Software Requirements Acquisition through Enterprise Modelling

Marite Kirikova*
Janis A. Bubenko jr **

Department of Computer and Systems Science
Royal Institute of Technology and Stockholm University
Electrum 230, S-16440, Kista, Sweden
marite@dsv.su.se, janis@sisu.se

Abstract

Enterprise Modelling technology prescribes systematic use and computer aided documentation of knowledge about enterprises, their objectives, activities, concepts, and actors. The basis of this technology is the Enterprise Model, assumed to be developed by users and requirements engineers during the requirements acquisition process. The Enterprise Model consists of several submodels, that have user-oriented meta-knowledge structures for communication with human sources of information. The Enterprise Model maintains relationships between information system requirements and other relevant, sometimes intentional, knowledge, acquired about the application domain. The main objective of this technology is to obtain a better alignment between the business activities and the supporting information system. The technology presented here is also applicable in the area of business process re-engineering.

1. Introduction

Knowledge acquisition, known as a "bottleneck" problem in Artificial Intelligence, has become an important issue also in the area of Software Engineering. By definition knowledge acquisition means knowledge elicitation and representation [1]. In Software Engineering and Information Systems Design, knowledge, acquired in requirements elicitation stage, is typically "hidden" in the documents representing the "requirements specification". Typical requirements specification documents (see for instance [2]) still exhibit several problems:

1. A requirements specification, as it is managed today by practical methods, reflects only a small part of the elicited knowledge. Large parts are lost and must be acquired once more, if the requirements specification or the information system has to be changed.
2. A requirements specification, typically presented in forms and diagrams suggested by structured analysis methods [3], [4], are often not understandable for nonprofessionals in the field of structured analysis and information systems [5].
3. A requirements specification does not reflect all the information needed in further design stages. It often even contains large amount of useless information [6].
4. The process required to develop a requirements specification of sufficient coverage and quality is normally given far too modest human and financial resourses. What is even more alarming is that the team working on requirements is often given too weak authority to involve relevant users and customers in the requirements process.

Enterprise[1] Modelling technology suggests solutions for these problems. All the elicited knowledge can be represented in the Enterprise Model (EM), developed by users together with requirements engineers during the requirements acquisition process. It serves as an additional source of knowledge in the requirements elicitation process. To be helpful for different groups of its users (managers, business people, customers, requirements engineers, information system designers,

* The author is on leave from Riga Technical University, Latvia, sponsored by the Swedish Institute, Stockholm, Sweden.

** The author's work on this paper is partly sponsored by SISU's participation in the ESPRIT project F3 (6612) [17], supported by NUTEK, Sweden

1 "Enterprise" should here be interpreted in a very wide sense. It could actually mean the whole enterprise or a small part of it . We consider as "enterprise" the object of particular efforts of management, analysis, investigation, development or design, performed by a particular group of persons.

Abstract

Enterprise Modelling technology prescribes systematic use and computer aided documentation of knowledge about enterprises, their objectives, activities, concepts, and actors. The basis of this technology is the Enterprise Model, assumed to be developed by users and requirements engineers during the requirements acquisition process. The Enterprise Model consists of several submodels, that have user-oriented meta-knowledge structures for communication with human sources of information. The Enterprise Model maintains relationships between information system requirements and other relevant, sometimes intentional, knowledge, acquired about the application domain. The main objective of this technology is to obtain a better alignment between the business activities and the supporting information system. The technology presented here is also applicable in the area of business process re-engineering.

1. Introduction

Knowledge acquisition, known as a "bottleneck" problem in Artificial Intelligence, has become an important issue also in the area of Software Engineering. By definition knowledge acquisition means knowledge elicitation and representation [1]. In Software Engineering and Information Systems Design, knowledge, acquired in requirements elicitation stage, is typically "hidden" in the documents representing the "requirements specification". Typical requirements specification documents (see for instance [2]) still exhibit several problems:

1. A requirements specification, as it is managed today by practical methods, reflects only a small part of the elicited knowledge. Large parts are lost and must be acquired once more, if the requirements specification or the information system has to be changed.
2. A requirements specification, typically presented in forms and diagrams suggested by structured analysis methods [3], [4], are often not understandable for nonprofessionals in the field of structured analysis and information systems [5].
3. A requirements specification does not reflect all the information needed in further design stages. It often even contains large amount of useless information [6].
4. The process required to develop a requirements specification of sufficient coverage and quality is normally given far too modest human and financial resourses. What is even more alarming is that the team working on requirements is often given too weak authority to involve relevant users and customers in the requirements process.

