

## ENTERPRISE ONTOLOGY DEVELOPMENT AND EXTENDING

*Need for enterprise ontology (EO) can be considered as one of the most challenging aspects to build Intelligent System for enterprise management and collaboration. This is a fundamental issue for successful development of business process automation, organization knowledge sharing and inter-organizational coordination. In this paper we analyze existing solutions for this need, examine the contexts these solutions can be applied and provide the vision how the formal definitions can be applied for the non -defined or poorly defined organizational concepts of knowledge-based organizations.*

### Introduction

Knowledge Intensive Organizations (KIOs) are becoming more and more critical for the modern world. Such type organizations experience significant growth in amount and total resources they influence and create. But what is even more considerable — they provide significant impact onto all human activities. The research is focused on the delivering improvements to KIOs in the most demanding area — working with knowledge by enterprise ontology development and extending. This work is not limited to separate Knowledge Intensive Organizations as a large traditional enterprise can also have a KIO-type unit.

Defining the term "ontology" is not an easy task. In this work the shortest but very meaningful definition is considered. It was originally provided by Tom Gruber in his famous work "A Translation Approach to Portable Ontology Specifications" in 1993 [ 1 ]. "An ontology is an explicit specification of a conceptualization" — this definition is used for more than a decade. During the latest years a lot of other definitions and explanations appeared [2]. By enterprise ontology we understand the ontology build for the use in the enterprise domain and for the enterprise tasks.

According to the past research the main aspects of Knowledge Intensive Organization growth and development are considered the enterprise ontologies, collaboration systems, and efficient knowledge sharing. From these items the enterprise ontology can be named as the most important as it forms the foundation for further development. In real intellectual organization its ontology is the core value and success driver. Managers and business analysts will have to use ontology both on formal or informal level to change and share the knowledge about enterprise and its environment. Formal and informal ontology can be viewed as enterprise programming language. It is widely discussed that in the future it

is very possible that enterprise will be configured with mere managerial descriptions. Another known issue for any organization is to make all people use same language for same concepts. And this issue is even of the higher importance for the Knowledge Intensive Organizations comparing to traditional organizations.

The goal of the research is to identify the well-defined enterprise ontologies or their elements, the process of the ontology extending and the impact of ontology implementation on the organization and its software systems: inner systems of organization and inter-organizational collaboration. These are the main aspects investigated in the scope of this research. The object inspected is enterprise ontology and its various aspects: enterprise modeling and knowledge sharing, inter-organizational communication, human and computer knowledge communication, role of enterprise ontology in the intelligent enterprise systems.

During the research we investigated the ontology in the context of enterprise domain and enterprise tasks. Specifically the search for approved standards was performed. It was found that the mature standards for Enterprise Ontology related concepts are not yet available.

### Enterprise Ontology

IT community is now experiencing the constantly growing amount of projects and groups developing knowledge bases and ontology-related aspects. The following are the useful sources to investigate the current achievements in this area: [3], [4], and [5]. A number of ontologies are developed by the current moment. Ontolingua ontology library [6] and DAM L ontology library [7] are considered as the earliest and best known. A variety of ontologies are developed by the commercial organizations and distributed freely.

The following areas are the place for the most intensive research and development at the moment: formal knowledge representation means (languages, notations, tools), domain and task ontologies development with the assistance of domain experts, methods and means for collaborative ontology developments, merging and reuse.

In this work we focus on the enterprise ontologies as the primary foundation to achieve true organizational intelligence. Nowadays there are many projects and initiatives with the goal to develop the ontology for specific enterprise tasks. The most demanding needs for enterprise ontology were investigated during the first stage of research. Considering domain and task attention of the ontology developers we can identify the following primary areas of interest:

- enterprise processes, workflows, scheduling;
- resources and capabilities;
- enterprise strategy, goal setting, objectives;
- marketing and sales;
- organizational structure, authority;
- decisions, risks, assumptions;
- meta-ontology concepts (state, actor, time and others).

