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ENTERPRISE KNOWLEDGE MODELLING: DOMAINS AND ASPECTS

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Abstract. The paper presents the Knowledge-based Enterprise framework aimed for the analysis of knowledge management and development of an Enterprise knowledge base. The approaches concerning the modelling of enterprise domains and aspects are presented and used for the development of the concept of Enterprise Knowledge Component. The Enterprise knowledge component (*B*, *T*, *K*) is defined as a composition of 3 obligatory parts: knowledge management methods (*K*), the knowledge about IT (*T*) services and tools, and business management knowledge (*B*). The formal modelling structure – the Enterprise Knowledge Space (*B*, *T*, *K*) is constructed for the refinement of the hierarchy of enterprise knowledge items. The Knowledge-based Enterprise framework is represented as modified Value Chain Model including the knowledge management layer and IT component. The major knowledge subsets of the enterprise knowledge base are identified.

Keywords: enterprise domain, knowledge aspects, enterprise knowledge component, enterprise knowledge space, knowledge-based enterprise model.

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1. Introduction

Knowledge management is the business activity intended to solve critical enterprise adaptability and competitiveness issues in a rapidly changing environment. The main goal of the knowledge management in enterprises is to create an organizational context for effective creation, storage, dissemination and use of enterprise knowledge, which are essential for

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securing enterprise competitiveness against the changing business environment and for setting the environment towards a desirable direction (Maier 2004).

There are some well-known knowledge management models (Holsapple, Joshi 1999), which highlight some important knowledge management aspects and knowledge management components aimed at implementing knowledge management in organizations.

In spite of the variety of knowledge management models and tools, there is a gap between these theoretical models and the practical implementation of knowledge management systems in organizations. This problem of adjustment of business requirements and IT capabilities is known under the name of "Business and IT alignment" (Henderson, Venkatraman 1990).

The integrated enterprise knowledge base is concerned as a tool for solving a range of business problems: business transformation into the knowledge-based business, business and IT alignment, and the support of computerization of business management tasks. The elaboration of the enterprise knowledge base into the information system engineering life cycle represents the knowledge-based information system engineering paradigm (Gudas, Lopata 2001).

There are 3 concepts related to the knowledge-based enterprise: "knowledge-intensive", "knowledge-centric" and "knowledge-based". The appropriate name for any enterprise based on knowledge-intensive work, or on knowledge-intensive products is a "knowledge-intensive" organization or firm. According to Zack (2003), the basic features of the knowledge-centric organization, regardless of whether its products are tangible or not, is that the knowledge-centric organization a) recognizes knowledge as a key strategic resource, b) rethinks its processes in the knowledge-oriented sense (i.e. it takes knowledge into account in every aspect of its operation and treats every activity as a potentially knowledge-enhancing act. c) align their knowledge management processes with their strategy (Zack 2003). On the basis of the literature analysis, the "knowledge-based" enterprise is defined as knowledge-centric enterprise, which integrates enterprise knowledge base into the overall business management and development framework.

The paper presents the knowledge-based enterprise framework targeted in the analysis of knowledge management activities and development of an enterprise knowledge base. The overview of modelling frameworks concerning the domains and aspects of enterprise knowledge are discussed (Table 1), and the concept of the enterprise knowledge component is developed (Fig. 1). The formal knowledge modelling structure, i.e. the enterprise knowledge space (B, T, K) is constructed for refining the hierarchy of enterprise knowledge items.

2. Enterprise knowledge domains and aspects in different modelling frameworks

Having defined the knowledge-based organization independently of the products the enterprise produces, the following approach is concerned with the identification of the types and the actual content of the enterprise knowledge.

