ENTERPRISE MODELLING AND KNOWLEDGE MANAGEMENT: TOWARD A UNIFIED ENTERPRISE KNOWLEDGE MODELLING

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Summary: Information and knowledge are becoming strategic resources of companies in addition to traditional ones. Therefore, information and communication technologies can be considered today as strategic technologies, and knowledge is considered as the key capital of enterprises. The main objective of this paper is to study the complementarity nature of enterprise modelling and knowledge management and keep track of the benefits of this complementarity. A strong point of view to compare these notions is to study the modelling approaches of each domain. To do so, we evaluate some important methodologies in each domain and then several modelling points of view are explained. By reviewing CommonKADS, MASK, CIMOSA, and GIM methodologies and their modelling views we propose a generic classification of the views as a global enterprise knowledge modelling. This classification is useful both for the practitioners and scientific to deal with knowledge and its modelling in enterprises.

Keywords: Enterprise Modelling, Knowledge Management, Knowledge modelling, enterprise knowledge modelling.

Résumé: L'information et la connaissance deviennent des ressources stratégiques des entreprises. Par conséquent, les informations et les technologies de communication peuvent être considérés aujourd'hui comme des technologies stratégiques, et connaissance est considérée comme le capital primordial des entreprises. Le principal objectif de ce papier est d'étudier la complémentarité de la modélisation d'entreprise et gestion des connaissances. Un point de comparaison de ces notions est d'étudier les approches de modélisation de chaque domaine. Pour ce faire, nous évaluons certaines méthodes dans chaque domaine. A travers de cette comparaison entre les méthodes CommonKADS, MASK, CIMOSA, et GRAI/GIM et leurs points de vue, nous proposons une classification générique des vues comme une modélisation globale de connaissance en entreprise.

Mots clé: Modélisation d'entreprise, gestion des connaissance, modélisation des connaissances,

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1 - INTRODUCTION

Globalisation as the process of creating of a common, world-wide and free market no doubt represents one of the key features of the external environment of our business systems today. Globalisation as the result of the rapid development of information and communication technologies (fast access to accurate and reliable data), transport systems and consideration of common standards also allows the fusion of local and national markets into a global one and is one reason for mergers of previous competitors [7].

Unpredictability and changeability in the internal and the external environment, is experienced by enterprises as *turbulence* [12], and requires responsiveness and flexibility in the organisation and in the execution of processes as well.

A product represents today just a material base for the connection of an enterprise with customers. Therefore, enterprises are directed into the integration of all aspects of business activity from customers and suppliers covering all phases in the product life-cycle.

Information and *knowledge* are becoming strategic resources of companies in addition to traditional ones such as raw material or energy, which use to be basis of progress of national economies for decades [12]. Therefore, information and communication technologies can be considered today as strategic technologies, and knowledge is considered as the key capital of enterprises.

This in turn is the motivation for the development of so-called knowledge management (KM) and its supporting tools, called knowledge management systems (KMS). One aspect of KM is the objective to transform implicit and tacit knowledge into an explicit formal representation, and to distribute it throughout the organisation (availability and re-usability of the enterprise knowledge).

Surviving in today's highly competitive and ever expanding worldwide economy requires a skilful management capable of monitoring and controlling highly complex problem situations and systems involving a growing number of interdependent parameters and variables. This phenomenon can be witnessed in a wide variety of organizations, institutions, and industries ranging from traditional manufacturing to software companies, medical facilities to government agencies. Increasing complexity of enterprise systems has stimulated the development of sophisticated methods and tools for enterprise modelling and analysis. Nevertheless, enterprise modelling and analysis methods remain largely unharnessed, and advances in modelling and analysis theories have yet to filter into the

mainstream of managerial decision-making [8].

In this complex context we believe that the two domains of enterprise modelling and knowledge management are the mutually completed solutions that together will provide helpful guideline to the enterprises by treating the knowledge and its sharing. One of the main finality of enterprise modelling is integration concept which aims at providing quickly the right information at the right place at the right time under the right format throughout the enterprises. Here we can find the intersection of two notions: their objective is to provide the right knowledge and information to learn and to make the right decision.

