______Deputy Manager (Engineering Automation Group)______

1. METADATA MODEL CORRECTNESS

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
1.1 Overall approach: KBE resource description via metadata models	↓	↓	↓	↓	↓	↓
Supporting the interoperability between KBE and PLM systems via metadata describing KBE resources is a recommendable approach.	☐	☐	☐	☐	√☐	☐
The scope of the metadata model to describe KBE applications structure and functionality is appropriate.	☐	☐	☐	√☐	☐	☐
The creation of a specific metadata model to become a KBE resource blueprint has potential benefits to promote the understanding of KBE applications.	☐	☐	☐	☐	☐	√☐
The decomposition of the metadata model into entities to describe KBE resource structure and entities to describe KBE resource functionality.	☐	☐	☐	☐	√☐	☐
The use of Model Driven Engineering principles in the KBE development domain shall beneficial for KBE implementation practice.	☐	☐	☐	☐	☐	√☐
1.2 Metadata model for describing the structure of KBE resources	↓	↓	↓	↓	↓	↓
Indexing the structure of KBE resources as proposed in the metadata model is useful for KBE experts to retrieve and reuse fragments of KBE codes.	☐	☐	☐	√☐	☐	☐
The visualisation of KBE applications structure is useful to share large applications with other KBE developers.	☐	☐	☐	☐	☐	√☐
The KBE component view is useful to understand the functionality of KBE resources.	☐	☐	☐	☐	√☐	☐
1.3 Metadata model for describing the functionality of KBE resources	↓	↓	↓	↓	↓	↓
The use of a process based definition model to express the rationale within KBE class codes is a valuable approach to specify KBE resources.	☐	☐	☐	☐	√☐	☐
Slicing KBE codes and representing them using the predefined workflow activities facilitates the comprehension of KBE resources.	☐	☐	☐	☐	√☐	☐
Mapping KBE application expressions to process activities helps non KBE experts to visualise how the application works.	☐	☐	☐	☐	☐	√☐
The proposed KBE specific activities cover a wide range of situations within KBE classes.	☐	☐	☐	√☐	☐	☐

1.4 Additional space for comments

2. METADATA MODEL APLICABILITY

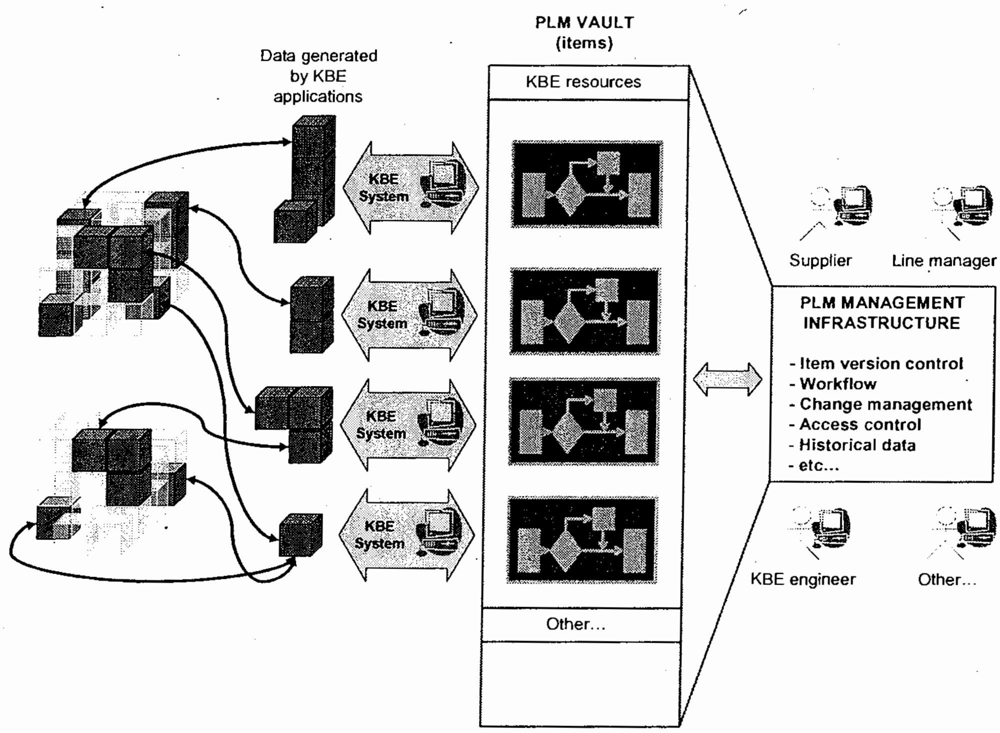
	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
2.1 The KBE resources metadata supports the comprehension of the following aspects:	↓	↓	↓	↓	↓	↓
The class structure of a KBE resource	☐	☐	☐	☐	√☐	☐
The interactions between objects in a KBE resource	☐	☐	☐	√☐	☐	☐
The high-level structure/architecture of a KBE resource	☐	☐	☐	☐	☐	√☐
The patterns of repeated behaviour occurring at runtime	☐	☐	☐	☐	√☐	☐
The load on each component at runtime	☐	☐	☐	☐	√☐	☐
The impact of changes in the KBE resource	☐	☐	☐	√☐	☐	☐
The data structures used in the KBE resource	☐	☐	√☐	☐	☐	☐
2.2 The KBE resources metadata helps to carry out the following tasks:	↓	↓	↓	↓	↓	↓
Investigating the functionality of a KBE resource (or part of it)	☐	☐	☐	☐	√☐	☐
Adding or changing the functionality of the KBE resource	☐	☐	☐	√☐	☐	☐
Investigating the internal structure of a KBE code artefact	☐	☐	☐	√☐	☐	☐
Investigating the dependencies between KBE code artefacts	☐	☐	☐	☐	√☐	☐
Investigating runtime interactions in the KBE resource	☐	☐	☐	√☐	☐	☐
Investigating how much a KBE code artefact is used	☐	☐	☐	☐	√☐	☐
Investigating patterns in the KBE resource execution	☐	☐	☐	☐	√☐	☐
Assessing the quality of the KBE resource design	☐	☐	☐	☐	☐	√☐
Understanding the domain of the KBE resource	☐	☐	☐	☐	√☐	☐