Table 1. Domains and aspects of the enterprise knowledge

Modelling framework	**Domains and aspects of the enterprise knowledge**			
Henderson, Venkatraman 1990	Business domain; Business strategy	Business domain; Business infrastructure	IT domain; IT strategy	IT domain; IT infrastructure
J. Zachman ISA Framework	Business domain; Motivation, Time	Business domain; Processes/ Functions, Data, People, Network	IT domain; Goals and objectives, Time, People	IT domain; Functions, Data structure, Network,
Iyer, Gottlieb 2004	Business process domain	Organization domain	Information/ knowledge domain	IT infrastructure domain
Porter's value chain model	Business domain, Support activities	Business domain, Primary activities		
GERAM, Williams and Hong 1995	Business domain; Management and control, Customer service	Business domain; Resource, Organization, Information, Function	IT domain; Humans, Machinery	IT domain; Software, Hardware
MEMO	Business domain; Goal (competitive-ness), Resource (Human resource technology), Struc-ture (Strategic Busi-ness units), Process (value Chain)	Business domain; Operational goals Employees, machinery, Organization structure, Task process	Information System (domain); Requirements metrics, Architecture, Object model	Information System (domain); Application, transaction workflow
Maes *et al.* 2000	Business domain; Strategy, structure	Business domain; Information and communications; Operations	Technology domain; Strategy, systems, structure	Technology domain; Infrastructure, Operations
ARIS (EPC)	Business domain; Event, Function, Work, Control flow	Business domain; Information flow, Resources, Organization unit, Role		
UEML	Business domain; Event, Process, Activity, Role	Business domain; Organization unit, Enterprise object (Product, Order, Resource (Humans, Machinery)	IT domain; Resource (Humans)	IT domain; Enterprise object Resource (Application, Machine)

The investigations in the knowledge management area are closely related to modelling frameworks in the area of enterprise architecture (EA) (Schekkerman 2003), enterprise modelling (EM) frameworks (Zachman, Sowa 1992; Maes *et al.* 2000; Ulrich 2002) and languages

(Vernadat 2002). The Enterprise domains and related aspects of the enterprise knowledge are identified in various EM/EA methodologies and frameworks (Table 1), and are used for developing the concept "enterprise knowledge component" (Fig. 1).

Henderson and Venkatraman have analysed business-IT alignment problem and proposed a Strategic Alignment Model (SAM) for business–IT alignment (Henderson, Venkatraman 1990). The model is aimed to support the integration of information technology (IT) and develop it into a business strategy by advocating alignment between and within 4 enterprise views, namely, Business strategy, IT strategy, Business infrastructure, and IT infrastructure. The major constructs of SAM-enterprise domains (namely, *Business domain* and *IT domain*) and views (*Business strategy, Business infrastructure, IT strategy, IT infrastructure*) are selected as criteria for the analysis of major concepts of various EM methodologies and EA frameworks (Table 1).

B. Iyer's and R. Gottlieb's decomposition of the enterprise architecture (Iyer, Gottlieb 2004) identifies 4 domains: the business process domain, the information/knowledge domain, the infrastructure domain and the organization domain.

Analysis of the Enterprise modelling (EM) methods and Enterprise architecture (EA) frameworks is the basis for presented theoretical findings. The analysis of the EM methods are analysed in (Gudas, Brundzaitė 2006, 2007). The 3 basic aspects of the enterprise knowledge are refined in the contemporary EM and EA approaches: *knowledge concerning strategy; knowledge concerning business management and control; knowledge related to usage of information systems and technologies*.

The problem of *Business and IT alignment* provides us with the insights concerning the role and impact of IT in the business process and provides the methodological view for the business-IT alignment (Henderson, Venkatraman 1990).

In order to sum up the above overview of enterprise modelling domains and aspects (Table 1), we make a premise that there are 3 integrated aspects of the enterprise knowledge: knowledge about business processes (*B*), knowledge about information technologies (*T*) and knowledge about knowledge management methods (*K*) (Fig. 1).