The paper is organised as below: in the second section we will bring our hypothesis and objectives of this study. In third and fourth sections, the main views and approaches in enterprise modelling and knowledge modelling tools are explained. The comparison of enterprise modelling and knowledge management views concerning modelling aspect is described in section five. The paper ends by some conclusions.

2 - ASSUMPTIONS AND OBJECTIVES

For the last 10 years, in the field of design and control of production systems, the scientific community has progressively shifted from a focus on information-based integration and control of opertional performances, towards an even more complex view on integration, including the firm's cognitive dimension as an additional aspect of performances. In this perspective, the efficient management of human capital becomes a strategic objective. The management and control of knowledge and skills have turned out to be essential factors of industrial processes' performance [4]. The notion of human resource and its impact on performances has to be considered in all its complexity. Such complexity can partially be managed by new modelling and decision aid approaches, based on a deeper formalisation of concepts like skills, competence, and knowledge.

Current research on the link between knowledge/skills/competence and the performance of industrial processes encompasses most of phases of product and processes life cycles: from design, through manufacturing and maintenance, to the distribution and services. The scientific area of competence and human resources modelling bridges all business processes and requires generic concepts, distinct types of applications.

We, in the field of operations management, ought to be at the forefront of research and practice in knowledge management. Yet our scholars are almost absent in the knowledge management literature and our practitioners are often relegated to the back seat in their companies' knowledge management campaigns. Ultimately, all knowledge management efforts in business organizations are supposed to help the organization produce and deliver better products and services— i.e.,

enable us in the production and operations management function do a better job.

This paper is based upon some sort of assumptions:

1) Enterprise modelling and knowledge management are two notions with the complementary nature to deal with complexity and rapid changing environment.

2) One of the major and important points of view to profit from these complementarities is to study the different modelling views and tools in each field.

3) Although there are some sorts of tools and formalisms to deal with knowledge modelling in KM field, we believe that the CommonKADS and MASK are two methods that could be cover most aspects of knowledge modelling in the enterprises with several views and formalisms.

4) Consequently in enterprise modelling field we based our study on two major methods by the supposition that these two models cover most of views in enterprise modelling. These methods are CIMOSA and GIM methodology.

3 - KM AND KNOWLEDGE MODELLING TECHNIQUES

3.1 - The nature of knowledge and its sharing

Several different definitions of knowledge can be found in literature [1, 3]. According to [10] knowledge can be defined as the meaningful structured accumulation of information.

Zack and Serino [15] divide knowledge into two groups: explicit knowledge and tacit knowledge.

Explicit knowledge is knowledge that has been formally articulated and written down. Therefore, such knowledge can be shared and spread.

Tacit knowledge is developed and derives from the practical environment (therefore, it can be also called knowledge from practice). Such knowledge is usually highly pragmatic and specific to situations in which it developed. Tacit knowledge is subconscious, it is understood and used, but at the same time difficult to formalise (albeit not always impossible to externalise—tacit knowledge is, for example, suitable for exchange through direct conversation, telling of stories, and going through joint experience).

From modelling point of view, the tools and techniques that help to model this knowledge in the enterprises context are the main approaches to share and transfer knowledge. Although in the literature we can find the approaches to model knowledge, there is not several frameworks and methodologies which directly model knowledge. The CommonKADS knowledge engineering methodology and MASK method are two methods that try to help knowledge sharing and transfer by applying knowledge engineering and knowledge capitalization tools with developing some formalism. In this paper we will based our study on these two major methods in knowledge modelling.

3.2 - knowledge modelling view in CommonKADS methodology

CommonKADS [11] provides a complete methodology for the development of knowledge based systems (KBS). The methodology describes principles, techniques, modelling languages, and document structures to assist in three phases of the construction of a KBS.

The *'contextual analysis'* phase focuses on the organisation that will eventually use the system, describing the business processes, resources, and knowledge assets of the organisation, as well as describing the impact that the KBS will have on the system. In the second *'conceptual analysis'* phase the methodology is used to clarify the knowledge that the KBS will be required to represent, the reasoning that it will be required to perform on that knowledge, and the interactions that it will be required to perform with users and other external agents. In the third *'design'* phase the methodology is used to create a design for the KBS that can easily be translated into code in some appropriate programming language (see Fig. 1).