2.3 Additional space for comments

2.4 Business functionalities elicited from KBE practitioners and the contribution of the proposed metadata model to achieve them	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
BF1. The use of the proposed metadata model to describe KBE resources promotes their modularity and easier development as they are more easily created by assembling documented components.	☐	☐	☐	☐	√☐	☐
BF2. The use of the proposed metadata model to describe KBE resources increases the efficiency in maintaining and updating KBE resources due to engineering changes.	☐	☐	☐	√☐	☐	☐
BF3. The proposed metadata model helps to formalise the representation of KBE resources.	☐	☐	☐	☐	☐	√☐
BF4. The use of the proposed metadata to describe KBE resources increases their transparency for non KBE experts.	☐	☐	☐	☐	☐	√☐

2.5 Additional space for comments

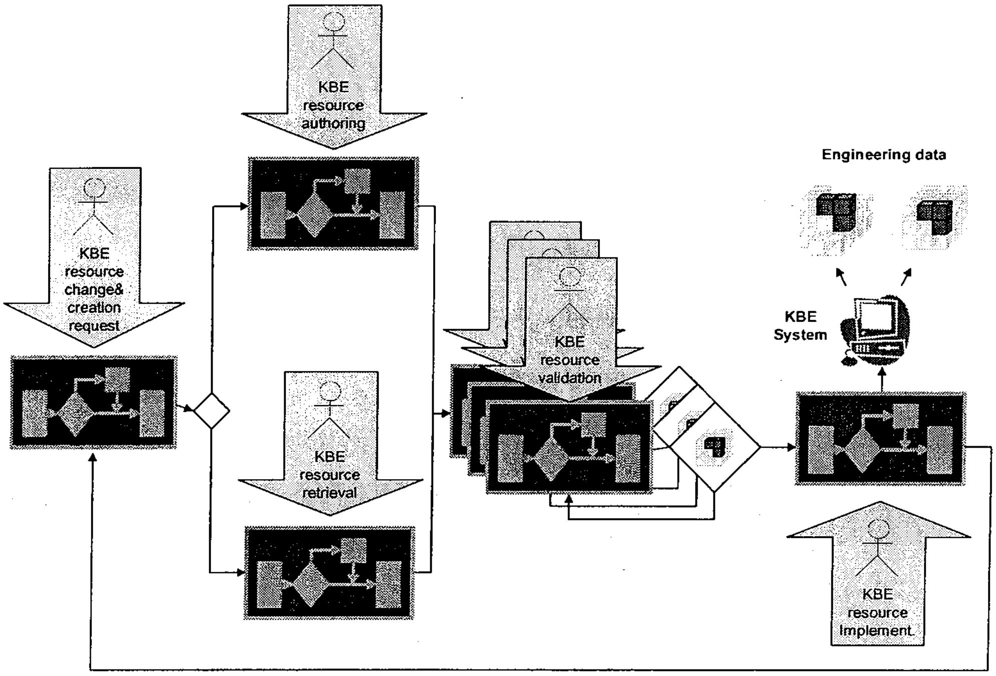
2.6 Use case: KBE resources become annotated PLM items to support reusability across engineering projects



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	√☐	☐

2.7 Additional space for comments

2.8 Use case: KBE resource lifecycle management



	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
The presented metadata model contributes to achieve this use case.	☐	☐	☐	☐	☐	√☐

2.9 Additional space for comments

3. METADATA MODEL TRANSFERABILITY

	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
3.1 PLM/KBE interoperability use cases and the contribution of the proposed metadata model to achieve them	↓	↓	↓	↓	↓	↓
The approach can be scaled up to industrial KBE implementations.	☐	☐	☐	√☐	☐	☐
The approach improves existing KBE application documentation practices.	☐	☐	☐	☐	√☐	☐
PLM technology can be used as a KBE resource repository.	☐	☐	☐	☐	☐	√☐
PLM systems could use the approach to specifically describe KBE items.	☐	☐	☐	☐	√☐	☐
3.2 The proposed metadata model for KBE resource description has potential…	↓	↓	↓	↓	↓	↓
As a contribution towards the automated generation of KBE code.	☐	☐	☐	√☐	☐	☐
As a mechanism to retain engineering knowledge for future retrieval and reuse.	☐	☐	☐	☐	√☐	☐
As a mechanism to retain KBE coding best practices.	☐	☐	☐	☐	√☐	☐
As a language to remotely specify KBE operations or services.	☐	☐	☐	√☐	☐	☐
As a language for KBE developers to communicate with engineering experts about the functionality of KBE resources.	☐	☐	☐	☐	☐	√☐
As a contribution to create a standard to support the interoperability between KBE software systems.	☐	☐	☐	☐	√☐	☐
As a language to leverage "KBE development by contract" between KBE users and developers.	☐	☐	√☐	☐	☐	☐
As a support tool for the training of future KBE engineers.	☐	☐	☐	☐	√☐	☐
As a mechanism to systematise/standardise KBE coding practices across an organisation.	☐	☐	☐	☐	☐	√☐
As a generic model to reuse legacy KBE applications through the use of data mining techniques.	☐	☐	☐	☐	√☐	☐
As a data gathering model for recoding the execution of design activities at runtime using CAD technology.	☐	☐	☐	√☐	☐	☐

3.3 Additional space for comments