The composition of Enterprise Knowledge Component (*B*, *T*, *K*) represents a new viewpoint to enterprise knowledge modelling (Fig. 1): enterprise management facilities (decision

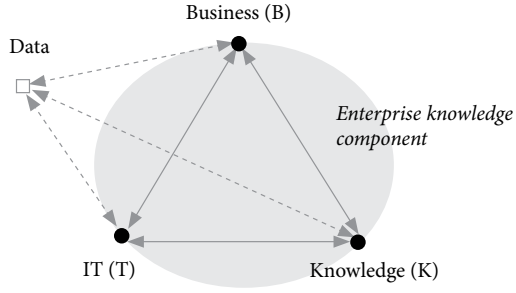

Fig. 1. Enterprise knowledge component (*B*, *T*, *K*) integrated with enterprise data (Gudas, Brundzaitė 2006)

making units) need complex integrated knowledge about Enterprise domains. In our approach Enterprise knowledge component (*B*, *T*, *K*) is a composition of 3 obligatory parts: knowledge management methods (*K*) that are necessary for IT-based (*T*) enterprise business process (*B*) management and integration.

For instance, some definite Enterprise knowledge component (Bn, Tj, Km) is defined as follows: (Bn = "Operational management method ABC", Tj = "Data mining tools", Km = "Business intelligence"). This Enterprise knowledge component specifies the required piece of knowledge retrieved by the Enterprise Knowledge management system responding to the query of some decision-making unit (department) located at the operational management level.

3. The enterprise knowledge space

In this chapter we explore the granularity of the enterprise knowledge with the purpose to systemize enterprise knowledge which will be applicable for the transformation of an enterprise into a knowledge-based enterprise, for the enterprise IT management and its alignment with business goals and the range of other business management functions.

The contemporary organizational theories distinguish 4 hierarchical levels in organizations: strategic level, tactical level, knowledge level and operational level (Laudon, Laudon 2002). On the basis of such a hierarchical system, it is possible to define 4 adequate levels in organizational information management processes.

We have modified a more-or-less ordinary hierarchical structure by placing knowledge management in the second level of the hierarchy, because of the overall nature of the knowledge management processes. The enterprise knowledge space (Fig. 2) was derived by fitting the integrated knowledge model component (Fig. 1) with the hierarchical information structure of the organization.

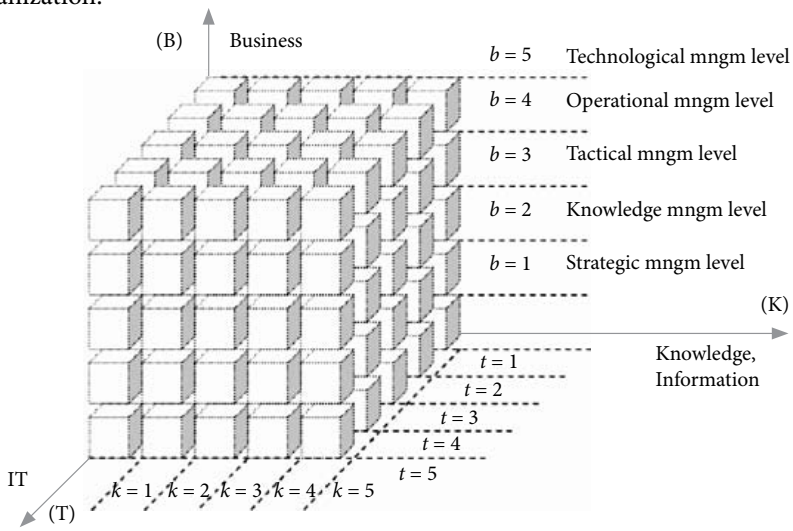

Fig. 2. Enterprise knowledge space *E* (*B*, *T*, *K*) (Gudas, Brundzaitė 2007)

The enterprise knowledge space *E (B, T, K)* is developed for the systematization of the enterprise knowledge modelling area; it is aimed to be employed for the development of practical enterprise knowledge modelling and management methods.