The methodology supports most aspects of a knowledge system development project, including project management, organizational analysis, knowledge acquisition, conceptual modelling, user interaction, system integration and design. Moreover, the CommonKADS methodology provides a structured approach to knowledge engineering.

CommonKADS approach uses six models that support these principles (Fig. 1):

1. The Organization Model (OM) identifies problems, opportunities and potential solutions in an organizational context and describes the high level organizational processes and associated knowledge assets. Fine worksheets support the organisation model namely; the organization model OM-1 identifies the problems and opportunities, OM-2 describes the variant aspects of an organization, An OM-3 shows how a process is broken down into tasks and names the agents and knowledge assets needed to carry out each task, An OM-4 describes each knowledge asset in more detail, and OM-5 defines the business, technical, project feasibility of the proposed solution and outlines the proposed research actions.

2. The Task Model (TM) describes the decomposition of organizational process into tasks and associated knowledge asset characteristics required to carry out the tasks. The task model describes each of the tasks identified in the organization model in more detail. Each task is represented by a CommonKADS TM-1 worksheet. TM-2 specifies the knowledge employed for a task and possible bottlenecks and area of improvement.

3. The Agent Model (AM) describes the characteristics of the human or the software component that carries out the execution of tasks. CommonKADS describes an agent as any human or software system that is able to undertake a certain task. Each agent is

represented by an AM-1 agent worksheet. OTA-1 is the integration of TM-1, TM-2 and AM-1 that provide some information for managerial decision making about changes and improvements in the organisation.

4. The Knowledge Model describes knowledge types i.e. concepts, rules, relations, tasks and inferences. A knowledge base is constructed with instances of the knowledge types.

5. The communication model describes the way in which the different agents communicate with each other while collaborating to carry out a task.

6. The Design Model describes the knowledge system implementation decisions.

The CommonKADS Methodology uses UML diagrams to specify its models and processes. Following types of diagrams are used:

1. **Activity diagrams,** which are used for specifying the organization model at a high level of abstraction, and for modelling the structure of tasks.
2. **State diagrams,** which are used in communication model to specify the communication plan control.
3. **Class diagrams,** which are used to describe the static information structure of the application domain.
4. **Use-cases diagram,** which are used for specifying the agent model.

The Methodology also defines its own language called *Conceptual Modelling Language (CML)*, which is a semi-formal notation for the specification of expertise models.

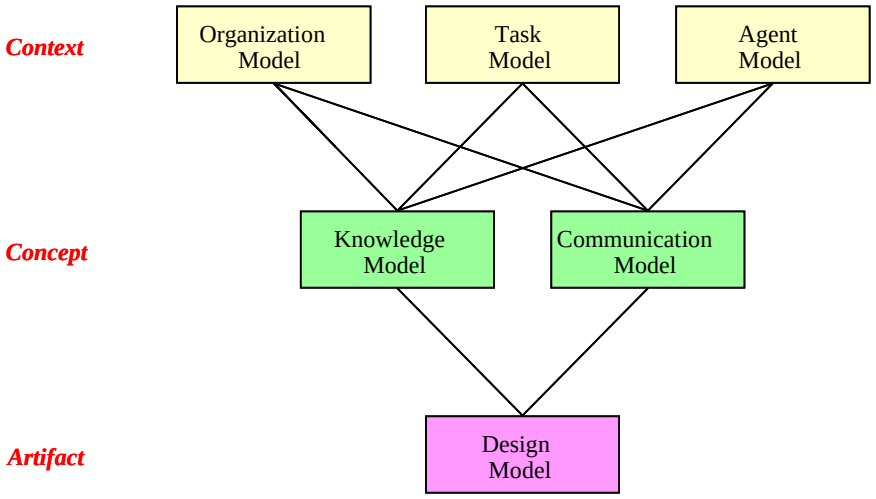

Fig. 1. CommonKADS models

3.3 - knowledge modelling view in MASK methodology

MASK (Method of Analysis and Structuring Knowledge) offers a flexible environment that allows to success knowledge capitalization projects. It has been applied in a large number of domains (safety, business process, mechanical design …) that have allowed its evolution [9]. This method is situated at the

heart of knowledge capitalisation and is based on some sort of assumptions which are the underline building block [2]:

1) Based on the notion of system theory and complex system it observed four main systems in each enterprise namely operating system, information system, decision system, and corporate knowledge repository (with some consideration knowledge system)

2) Semiotic and systemic hypothesis as two theoretic aspects of a knowledge system and together produces the macroscope for the general complex system which enables to globally understand a knowledge asset in an organisation.