These areas of interest are revealed in more or less details in the enterprise domain-task ontologies. Still at the current moment the industry doesn't have an accepted standard for the shared ontology concepts. The unification of the available concepts is still a major task. For now the enterprises usually use several available ontologies and define their own set of accepted concepts with shared understanding in the borders of organization. Inter-organizational shared ontologies can be now negotiated for each particular case only.

In order to ease the enterprise modeling tools and working with ontologies, many software developers provide specialized tools and instruments. One of the best reviews of such available tools can be found at [8]. These tools are usually just extended with ontology support additionally to the traditional uses of enterprise modeling.

During last 10 years there were many initiatives to suggest adequate ontology which could be used for the domain of enterprise modeling and engineering. For the purpose of this research the following best known efforts are analyzed and compared in Table 1.

It is considered that the primary role of the ontology in the enterprise domain is to be an efficient communication medium:

- between people in the same organization or in inter-organizational communication,
- between people and intelligent software - interface for experts and engineers,

- between various software systems — the interoperability issue.

Also the enterprise ontology is intended to assist: acquisition, representation, and manipulation of enterprise knowledge; such assistance is via the provision of a consistent core of basic concepts and language constructs; structuring and organizing libraries of knowledge; the explanation of the rationale, inputs and outputs of the enterprise intelligent software [1].

### Concepts for the Intelligent Organization

To be intelligent the organization should prove its system view on the operations it performs. The top-level organizational concepts for this are stakeholders theory and value-based management (VBM). Stakeholders theory claims that any organization should achieve and maintain the balanced satisfaction of its influential stakeholders. Only under such conditions it can survive and grow. Value-based management principles state that the enterprise is functioning to create value. Thus the primary goal of the enterprise is the management of the value-creation processes and the measuring of such value.

These concepts exist for several decades already however not many enterprises could achieve and keep such an ideal state for a long time. There were lots implementation approaches in the past. Nowadays the most mature and system methods are those evolved in 90<sup>th</sup>: Balanced Scorecard [17] and Intangible Assets Monitor [18]. To achieve the system view and system enterprise functioning, these methods are combined with traditional disciplines like Activity-Based Costing and various others. Knowledge Intensive Organizations mostly perform project-based operations, thus concepts to successfully manage projects become the top priority for them. With this regard the work breakdown structure (WBS) concept is expected to be realized according to PMBOK[19] definition.

As the enterprise ontology development is now moving to the higher levels of the enterprise management, the listed organizational concepts can be considered as the first candidates to be formally defined in the enterprise ontologies. The organizational theorists' books and articles are viewed as excellent sources for the expert opinions and more or less mature definitions. The works of Henry Mintzberg, Karl-Erik Sveiby [18], David Norton and Robert Kaplan [17] can be good examples of expert opinion sources. Even more formal structures are defined in the software development methodologies and requirements to them defined in SEI CMMI,

PSP, TSP; RUP, agile methodologies like XP, Crystal [20-21].

The existing approaches for enterprise ontology development are reviewed; existing methodologies, tools and languages are analyzed. The evaluation criteria with regard to the ontology competence are prepared to apply to the final result. Examples of such criteria can be found in Table 2 [11 ;22].

It is clearly expected that the organizational and business literature will be thoroughly analyzed against enterprise ontology to find contradictions, consisten-

cy mistakes, right naming for ambiguous terms. It will be usual for the authors of the new concepts and models to test their achievements against the available and in-use enterprise ontologies before publishing.