Each item *e* in the Enterprise Knowledge Space *E (B, T, K)* is identified along 3 axes:

$$e(b;t;k) \in E, \quad \forall b,t,k \in \{1,...,5\}. \tag{1}$$

Each of 125 items within the Enterprise Knowledge Space possesses its own semantics and identifies the definite component of enterprise knowledge, which integrates 3 aspects of the enterprise: business (*B*), information technology (*T*) and knowledge (*K*) at the same level of elaboration. E. g., item e_{111} represents the integration of knowledge concerning 3 aspects of Enterprise management: the strategic business management activities, strategic knowledge management methods and particular IT types that are used at the strategic management level.

There are 3 two-dimensional subspaces of the Enterprise Knowledge Space, namely, E1 = (*B*, *T*), E2 = (*B*, *K*), and E3 = (*T*, *K*). The subspace E1 "Business – IT" (*B*, *T*) defines information technologies that are used to support business activities at a definite management level (strategic, knowledge, tactical knowledge etc.). The subspace E2 "Business – Knowledge" (*B*, *K*) describes business management methods and their interaction with the organizational knowledge. The subspace E3 "IT – Knowledge" (*T*, *K*) characterizes the IT in the way it is used at each level of knowledge management. These subspaces of the Enterprise Knowledge Space support the analysis and integration of knowledge concerning different domains and aspects of Enterprise management activities.

For instance, the subspace "Business – Knowledge" (*B*, *K*) could be specified as follows:

E2= (*B* ={B1 – Strategic management level (this level embraces strategic management methods), B2 – Knowledge management level (this level embraces knowledge management methods), B3 – Tactical management level (this level includes tactical management methods), B4 – Operation management level (this level concerns operational management methods), B5 – Technological process control level (this level embraces process control and management methods));

K = {K1 – Ontological modelling level; K2 – Meta-meta-modelling level, K3 – Meta-modelling level, K4 – Conceptual modelling level, K5 – Particular (instant) modelling level}).

For instance, the levels of decomposition of the aspect of Enterprise "information technology (*T*)" could be as follows: (T1 – Ontology modelling IT (methodologies and tools), T2 – meta-meta-modelling IT (methodologies and tools), T3 – meta-modelling IT (methodologies and tools), T4 – enterprise conceptual modelling IT (methods and tools), T5 – partial enterprise modelling IT (packages, patterns, plug-in, etc.)).

These two-dimensional models logically interrelate with such well-known models as J. Zachman's Enterprise Information Architecture (ISA Framework) (1992) and Multi-perspective Enterprise Modelling (MEMO) (2002).

Maes *et al.* (2000) presents a three-dimensional Integrated Architecture Framework (IAF) for business-IT alignment. The IAF model is based on the ISA Framework (J. Zachman) and a well-known business-IT alignment model developed by Henderson and Venkatraman (1990).

The analysis of contemporary Enterprise knowledge modelling methods presented in Gudas, Brundzaitė (2006, 2007) shows, that there are no methods which could directly suit for the integrated modelling the defined knowledge aspects at the defined levels of detail.

Below, we are going to discuss a business modelling method, which is intended to model 3 interrelated aspects (business, IT and knowledge) of an enterprise in the integrated way.

4. Framework for enterprise knowledge management modelling

In the organizational management practice, Porter's value chain model (1985) is widely recognized. IT is applied for business system analysis, based on the separation between primary and secondary activities.

The value chain model represents a process-oriented attitude to business. In the Knowledge management (KM) field, the process-oriented view is also recognized as a success factor, thus the selection of Porter's value chain model as a background for enterprise knowledge modelling is quite adequate for analysing and modelling the enterprise knowledge management problem.

The interrelationship between primary and secondary business processes explored in Gudas, Lopata (2001) identified a different nature of these 2 enterprise activities: secondary processes possess informational nature and are referred to as *enterprise (management) functions*; while primary processes are concrete (non-informational) and are named *enterprise (material) processes*. Similar insights are represented in the organizational control systems modelling (OCSM) framework developed by Kampfner (1999).