Enterprise[1] Modelling technology suggest solutions for these problems. All the elicited knowledge can be represented in the Enterprise Model (EM), developed by users together with requirements engineers during the requirements acquisition process. It serves as an additional source of knowledge in the requirements elicitation process. To be helpful for different groups of its users (managers, business people, customers, requirements engineers, information system designers,

* The author is on leave from Riga Technical University, Latvia, sponsored by the Swedish Institute, Stockholm, Sweden.

** The author's work on this paper is partly sponsored by SISU's participation in the ESPRIT project F3 (6612) [F3 1991] , supported by NUTEK, Sweden

1 "Enterprise" should here be interpreted in a very wide sense. It could actually mean the whole enterprise or a small part of it . We consider as "enterprise" the object of particular efforts of management, analysis, investigation, development or design, performed by a particular group of persons.

programmers), the Enterprise Model has to contain and provide appropriate components of knowledge. Or, in other words, the Enterprise Model should consist of knowledge supporting different issues and aspects of requirements engineering. Six recent results of investigations in areas, relevant to requirements engineering, together with the Enterprise Model itself, are surveyed in section 2. Our ambition was to get a more consistent and interdisciplinary view of these necessary components of knowledge, as seen by different authors. We also wanted to find out what are, according to a number of authors, the main issues and questions, models have to be able to "answer" and help to reason about. In section 3, the Enterprise Model is explained in more detail. Expressiveness and usability of the Enterprise Model as an artificial knowledge structure are discussed in section 4.

2. A Survey of Meta-Knowledge Structures for Requirements Acquisition

Gathering information system requirements in enterprises implies dealing with complex and mostly not formalised knowledge. This knowledge represents views and models of the enterprise, reported by, or elicited from, different knowledge sources: human beings or artificial knowledge systems. We will call "the human knowledge system" - the knowledge that is situated in the heads of particular human beings. The term "artificial knowledge system" will be used to refer of any other system of knowledge maintained dynamically by software systems or available by static representations and descriptions [7].

The complexity of knowledge requires guidance and support in its use. Therefore meta-knowledge - knowledge about knowledge, has to be available in order not get lost in managing different models and representations. Meta knowledge shows *about what* we have knowledge, or *where we can obtain* particular knowledge, or *how to use* the knowledge we have [8]. Meta-knowledge itself can represent an enterprise in different levels of interpretation. We could therefore speak about meta-, meta-meta- and meta-meta-meta-...-knowledge as well [9]. In this paper, considering "knowledge about knowledge", we will mostly use term "meta-knowledge" to talk *about what* knowledge is gathered.

The requirements engineering process itself can be seen as a combination of different company activities, i.e. "enterprises", which require computer support. The Enterprise Model schema can, therefore, be seen as the structure of an information base that contains knowledge, gathered during the requirements elicitation. In this section we will consider several frameworks (meta-knowledge structures), relevant to requirements engineering. The frameworks reviewed are named Structure 1 to Structure 7. We do mainly discuss the contents of meta-knowledge structure elements, as presented by their authors. Our purpose is to find additional relevant issues and arguments, that, have to be considered and included in Enterprise Modelling in order to prove and improve its quality.

Structure 1 - PURPOSE, FUNCTION, STATE, FORM [10] (enterprise - "team performance in complex systems"). In [10] results of investigations concerning knowledge, necessary for group members, in order to achieve successful team performance, are discussed. The results are presented as mental maps of knowledge. Their significance is proved by experiments. We are considering them because most of activities in requirements engineering are performed by groups and requires appropriate knowledge of their members.

Structure 1 in the article appears by quoting the definition of a "mental model" [11]. PURPOSE corresponds to knowledge describing, why a system exists, FUNCTION - to knowledge explaining, how a system operates, STATE is meant for explanations and predictions about, what a system is or will be doing, and FORM depicts descriptions of what a system looks like.

Structure 2 - EQUIPMENT, TASK, TEAM [10] (Enterprise - "team performance in complex systems"). Structure 2 reflects the main objects of interest in successful group work. EQUIPMENT knowledge explains characteristics of equipment elements, relationships among them, temporal patterns of equipment functioning and requirements fulfilled and objectives supported by equipment, as well as physical theories and principles concerning equipment. TASK knowledge is about situations, criteria, analogies, procedures, strategies, methodologies, operational and logical basis and mathematical principles and theories concerning tasks. TEAM knowledge is about roles of team members, relationships among team members, temporal patterns of team performance, functioning and co-functioning of team members, overall mechanisms of team performance. It also explains why teams and team members are needed and concerns behavioural principles and theories, such as psychology, management, etc.