### Enterprise Ontology Extension with WBS and BSC

It is typical for Knowledge Intensive Organizations to work on project basis. The Work Breakdown Structure concept is traditional for project management. This concept is also well-known for its initial ambi-

Table 1. Organizational and Enterprise Ontologie

Title and Description	Language	Active Period
<p><b>Enterprise Ontology: EO (AIAI)</b> The Enterprise Ontology was developed within the Enterprise Project, a collaborative effort to provide a framework for enterprise modeling. The Ontology was built to serve as a basis for this framework which includes methods and a computer tool set for enterprise modeling.</p>	Informal English and Ontolingua	1993-2000
<p><b>Toronto Virtual Enterprise: TOVE (University of Toronto)</b> The goal of the TOVE project is to create a data model that: 1) provides a shared terminology for the enterprise that each agent can jointly understand and use, 2) defines the meaning of each term (semantics) in a precise and as unambiguous manner as possible, 3) implements the semantics in a set of axioms that will enable TOVE to automatically deduce the answer to many "common sense" questions about the enterprise, and 4) defines a symbology for depicting a term or a concept in a graphical context.</p>	Prolog	1993-2000
<p><b>Core Enterprise Ontology: CEO</b> CEO is the first proposal of a methodological frame to construct enterprise ontologies. The Core Enterprise Ontology comprises a categorization of the enterprise concepts and a first proposal of Upper Ontology. In this approach, specific enterprise ontology is build starting from CEO and proceeding top-down in the refinement and decomposition hierarchies.</p>	Informal English (now)	Ongoing effort
<p><b>Process Specification Language: PSL</b> The Process Specification Language defines a neutral representation for manufacturing processes. PSL is being standardized within Joint Working Group 8 of Sub-committee 4 (Industrial data) and Sub-committee 5 (Manufacturing integration) of Technical committee ISO TC 184 (Industrial automation systems and integration).</p>	KIF	Ongoing effort
<p><b>OpenCyc, certain domain areas</b> OpenCyc is the open source version of the Cyc technology, the world's largest and most complete general knowledge base and commonsense reasoning engine. OpenCyc can be used as the basis of a wide variety of intelligent applications such as: speech understanding, database integration, rapid development of an ontology in a vertical area, email prioritizing, routing, summarization, and annotating.</p>	CYCL	Ongoing effort
<p><b>Business Management Ontology: BMO</b> The Business Management Ontology (BMO) represents an integrated information model, which helps to better align IT with business. It brings together business process design, project management, requirements management, and business performance management (in the form of balanced scorecards). As such, it forms the basis for an integrated, vendor-neutral, Business Management Knowledge Base, from which various artifacts can be generated.</p>	OWL, edited with Protege	Ongoing effort

Table 2. Ontology Competence Criteria

Criterion	Description
<b>Functional Completeness</b>	Can the ontology represent the information necessary to support some task?
<b>Generality</b>	To what degree is the ontology shared between diverse activities such as engineering design and production, or design and marketing? Is the ontology specific to a sector, such as manufacturing, or applicable to other sectors, such as retailing, finance, etc?
<b>Efficiency</b>	Does the ontology support efficient reasoning, i. e., space and time, or does it require some type of transformation?
<b>Perspicuity</b>	Is the ontology easily understood by the users so that it can be consistently applied and interpreted across the enterprise? Does the representation "document itself?"
<b>Precision/Granularity</b>	Is there a core set of ontological primitives that are partitionable or do they overlap in meaning? Does the representation support reasoning at various levels of abstraction and detail?
<b>Minimality</b>	Does the ontology contain the minimum number of objects (i. e., terms or vocabulary) necessary?

guity. This was such a serious problem that Project Management Institute had to develop a special "Practical Standard for Work Breakdown Structures" definition of the project work".