The modified Knowledge-based Enterprise model (KBEM) is developed by identifying the knowledge management function (*K*) alongside with other management functions (*F*) in the Value Chain Model (Fig. 3). Additionally, for the completeness of the enterprise analysis, the component *Resources* (*R*) is included.

The KBEM is comprised of the main components: Business Process (*B*), Knowledge Management component (*K*), Process Management Cycle (*EMCp*), Knowledge Management Cycle (*EMCz*) which are supported by the IT component (*T*) and the Resource component (*R*).

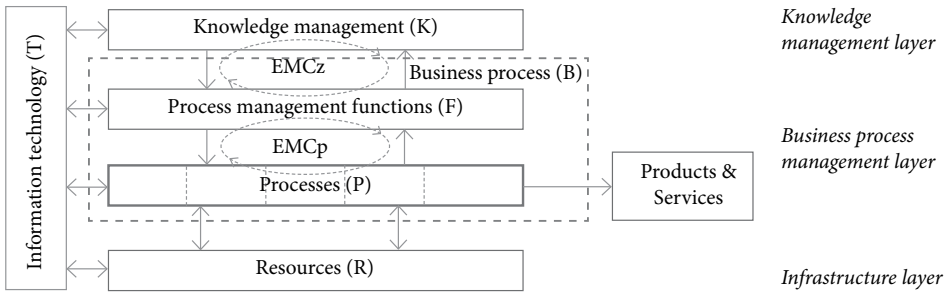

Fig. 3. The Knowledge-based Enterprise represented as modified VCM, including knowledge management layer (Gudas, Brundzaite 2006)

The semantics of the Knowledge-based Enterprise model is described in more detail by Gudas, Brundzaite (2006). The peculiarity of the developed KBEM model is the refinement of qualitatively different business activities (Management functions *F*, Knowledge management *K* and manufacturing Process *P*). The KBEM identifies and formally represents interactions among these Enterprise activities *F*, *K* and *P* as control processes *EMCz* and *EMCp* with different semantics.

The Business Process management level (level 5) is presented in Fig. 3 as separate layer dedicated to define the interactions of the management functions *F* and manufacturing processes *P*.

The interaction of the different layers of the KBEM is considered as the control loop (information feedback) as formally described by Gudas *et al.* (2004, 2005) as *EMC* (*Elementary Management Cycle*). The semantic models of identified management transactions *EMCp* and *EMCz* are different, and are defined as follows:

– Process management cycle *EMCp* implements a set of *Process* management functions. *EMCp* is responsible for the control over the component *Processes* (*P*), which primary activities of an enterprise (development of products and services in a proper way (Quality, Time schedule etc.));
– Knowledge management cycle *EMCz* is the higher level EMC, where the component *Knowledge management functions* (*K*) is responsible for the adequate activities of the KBEM component *Process management functions* (*F*). The *EMCz* is focused on the alignment of *Business process* (*B*) with the Enterprise strategic goals.

As the Process management cycle *EMCp* is extensively discussed by Gudas *et al.* (2005), below, the particularities of the Knowledge management cycle *EMCz* are described in brief.

By definition, an elementary management cycle *EMC* (cf. Gudas *et al.* 2005) consists of the predefined sequence of mandatory steps of information transformation (*Interpretation*, *Information Processing*, *Realization*); these steps constitute a management cycle (a feedback loop).

The content of information and semantics of transformation of these mandatory steps within an *EMC* depends on the subject area (problem domain). For instance, the subject area of the Knowledge management cycle *EMCz* is a definite set of Processes management functions. It is evident that this subject area of *EMCz* (i.e. information and semantics of transformation of *EMCz*) is totally different from that of the Process management cycle *EMCp*. The *EMCz* deals with the information about the characteristics of management functions (quality, efficiency, etc.); meanwhile, the Process management cycle *EMCp* controls the characteristics of products, services and the state of the *Process* itself (i.e. technological process).