Structure 3 - PLAN, DO, SEE [12] (enterprise - "business-cycle modelling"). Structure 3 is introduced by S.Mitsumori [12] as a corporate activities model. He suggests that each activity needs a supporting information system for it to be successfully performed. In his interpretation, an enterprise structure reflects three kinds of business activities. PLAN activities are for totally nonrutine tasks. The main data used for those activities must be gathered outside the business organisation according to the nature of each planning problem. Neither data structures nor algorithms of supporting information system can be predefined. DO are routine tasks. Data structures and algorithms for information system supporting these tasks can be predefined independently of each processing. SEE activities are for partially nonrutine tasks. The tasks are executed to analyse outcomes of "do" activities. Data structures of supporting information system can be defined, although algorithms cannot.

Structure 4 - PURPOSE, FUNCTION, STRUCTURE [13] (enterprise - "systems engineering"). Requirements engineering is considered by A.Sage [13] as a systems engineering activity. Author illustrates transitioning of the requirements through purposeful, functional and structure stages into technical specifications. Again, each of mentioned stages requires appropriate knowledge for formulation, analysis, and interpretation. So, according to Sage, we can consider PURPOSE, FUNCTION, and STRUCTURE as units of meta-knowledge concerning enterprises.

Sage also stresses the particular role of *management*, as well as the need for *knowledge of teem members* and the necessity of *problem solving capabilities* in requirements engineering. The need for representing and discussing issues in a *temporal* dimension is pointed out, too.

Structure 5 - WORK ORGANISATION, TECHNICAL ARTEFACTS, PHYSICAL SPACE, WORK ACTIVITIES [14] (enterprise - "analysis of diversity and flexibility of organisations"). The framework in [14] is not meant as a model of reality, but rather as a map of frame of reference, useful when addressing the various dependencies among work activities and other elements. In the interpretation of authors, A.Kjaer and K.Madsen, the first three elements are considered as a structure elements, and the last one, the work activities, as a process. The terms "structure" and "process" are used in context of relatively stable and dynamic aspects of organisation. Considering the context of knowledge concerning enterprises all the four elements of this framework are structure elements of meta-knowledge.

WORK ORGANISATION requires knowledge about formal and informal division of labour among and within the various occupational groups, as well as their skills and qualifications. TECHNICAL ARTEFACTS concerns knowledge about tools as well as about other technical artefacts that may support work. PHYSICAL SPACE depicts knowledge about dedicated functions of workplace. WORK ACTIVITIES concerns knowledge about the process of work (functional and behavioural aspects).

Structure 6 - MANAGEMENT, TASK, STRUCTURE, TECHNOLOGY, ACTORS [15] (enterprise - "software risk management"). Software risk factors have to be considered already in the early stages of information system development, if not, then it is a difficult task to consider them in the later stages of design. To avoid such problems, appropriate knowledge about possible risk issues has to be available in the Enterprise Model. Authors [15] present the Environmental Model, that recognises risk management as a satisfacing behaviour. They derive a set of risk generating components, which can be used to detect possible sources of risk during software development. Concepts *task, structure, technology,* and *actors* are considered as main components generating a risk profile.

TASK concerns knowledge for definition of project objectives, what the project should accomplish, what software systems to develop and what changes to carry out in client organisation. STRUCTURE involves knowledge about systems of communication, systems of authority, systems of work flow and the physical environment within software project environment. TECHNOLOGY includes knowledge about available methods, tools, and infrastructure to develop and implement the software system. ACTORS depicts knowledge about all participating persons and other stakeholders. It concerns their skills, experiences, expectations, commitments, beliefs and values. MANAGEMENT concerns knowledge about managers, organisational maturity, and management methods.

Structure 7 - OBJECTIVES, ACTIVITIES AND USAGE, ACTORS, CONCEPTS, INFORMATION SYSTEM REQUIREMENTS - The Enterprise Model [16] (enterprise - "requirements engineering"). This structure is introduced particularly for requirements engineering. It is a basis for Enterprise Modelling technology being under the development in ESPRIT III Project "From Fuzzy to Formal" [17]. This meta-knowledge structure prescribes relationships between the structure units (Fig 1).