3) The semiotic hypothesis is that the knowledge asset of an organisation is an “object", a “phenomenon" perceived by anybody as a global set of elements that may be either virtual, real, conceptual, physical, etc. semiotic view show a system based on three concepts as semiotic triangle. These axes are syntactic, semantic and pragmatic.

4) The systemic hypothesis is that the knowledge asset of an organisation is a system as described in the general system theory. This general system definition leads, as for the semiotic, to a triangle scheme: ontological or structure, phenomenological or functional, and genetic or evolution.

Table. 1).

MASK uses its own formalisms to model historic view, lineage view, concept view, phenomena view and task point of view. It uses SADT formalism to model activity point of view but with some modification [6].

Method MASK based on this macroscope look upon knowledge as a semiotic approach with systemic view and define nine possible points of view; a syntactic, semantic and pragmatic point of view, each one having in turn three other points of view: structure, function and evolution.

In this macroscope context, Knowledge is perceived as *information* which takes a given *signification* in a given *context*. There are three fundamental points of view to model knowledge: information, sense, and context. Each point of view is decomposed in three other fundamental points of views: structure, function and evolution. Then nine points of views could be defined. The information point of view is classical: structure is modelled by data structures, function is modelled by information processing and evolution by versioning. MASK is involved in the six others point of views. For signification, the points of view of structure, function and evolution are respectively modelled by concepts networks, tasks and lineage. For context, the points of views of structure, function and evolution are respectively modelled by phenomena, activities and history (see

Table. 1. Knowledge modelling and macroscope via MASK

		Systemic triangle		
		Structure	**Function**	**Evolution**
Semiotic triangle	**Information**	Data	Information processing	Versioning
	Sense	Concept modelling	Task modelling	Lineage modelling
	Context	Phenomena modelling	Activity modelling	Historic modelling

3.4. Synopsis of modelling view in KM

As mentioned earlier, each method of KM has six modelling views that cover several aspects of knowledge in the enterprises**.**

Table. 2 shows these views in CommonKADS and MASK. Although they use different terminologies to describe the context in which knowledge could be modelled but there are two approximately closed views that could be used interchangeable; activity modelling and task modelling with a little different that task modelling in MASK is about sense and activity modelling is about context. Another view is domain modelling in KADS and phenomena modelling in MASK.

Table. 2. Modelling view in KM

Synopsis of the modelling view in KM		
views	Methods	
	CommonKADS	MASK
Activity / task	yes	yes
Organisation	yes	no
Agent	yes	no
Domain / Phenomena	yes	yes
Communication	yes	no
Concept	no	yes
Inference	yes	no
Historic	no	yes
Lineage	no	yes

4. ENTERPRISE MODELLING VIEW AND MODELS

The use of methods and tools based on models benefits enterprises in several important ways. First, conceptual models can be used to transfer enterprise-specific knowledge among domain experts, system analysts and other stakeholders in three steps. In the first step,

domain experts record their knowledge of the enterprise in an enterprise model set. The system analyst then studies this set to gain a good understanding of the enterprise and its characteristics. Finally, the two parties meet to discuss missing pieces of information and ambiguities in these models. Thus, the time and associated cost of knowledge transfer activities is significantly reduced in two ways. First, the interview process, formerly an activity in which success depended largely on the analyst's interviewing and the domain expert's description skills, is now replaced by the structured best-practice guidelines and procedures provided by the modelling methods. Second, the amount of time required for meetings between the two parties is dramatically reduced.

We use the term "enterprise model set" to refer to a group of models built to obtain a coherent and comprehensive picture of an enterprise. This set includes models of various types, and each type of models defines "a perspective or viewpoint from which the system is considered for a given purpose, concentrating on some aspects and hiding irrelevant ones to reduce complexity" [15]. An enterprise model set can include various activity, process, organization, information, and behavioural models.