So, the content (semantics) of information processed within these 2 management cycles (*EMCz* and *EMCp*) is different. The mandatory steps (*Interpretation*, *Information Processing*, *Realization*) of the Elementary Knowledge Management Cycle (*EMCz*) are defined as an information transferring processes focused on the control of the content of management functions *F*.

Whereas the modified Value Chain Model is focused on the enterprise knowledge management activities and components, it is named *Knowledge-based Enterprise Model* (*KBEM*).

5. The identifiers of the enterprise knowledge

The formal description of the Knowledge-based Enterprise Model (*KBEM*) as a model *M* featuring the knowledge management function *G* can be expressed as the Cartesian product as follows:

$$M = (G)\times(F_1,...,F_n)\times(P)\times(R)\times(R), \tag{2}$$

where *G* is the knowledge management function, F_1, ..., F_n represents business management functions, *P* stands for business processes, *R* signifies business resources.

This means that each Enterprise Knowledge Model item $m \in M$ in the Knowledge-based Enterprise is related to the appropriate knowledge management function g ($g \in G$), process management function f ($f \in F$), process p ($p \in P$), and resources r ($r \in R$). To put it in other terms, the Knowledge-based Enterprise Model item *m* is identified by a set of identifiers:

$$m(g; f; p; r) \in M\ . \tag{3}$$

The Enterprise Knowledge Model item *m* is located in the Enterprise Knowledge Space *E* (see Formula 1, Chapter 1.2), and is identified by additional identifiers. Enterprise knowledge model item *m* in the Enterprise Knowledge Space *E* (*B*, *T*, *K*) is defined as:

$$m_e\ (b; t; k; g; f; p; r; l) \in M_e\,, \tag{4}$$

where l ($l \in L$) is the time period index, $m_e \in M_e$. M_e is the enterprise knowledge model in consideration of the enterprise knowledge space.

The Enterprise Knowledge Model M_e enables to shape the model of knowledge-based business, since it considers knowledge management function (the identifier *g*) as well as other process management functions (the identifier *f*), processes (the identifier *p*) and their interactions comprising all 3 aspects of Enterprise knowledge component (the identifiers *b*, *t*, *k*). Each aspect of Enterprise knowledge (*b*, *t*, *k*) is decomposed into 5 levels of details in the Enterprise Knowledge Space (Fig. 2).

6. Enterprise knowledge management layer

The Knowledge management (KM) layer (Fig. 3) consists of Knowledge management activities. The KM layer is a multi-level hierarchical structure (Gudas 2008), and is comprised of the knowledge management levels as follows: the Enterprise Strategic management level (the Top Level, No. 1), the Enterprise meta-Knowledge management level (Level 2), the Enterprise Knowledge Management level (Level 3), the Enterprise Management level (Level 4).

This hierarchy of knowledge layers of the KBEM correlates with the knowledge hierarchy of T. Love (Love 2001): the technical knowledge about the problem domain (its methods and techniques as well as theories); the strategic non-technical knowledge (Ontological issues, Epistemological perspectives, General theories about knowledge management, theories about processes).

In the KBEM, a kind of the technical knowledge is located on Level 6, Manufacturing Process Management, Level 5, Business Process Management and Level 4, Enterprise Management.

The strategic knowledge is located at Level 3, Enterprise Knowledge Management, Level 2, Enterprise Meta-Knowledge Management and Level 1, Enterprise Strategic Management.

The knowledge related to the Knowledge management layer features some definite Enterprise strategic management paradigm, methodologies and models as well as IT tools to support knowledge management. For instance, the Business and IT Strategic alignment framework (Henderson, Venkatraman 1990) is the Enterprise management paradigm related to the Enterprise Strategic management level (Level 1).