OBJECTIVES knowledge is intended for describing and discussing the reason, or motivation, of activities, actors and concepts of other structure units. ACTIVITIES AND USAGE knowledge describes the organisational activities, i.e., the processes and tasks of enterprise, existing and/or new ones, with respect to their structure, material and informational flows, as well as to actors or resources carrying out the tasks. ACTORS knowledge concerns the types and roles of actors involved in enterprise activities. CONCEPT knowledge describes concepts, object types, relationship types and object or relationship properties referred to by elements of other meta-knowledge structure units. IS REQUIREMENTS knowledge describes requirements, functional as well as non-functional, concerning the information system.

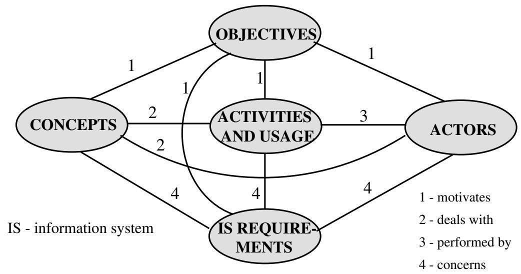

Fig. 1 Structure 7- Enterprise Model in requirements engineering

Discussion. The first six meta knowledge structures are pragmatically oriented and suggest "pieces" of knowledge, relevant as "issues of interest" in requirements engineering. The core of this pragmatic view to the things in an enterprise are work activities. Other issues reflect problems that motivate work activities, people who are participating in them, as well as instruments and materials used in the work. They also reflect place and time regarding work activities. Considering these issues, we can state seven main types of questions, to be supported by the Enterprise Model:

- **What** work activities should be performed?
- **How** they are performed, considering different levels of detail?
- **Why** particular work is done in a particular manner, what are the main causes of decisions concerning activities?
- **Who** is performing activities, what are their roles, functions, knowledge, skills, responsibilities, expectations, beliefs, and values. How they are communicating?
- **Using what** equipment and other technical artefacts activities are performed?
- **When** activities take place, what are their temporal patterns and relationships?
- **Where** activities take place, what are the main characteristics of the particular physical space? How does it influence activities?

Structure 7 presents not only pragmatic, but also semantic issue, that reflects *what* are the things we are talking about by terms of definitions, explanations and semantic models.

As we can see, in its current stage of development, the Enterprise Model (Structure 7) does not explicitly give answers to questions "when?" and "where?". Time patterns are considered as relevant in knowledge necessary for successful team performance, they appear in several topics of system engineering [13] and are outlined in the contents of knowledge concerning software risk management. The physical space issue is considered in areas of analysis of diversity and flexibility of organisations and software risk management. Therefore time and space issues are desirable in Enterprise Model. The significance of the time issue is also reflected in the ongoing research work in Temporal Databases [18], [19], and information system development methods that include the temporal aspect of information [20].

The requirements engineering process is management dependent. We can distinguish as issues of interest at least two related management environments here - project management, and the management of the organisation of the application domain itself. The Enterprise Model provides knowledge for the purpose of management and "embedding" of requirements, but the two different environments are not explicitly recognised in separate meta-knowledge models.

In the next section we will explain the Enterprise Model in more detail and discuss how different issues of interest can be reflected in it.

3. Enterprise Modelling Technology

Enterprise Modelling technology prescribes usage of several Enterprise submodels in knowledge acquisition. We can consider each of the submodels as a subsystem of artificial knowledge. The submodels are developed in group activities, by users, stakeholders, and requirements engineers, during particular knowledge acquisition processes. The submodels are: Objectives Model (OM), Activities & Usage Model (AUM), Actors Model (AM), Concept Model (CM) and Information System Requirements Model (IRSM), corresponding to the elements of Structure 7 (Fig. 1). Each submodel has its own meta-knowledge structure. So in that case Structure 7 - Enterprise Model serves as meta-meta-knowledge structure concerning the contents of knowledge considered in each Enterprise sub-model. Meta structure components of the submodels have been introduced on the basis of experience in real life business analysis processes [16]. Those structures involves elements that have been found to support human thinking and reasoning and are convenient in knowledge elicitation. At the same time the modelling technology is computer supported, and therefore permits computer-aided checking and analysis of the acquired knowledge.

All the submodels are inter-related. They form the overall Enterprise Model, that, when populated, represents the current artificial knowledge we have in any stage of the requirements acquisition process. In this chapter we briefly consider the contents of submodels as well as their role in requirements acquisition.