4.1 - modelling view in CIMOSA methodology

CIMOSA (CIM open system architecture) is an open system architecture which has been developed for integration in manufacturing but which is widely applicable to integration of any type of enterprises. CIMOSA provides guidelines, architecture and an advanced modelling language for enterprise modelling covering function, information, resource, and organization aspects of the enterprise [14]. The modelling framework shown in Fig. 2 structures the CIMOSA Reference Architecture into a generic and a partial modelling each level supporting different views on the particular enterprise model. The concept of views allows to work with a subset of the model rather than with the complete model providing especially the business user with a reduced complexity for his particular area of interest. CIMOSA has defined four different modelling views Function, Information, Resource and Organisation. However this set of views may be extended if needed.

The CIMOSA Reference Architecture supports three modelling levels of the complete life cycle of enterprise operations (Requirements Definition, Design Specification and Implementation Description). Again, the sequence of modelling is optional. Modelling may start at any of the life cycle phases and may be iterative as well. Depending on the intention of model engineering, only some of the life cycle phases may be covered. Enterprise operation should not be modelled as a large monolithic model but rather as a set of co-operating processes. With a set of common building blocks, the CIMOSA Reference Architecture provides the base for evolutionary enterprise modelling. This allows different people to model different areas of the

enterprise but provides the integrity of the overall model.

At a macro-level, an enterprise can be decomposed into a set of domains, which are functional areas of the enterprise delimiting a given set of complete processes of the enterprise, called *domain processes*. These domains have interactions with one another in the form of exchange of objects and events (or requests), defined as *domain relationships*. A domain process is an entire process, i.e., a complete chain of activities flowing through the enterprise and irrespective of organisational boundaries (control flow). It is triggered by one or more *events* and terminates when it produces a definite desired end-result. An event is any happening (solicited or not) which represents a change in the enterprise system state (e.g., the arrival of a customer order or the break-down of a machine). A domain process is made of sub-processes, called *business processes*, and/or *enterprise activities* which are elementary steps of processes as seen by the user. Domains, domain processes, business processes and enterprise activities are subject to *objectives* (which define their raison d'être) and/or *constraints*. Enterprise activities are the place of action. They require *resources* and time to transform inputs into outputs, i.e., *enterprise object* states into different states. These states (which can also represent combinations of objects) are called *object views*. They represent manifestations of objects at some point(s) in time.locus.

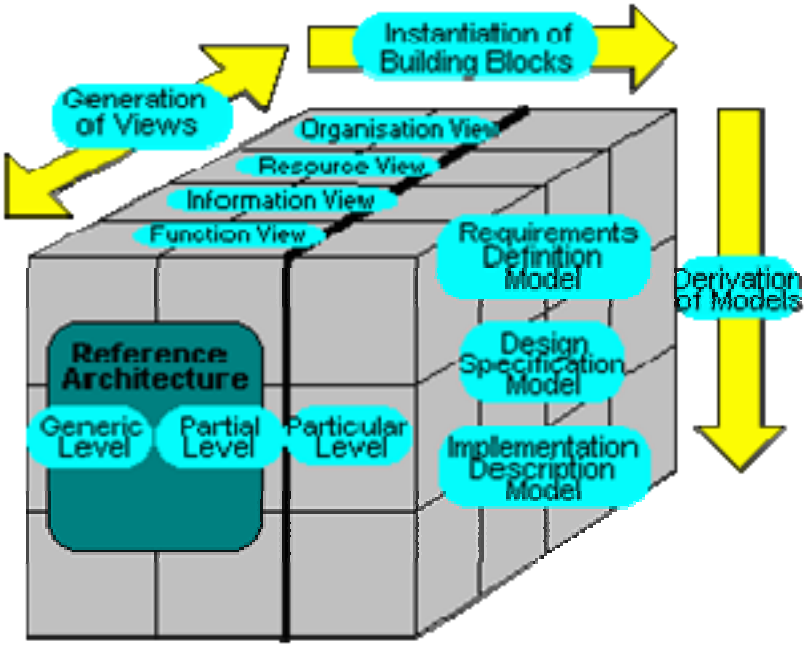

Fig. 2. ***The CIMOSA Modelling Framework*** **[14]**

4.2 - modelling view of GIM methodology

GIM (GRAI integrated methodology) is a methodology for design and analysis of production systems based on the GRAI method [5]. It includes modelling languages (GRAI grid, GRAI nets, Actigrams, Entity / Relationship Model) and focuses on decision

system analysis of the enterprise. It was developed by the GRAI at the University Bordeaux 1. GRAI-GIM is a modelling methodology intending for general description and focusing on production management system. The objective of GRAI-GIM is to develop specifications for manufacturing systems. It designs architecture of manufacturing systems and circumferential elements, determining specifications of all the constituent elements to select existing market elements and develop customised ones.