WBS concept is defined as [19]: "A deliverable-oriented grouping of project elements that organizes that the terms used in the definition need signifi-

Table 3. BSC to EO mapping

BSC concepts	Enterprise Ontology terms
Vision	STATE of AFFAIRS, PURPOSE
Strategy	A PLAN to ACHIEVE a PURPOSE
Perspective	Just a domain area, no direct mapping
Critical Success Factor	A PURPOSE declared by an Actor to be critical to the success of one or more higher-level PURPOSES
Objective	A PURPOSE with a defined measure
Measure	ACTIVITY SPECIFICATION describing how to collect and analyze metrics
Target / Score	The value for measure with scoring rules

cant elaboration. The preliminary proposal for WBS formalization includes the use of the following Enterprise Ontology concepts:

- PU RPOSE or O BJECTIVE - to define the states required to achieve after the project scope is fulfilled;
- the "descending levels" can be formalized as "HELP-ACHIEVE" relationships between STATES OF AFFAIR;
- the "project work" is an ACTIVITY SPECIFICATION or PLAN.

The described mapping is partially realized with Prolog predicates with goal to visualize the achieved knowledge about the project. The knowledge was then mapped to the DB tables structures for analysis in OLAP. The visualizing was achieved with multidimensional views provided by the PivotTable.

Another area for extensions covers the entire enterprise management, not just project management. It is well-known that value-based management practices can contribute tremendous value into the enterprise management practices. But due to the complexity to use those, and especially integrate all concepts, most implementations of VBM/BSC practices failed. We believe that combined with formal definitions programmed into enterprise IT systems the ratio of successful VBM/BSC implementations should significantly increase.

In the Table 3 the selected BSC concepts are mapped into Enterprise Ontology terms. The further work will include the complete formalization of these concepts and measuring the efficiency of use.

### Conclusion and Further Implications

It was found that customized enterprise ontology is gradually becoming the mean which depicts the current organizational theory of business. It provides the best system view on the organizational vision, existing beliefs and the style the organization is doing work. In the result of the in-depth analysis it is possible to synthesize the process for successful

ontology development, customization and use in the particular organization.

At the current moment a very small amount of successful implementation of enterprise-wide ontologies is known. However there are several prospective ongoing initiatives which already achieved valuable output. It is common belief that Enterprise Ontology is becoming the foundation to solve the main KIO needs. Truly intelligent organization should have the following knowledge assets in the nearest future: 1) a set of reusable business processes (how-to knowledge)

described in terms of customized and extended enterprise ontology; 2) a set of declarative knowledge will be formalized and shared among the staff members: information about clients, industries, staff and capabilities, technologies and external environment.

The further work in this area will include the research and choice of the set of critical concepts and terms for knowledge intensive organization in specific area (for example for consulting of software development enterprise). In this context the terms will be defined and organized into meaningful and reusable set of knowledge concepts. The developed and customized enterprise ontology is expected to be integrated with available systems to demonstrate the new intelligent way to solve critical tasks:

- workflow planning and monitoring;
- task-people matching according to availability and competences;
- intelligent forecasting based on guess-parameters or available historical data.

Another effort will focus on methods and approaches to develop and deploy ontologies. Specifically the issues with ontology significant changes or ontology definition mistakes are planned to be investigated. The available methodologies should be compared; possible approach like "rapid ontology development and implementation" will be researched. Recommendations about requirements for tools, collaborative environment and best-practices should be provided.

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## ПОБУДОВА ТА РОЗШИРЕННЯ ОРГАНІЗАЦІЙНОЇ ОНТОЛОГІЇ

*Необхідність організаційної онтології є одним із найскладніших завдань побудови інтелектуальних систем підтримки організаційного управління та співпраці. Наявність якісно визначеної та несуперечливої організаційної онтології є передумовою успішності автоматизації організаційних процесів, поширення організаційного досвіду та співпраці з іншими організаціями. У статті проаналізовано існуючі методи та інструменти вирішення цього завдання, їх контекст та обмеження. Запропоновано бачення процесу створення організаційної онтології, її розширення для конкретної організації, шляхи впровадження і використання для потреб організації. Для прикладу подано бачення процесу формального онтологічного визначення деяких критичних концепцій організаційного управління — поняття збалансованих оціночних індикаторів (стратегії, цілей) та поняття структури робіт проекту.*