3.1. Objectives Model (Goal, Problem, Opportunity, Cause, Rule, Development Action, Motivates Relationship, Influences Realationship)

In this part of an EM we describe, in a structured way, the "why" component of a requirements document. *Goals* are used for expressing intentions. They may be expressed as measurable sets of states, aims, visions or directions. *Problems* are used for expressing that the environment is, or may become, in some non-desirable set of states. *Opportunities* are used for expressing possible states that are not regarded as goals, but opportunities that we may take advantage of. *Causes* are used for expressing the reasons for problems. *Rules* are restrictions on objects and links within the Enterprise Model. *Development Actions* are used for expressing actions or activities to be performed on the environment. Generally both kinds of relationships *Motivates* and *Influences* can hold between each pair of other elements in the initial stages of requirements acquisition.

In knowledge acquisition process OM serves as a problem solving environment and supports three essential points concerning problems [13]: (1) detection of existence of potential problems; (2) ability to diagnose potential cause(s) of difficulty; (3) ability to solve the problem, i.e., to correct the situation through determination of goals and a course of action or correction, that will ameliorate the problem and implement this such as to respond to particular situation at hand. Detection of problems, diagnosis of them, and searching for alternative solutions, are provided either by knowledge elicitation or knowledge analysis. Knowledge analysis should preferably be computer aided, because of the complexity of model. In real life situations several hundreds of instances may be under analysis.

Goals and rules determined in the objectives models should be supported by appropriate activities in the Activities & Usage Model.

3.2. Activities and Usage Model (Process, Information, Material, External Process, Has Input Relationship, Has Output Relationship)

In this part of the Enterprise Model, the particular organisational activity (in a wide sense), existing to be modified or to be developed, is defined and described from the point of view of processes and the information and material flows between them. A *Process* is a collection of activities which assume a number of inputs and produces a number of outputs. Processes can be performed by humans or by machines. They are normally controlled by business rules and need different kinds of resources (e.g., computers, human actors). Processes may be decomposed into subprocesses. *Information* denotes here an "information set". At different levels of design and analysis, information sets can be more or less precisely defined. In the early stages they are normally rather vaguely defined. A vague definition, however, should always try to relate the information set to at least one component in the Concept Model (see section 3.4). In later development stages, an information set should be precisely defined, by relating it to all components of the Concepts Model it is concerned with. A *Material* set denotes a particular set of "real world things", that can be transported, or flow, from one point (process) to another. An *External* process is a process that is external to the enterprise or to the system being designed or to both.

3.3. Actors Model (Individual, Non-human Recourse, Organisational Unit, Role, Binary Actor Relationship, Actor ISA Relationship, Actor Part-of Relationship)

This submodel is used to discuss and define the set of actors of the studied activities and their interrelationships. *Individuals* corresponds to human individuals (persons) in the enterprise. Individuals are identified by their names. *Non-human* resources can be types of machines, systems of different kinds, equipment, etc. *Organisational Units* depict organisational structures, such as groups, departments, divisions, projects, and teams. Individuals and organisational units may play different *Roles* in different contexts, e.g., an organisational unit may be administrator and authoriser in one and the same context, and the receiver of information in some other. Non-human resources may play roles, too. The *Binary Actor Relationship* is used for describing semantic relationships between actors. The *Actor ISA Relationship* is used for expressing generalisation relationships between Roles or between Non-human Resources. The *Actor Part-of Relationship* serves for expressing aggregation relationships.

The Actors Model is used to better understand organisational relationships and communication possibilities. It reflects the structure of roles and responsibilities in performance of assigned tasks. This model also supports the control of usage of material resources.

3.4. Concepts Model (Concept, Attribute, Concept Model Component Group, Binary Concept Relationship, ISA relationship, Part-of Relationship)

The concept sub-model is used to define the "ontology" of the "universe of discourse" that concerns the set of object types, relationships, and object properties of the application we are talking about. In this sub-model we also further refine business rules of the objectives model into static as well as dynamic rules for the concept sub-model states as well as for permissible state changes. A *Concept* with name "Concept Name" is something in the domain of interest that we want to reason about and to characterise using relationships to other concepts. *Attribute* is a concept which is used only to characterise another concept. *Concept Model Component Group* is a grouping of concepts, concept relationships and concept attributes. It could be, e.g., a part of concepts schema of interest to particular business process. A *Binary Concept* relationship is a named, semantic relationship between two concepts or between one and the same concept. *ISA Relationship* is a specific kind of semantic relationship between concepts used for expressing generalisation. A *Part-of Relationship* is a special form of semantic relationship, where the interrelated concepts are seen from the top level concept as a "whole".