GIM proposes different formalisms to capitalize the knowledge, to structure the production system, and to support dialogue and exchanges between the actors. GRAI-GIM includes[13]:

1. the GRAI conceptual reference model,
2. the GRAI-GIM modelling framework and associated modelling languages, and
3. the GRAI-GIM structural modelling method.

In GRAI-GIM, an enterprise consists of a physical system, a decision system and an information system. An enterprise can be described using four views (**Fig. 3**):

1. Functional,
2. Physical,
3. Decisional, and
4. Informational

The Entity / Relationship Model is used by GRAI-GIM to model the informational model; the GRAI languages (GRAI Grid and GRAI Nets) are applied in the decisional model while actigrams are used in functional and physical modelling.

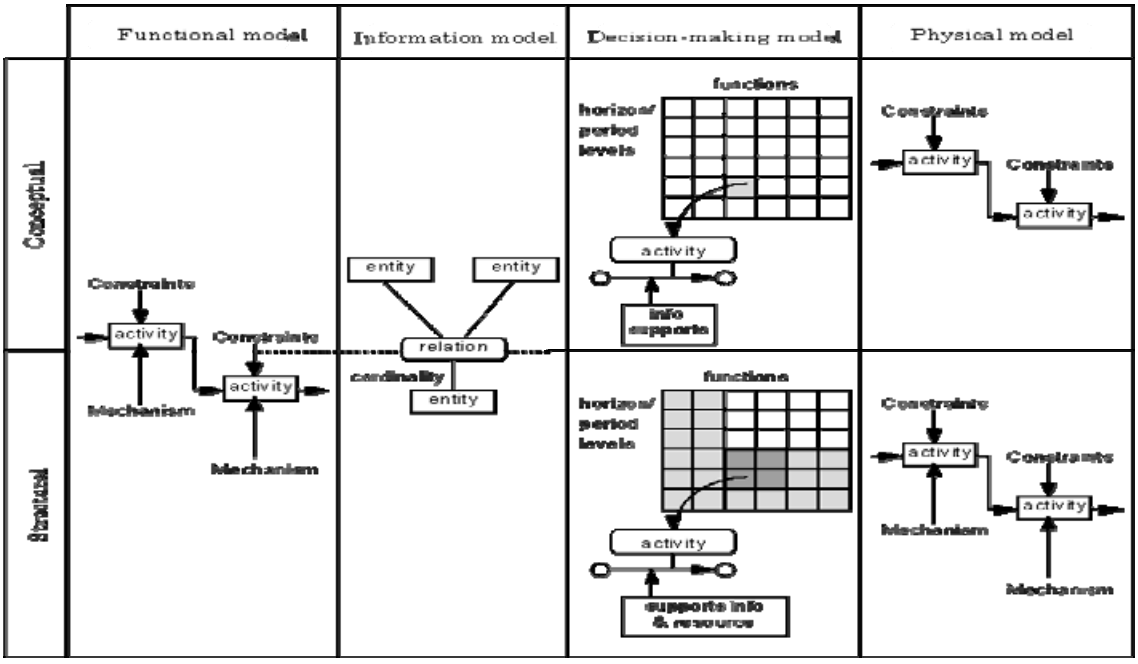

Fig. 3. GRAI-GIM modelling framework and associated modelling languages **[5]**

4.3 - Summary of modelling review in EM

Each selected enterprise modelling method presented in this paper has five points of views. These views are showed in .

Table. **3**. We can observe that some views like activity or information are common to the two methods. In CIMOSA functional modelling is divided on functionality and behaviour approaches which could be defined as activity and process, then we put them in different models.