The Concept Model integrates all the Enterprise Models, which initially can be developed more or less independently. It shows all the concepts introduced, and allows, through interrelationships with the other models, to investigate what roles the concepts play in the other models, and check whether their definitions are consistent. The Concepts Model is particularly important for the Information Systems Requirements Model (see next section). It is assumed that all the concepts used in ISRM are explicitly defined with a reference to the Concepts Model.

3.5. Information Systems Requirements Model (IS Goal, IS Problem, IS Constraint, IS Requirement, IS Valuable Characteristic, Motivates Relationship, Influences Relationship)

This part of the Enterprise Model elaborates the specific objectives and requirements that are put on the information system to support the activities and objectives listed previously. *IS Goals* are used for expressing (high level) intentions regarding the information system. They may be expressed as measurable or non-measurable properties, aims, visions or directions. *IS Problems* are used to express un-desirable states of facts about the current situation with respect to the information system to be developed. *IS Constraints* are used to express any kind of constraint or restriction regarding the information system to be built or the process of building it. An *IS Requirement* expresses a definite requirement for a particular property of the information system to be designed. The property can be a functional or a non-functional one. *Valuable Characteristic* is used to express a valuable characteristic of the system which is not a definite requirement, but a desirable property that can be "relaxed" depending on available time and other resources.

The Information System Requirements Model is meant for stating and analysing the objectives, problems and requirements of the information system to be designed. It is used as a basis for elaboration of a well agreed-upon requirements specification. This Model is a consequence of all the earlier modelling efforts. We can say that projections are made from all the other models to ISRM. Modelling activities in ISRM permit us to simulate impact of particular model to the other parts of the Enterprise Model and may thus hinder developers from making serious errors in setting the requirements.

3.6. Intermodel links

Intermodel links belong to the overall Enterprise Model (EM) and are not elements of some particular submodel. Each element of the OM can, for instance, motivate the appearance of elements in each of the other submodels. Rules of the OM can control Material and Information inputs of Processes in the AUM. Actors in the AM can be responsible for Goals or they can be originator*s* of nodes in the OM and other models as well. Also, they can be performers, initiators, or responsible actors of Processes in the AUM.

Current implementation of the Enterprise Modelling technology does not restrict the variety of names that can be used for intermodel links. Fragments of several submodels can be made available on the screen simultaneously for convenience of introducing the links. Using intermodel and intramodel links, special meta structures of EM elements can be generated for particular purposes of analysis.

3.7. The process of Enterprise Modelling

The Enterprise Modelling process is issue driven and situation sensitive. Knowledge elicitation and knowledge analysis phases follow each other at times as it is necessary. Knowledge, being acquired, is represented in the Enterprise Models during both phases. The knowledge elicitation phase is usually organised in group sessions and supported by tools for visual knowledge representation (e.g. goal structures, concept models, data flow diagrams). Knowledge analysis is normally performed by knowledge engineers using manual and computer supported methods of knowledge analysis and modelling.

The modelling process usually starts with objectives analysis, where the main problems and goals are suggested, discussed, and reflected in the OM. The process can also start with an analysis of the existing activities, its organisational structure, and representation of so acquired knowledge in the AUM. Issues for elicitation and analysis are chosen depending on the knowledge already existing in Enterprise Model and depending on the knowledge sources available.

To acquire requirements of sufficient quality [13], all the main issues of interest can be, and should be considered during Enterprise Modelling. Four of the enterprise Models, the OM, CM, AUM, and AM can cover all the pragmatic issues (Fig. 2).

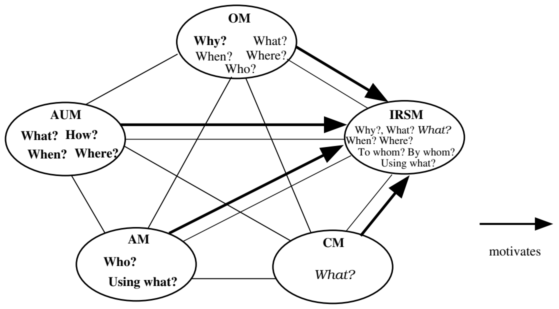

Fig. 2 Consideration of main issues of interest in Enterprise model

Analysis of goals and problems in the OM can give answers why particular development actions or processes (what) are introduced, way particular actors (who) are playing particular roles, and when and where things are happening or should happen. Modelling in the AUM can show not only what the processes are (or should be), but also how they are functioning, including their localisation (where) and their temporal aspects (when) (see section 3.2). The AM model supports information about performers (who) of the processes as well as the materials and equipment used in them (using what). The CM supports the "What?" perspective in a broader sense. It gives answer to the question "What are the conceptual elements in Enterprise Model we are talking about?". Thereby it supports the minimisation of redundancies during knowledge acquisition process. The consequences of objectives modelling, the modelling in each submodel, and the overall analysis of the Enterprise Model are projected to the IRSM (see section 3.5).

Enterprise Modelling is a process that prescribes creativity and flexibility of requirements engineers' thinking. However, it needs appropriate strategic and operational management. The quality of the results is to a large extent human agreement dependent. Nevertheless, computer-aided checking of structure elements can be used as partial, built-in quality assurance procedures.

4. Expressiveness of the Enterprise Model

The Enterprise Model is organised as a system of models, and serves as a source of knowledge in the process of requirements elicitation. Knowledge-like, modular organisation of the Enterprise Model supports its usability.

Looking intuitively to the meta-knowledge structure elements, given in section 2, we can say that the Enterprise Model in its current stage of development covers all the other structures, except for the "physical space" and "time" issues. Figure 3 shows possible mappings between Structures 1,2,4,5, and 6 to the Enterprise Model (Structure 7). Elements of Structure 3: PLAN, DO, SEE map with Enterprise model in the following way. DO maps to IRSM. OM, AUM, AM and CM can be interpreted as PLAN or they can be considered as SEE, if impacts of possible requirements on domain organisation are analysed. The Concepts Model is not considered in Fig 3, as it plays mainly a semantic, and to a lesser degree, a pragmatic role in Enterprise Modelling. In no one of the other structures surveyed (1-6), is the corresponding semantic element introduced.

	Structure 7			
	OBJECTIVES	ACTIVITIES & USAGE	ACTORS	IS REQUIREMENTS
Structure 1	PURPOSE	FUNCTION, STATE, FORM		FUNCTION, STATE, FORM
Structure 2	EQUIPMENT, TASK	EQUIPMENT, TASK, TEAM	TEAM	EQUIPMENT, TASK, TEAM
Structure 4	PURPOSE	FUNCTIONS, STRUCTURE	FUNCTIONS, STRUCTURE	FUNCTIONS, STRUCTURE, PURPOSE
Structure 5	WORK ORGANIZATION	WORK ORGANIZATION, WORK ACTIVITIES, TECHNICAL ARTIFACTS, PHYSICAL SPACE	WORK ORGANIZATION, WORK ACTIVITIES,	WORK ORGANIZATION, WORK ACTIVITIES, TECHNICAL ARTIFACTS, PHYSICAL SPACE
Structure 6	MANAGEMENT, TASK	TASK, STRUCTURE, TECHNOLOGY	STRUCTURE, ACTORS, TECHNOLOGY, MANAGEMENT	TASK, TECHNOLOGY STRUCTURE

Fig. 3 Mappings between meta-knowledge structure elements

EM can support requirements engineering with the knowledge models appropriate for team work, not only in knowledge elicitation procedures, but also in systems analysis, design, decision making, and management. It seems to have an appropriate capacity for requirements engineering. Besides the expressiveness of the Enterprise Model, benefits from the development of the semantically oriented Concept Model should be noted.

5. Conclusions

Enterprise Modelling technology supports requirements engineering process with well organised knowledge models. These models are adapted for analysis and understanding of pragmatic, as well as semantic issues, relevant in requirements identification. The Enterprise Model itself is flexible, and permits structure modifications and extension of the scope of its submodels.

The structures of the models are user friendly and convenient for knowledge elicitation. Analysis of knowledge can be performed manually and, to some extent, by software support.

The Enterprise Model supports different forms of knowledge representation (natural language, diagrams, conceptual schemes, etc.). There are few restrictions on the kinds of knowledge or information to be incorporated in the model.