Table. 3. Enterprise modelling views

Synopsis of the modelling view in EM		
Models	Methods	
	GIM	CIMOSA
Activity / task	yes	yes
Physical system	yes	no
Process	yes	yes
Organisation	no	yes
Decision	yes	no
Information	yes	yes
Resource	no	yes

5. COMPARISON OF EM AND KM

Now with a comprehensive look at the methods in modelling both in KM and EM field there are several views. Some of them are common views in all methods like activity and task and some view are unique to each method. Table. 4).

Because one of the main objectives of this research is to show and the use the complementary nature of KM and EM here we propose a generic classification to integrate the modelling views and develop the building block of enterprise knowledge modelling (see

Table. 4. Comparision of EM and KM modelling view

Models	KM		EM		Classification
	KADS	MASK	GIM	CIMOSA	
Activity / task	yes	yes	yes	yes	Context
physical system	no	no	yes	no	
Communication	yes	no	no	no	
Process	no	no	yes	yes	
Organisation	yes	no	no	yes	Intent
Decision	no	no	yes	no	
Agent	yes	no	no	no	Content
Domain / Phenomena	yes	yes	no	no	
Concept	no	yes	no	no	
Inference	yes	no	no	no	
Resource	no	no	no	yes	
Information	no	no	yes	yes	
Historic	no	yes	no	no	Evolution
Lineage	no	yes	no	no	

5.1 - Discussion

For the comparison of methods we propose a framework to classify all views into four mains categories. These categories are context modelling, intent modelling, content modelling, and evolution modelling.

Context modelling. One of the important issue to model knowledge is to model the context in which knowledge exists. Several methods in both enterprise modelling and KM develop views and languages to describe the context. This context includes tasks, activities, and business processes in the enterprises. moreover, the communication between agent or tasks also consider as a dimension of context. Although context modelling is the common point of these two fields but one can find more in detail context modelling in EM methods and there are several good languages to model context in EM domain.

Intent modelling. In the literature of both EM and KM, there are several papers that describe the essential of intentionality of top management to launch a global project in the enterprise. However, we can find only in GIM a clear decision modelling and some sort of organisational modelling in CommonKADS and CIMOSA but we can not find a clear modelling of strategy and leadership support for the methods.

Content modelling. Content is the heart of our classification of knowledge modelling. This dimension includes several aspects that should be modelled. Agent modelling is an important view to model knowledge in enterprise. We know that knowledge exists in some form and somewhere in the organisation but a very important part of knowledge is tacit knowledge and this knowledge is with the human and so employees in the enterprises. One of the weaknesses of EM methods is that they do not

deal with agent or actors directly as a modelling view. Inference and concept modelling as other important parts of knowledge exist in KM methods. KM methods take care of information implicitly in throughout of modelling.

Evolution modelling. Even though in the EM context, the researchers talk about evolution management in the company and maturity models but we did not find some sort of languages or modelling view dealing with evolution modelling in detail. This aspect is well defiled in MASK methodology in two different models; one for pragmatic dimension and so context evolution as historic modelling and another one for the evolution of sense and signification as lineage modelling.

5.2 - perspective and conclusion

Knowledge management and enterprise modelling are two disciplines that originate from different trajectories but with strong common points and complementarilies. Both are for the objective to deal with changing environment and complexity surrounding the enterprises. Enterprise modelling is a way to externalise knowledge and model it in several views to transfer and share it at the right time, right format and for right person. Most important goal of KM is to manage knowledge in the organisations. This management is by the KM process and to provide the right knowledge for the right person at the right time to enable decision making in enterprise and favourite organisational learning.

KM by nature is multidisciplinary and from several fields of study one could look at that for example from management science perspectives, from economic, from engineering and also from computer science. Modelling and formalising of knowledge in several shapes is the main focus of production management and engineering. Then, since knowledge exist in documents, in procedures, in organisations, in processes, activities, and in human mind, it is very important to look at knowledge from several points of view to present a comprehensive approach to knowledge. One intersection of EM and KM is knowledge engineering and capitalisation and from this perspective and also from modelling approaches we defined this study basically by reviewing modelling approaches in these two fields. The classification developed here helps practitioners and scientific to view knowledge phenomena from a generic and macro view.

Based on our findings, some general guidelines may be stated. Even though in this paper we investigate the complementarity of KM and EM in a macroscopic vision but to go in detail as a perspective, authors also have to develop generic, common language.

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