With respect to the four requirements engineering problems, listed in the introduction, EM offers the following support:

1. Less information is "lost" in the elicitation and acquisition stages, as EM prescribes, and gives a place in its structure for many kinds of relevant application knowledge to be documented.
2. The notation used by the EM is closer to the way users and non-IT professionals see their problems, goals, and opportunities. They understand the descriptions better, and can, therefore, take an active part in the process.
3. Gathering "useless information" can never be completely avoided. The EM has, on the other hand, an experience based structure, where information needed for the later design stages, is required to be represented.
4. Specific guide-lines and "preconditions" are worked out for starting the EM activity (not discussed in this paper). If these guide-lines are followed, the possibility to perform a proper, authoritative, and participative requirements engineering process is increased.

Further development of Enterprise Modelling technology is, among other things, concerned with incorporation of time and space aspects in the meta level of submodels, development of software procedures for "rules of thumb" guidance to users of the models, and design of meta knowledge models for project and application management.

References

[1] Johannsen G., Alty J.L. *Knowledge Engineering for Industrial Systems* // Automatica. 1991. Vol. 27. No. 1. P. 97-104.

[2] *An American National Standard. IEEE Guide to Software Requirements Specifications,* ANSI/IEEE Std 830-1984, The Istititute of Electrical and Electronics Engineers, Inc. 345 47th Street, New York, NY 10017, USA, 1984.

[3] *Yourdon E. Modern Structured Analysis*, Prentice-Hall, Englewood Cliffs, NJ, 1989.

[4] Davis A.M. *Software Requirements Analysis and Specifications*, Englewood Cliffs, N.J.: Prentice Hall, 1990.

[5] Bubenko J.A., Dahl R., Nellborn Ch., Song W. *Computer Support for Enterprise Modeling and Requirements Acquisition*, SISU, Sweden, 1992.

[6] Norjberg J., Bansler J.P., Havn E. *Programmers' Need to Know* // Proc. of the 15th IRIS / G.Bjerknes, T.Bratteteig, K.Kautz, Eds, University of Oslo, 1992. P. 271-284.

[7] Kirikova M. *Mehods and Tools for Knowledge Acquisition Concerning Complex Technical Systems*. Dr.s.ing. Thesis, Riga, Riga Technical University (in Latvian).

[8] Gerow J. *Psychology: An Introduction*. Scott, Foresman and Company, 1986.

[9] Ohsuga S. *Framework of Knowledge-Based Systems - Multiple Meta- Level Architecture for representing Problems and Problem Solving Processes* // Knowledge Based Syst. 1990. Vol. 3, No. 4. P. 204-214.

[10] Rouse B.W., Cannon-Bowers J.A., Salas E. *The Role of Mental Models in Team Perfomance in Complex Systems* // IEEE Trans. on Syst., Man and Cybern. Vol. 22 No. 6. P. 1296-1308.

[11] Rouse W.B., Morris N.M. *On Looking into the Blsck Box: Prospects and limits in the Search for Mental Models* // Psuch. Bull. Vol 100 P. 349-363.

[12] Mitsumori S. *Corporate Information Systems and Information Technologies* // IEEE Transact. Man. Cybern., Vol. 22, NO. 6, P. 1323-1330.

[13] Sage A.P. *Systems Engineering*. New York: Chichester: Brisbane: Toronto: Singapore: John Wiley & Sons, Inc. , 1992.

[14] Kjaer A., Madsen K.H. *The dependencies between Work Activities, Technical Artifacts, Space, and Work Organization* // Proc. of the 16th IRIS / J.P.Bransler, K.Bodker, F.Kensing, J.Norjberg, J.Pries-Heje, Eds, University of Copenhagen, 1993. P. 39-44.

[15] Lyytinen K., Mathiassen L., Ropponen J. *Software Risk Management as Satisficing behaviour: an Environmental Model.* University of Jyvaskyla, 1993.

[16] Bubenko J.A jr. *Extending the Scope of Information modelling* / Fourth International Workshop on the Deductive Approach to Information Systems and Databases. Lloret - Costa Brava: UPC, 1993, P. 73-98.

[17] F3 Consortium, *From Fuzzy to Formal*, Technical Annex Part II, ESPRIT Project 6612, The F3 Consortium, 1993.

[18] Orci T. *Temporal Reasoning and Data Bases*, PhD Thesis, Royal Institute of Technology, Stockholm, Dept. of Computer and Systems Science, Sweden. DSV No. 93-008-DSV, 1993.

[19] *A Consensus Glossary of Temporal Database Concepts* / Ch. S. Jensen et.al, distributed on computer net, 1993.

[20] TEMPORA Consortium, *TEMPORA (P2469) Project Manual* BIM Information Technology, Belgium, 1994 (under production).