The Enterprise meta-Knowledge management level (Level 2) is comprised of meta-knowledge and services aimed at knowledge base management. For instance, some appropriate Enterprise information architectures (frameworks) are associated with this level, among which GERAM, MEMO (Frank 2002), TOGAF, or some other EIA framework (Schekkerman 2003) may be mentioned.

The Enterprise Knowledge Management level (the Level 3) is comprised of knowledge concerning theories, methods, tools and services aimed at the execution of knowledge management activities.

The Business Process Knowledge Management level (Level 4) is comprised of knowledge concerning theories, methods, tools and services aimed at the execution of BP management activities (Management functions *F* and Processes *P*).

The Business Process management layer is presented at Fig. 3 as a separate layer dedicated to define the Process management cycle *EMCp* reflecting the interactions of the management functi *F* and manufacturing Processes *P*.

In Fig. 4, the major subsets of the enterprise knowledge base of the generalized Enterprise Knowledge Modelling framework are presented (the Class diagram, UML). The subsets of Enterprise knowledge correlate with the layers of the Knowledge-based Enterprise (Fig. 3).

The subsets of Enterprise knowledge are the basic knowledge components of the integrated Enterprise Knowledge Base. The integrated Enterprise Knowledge Base is considered to be the basic component of the Knowledge-Based Enterprise and will enable to support advancement concerning progress in dealing with business management problems:

- transformation of an enterprise into a knowledge-based Enterprise;
- enterprise IT management process;
- strategic alignment of knowledge-based business and required IT.

7. Conclusions

The existing contemporary information systems development methods that are based on enterprise modelling do not suit for the transformation of business into knowledge-based business provided it is based on information technology.

The presented approach to the knowledge-based enterprise which is based on information technologies is grounded on the knowledge-based IS engineering paradigm.

The concept of the Enterprise Knowledge Space is defined, which delineates the boundaries and granularity of enterprise knowledge layers and components. The framework of the Enterprise Knowledge Space is based on the analysis of Enterprise domains and aspects of

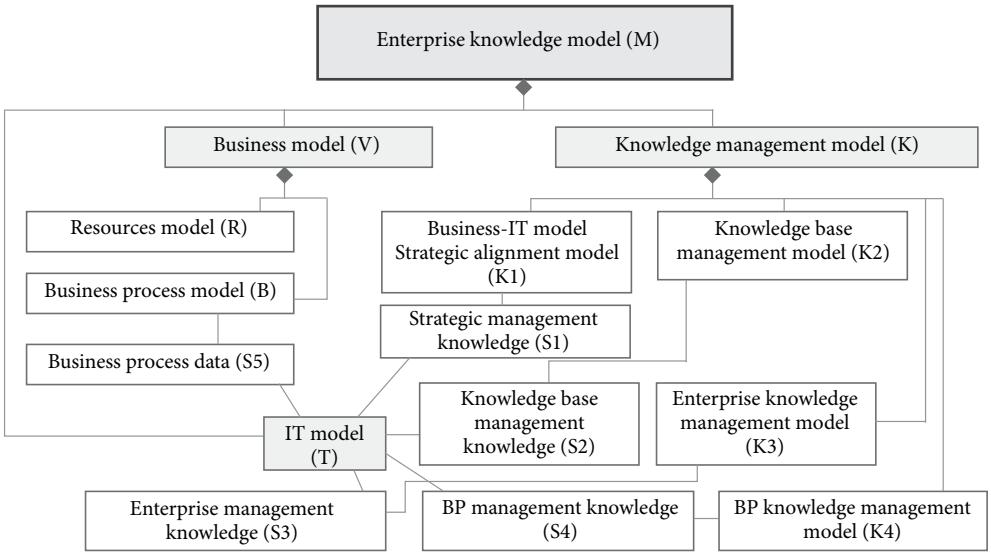

Fig. 4. The major knowledge subsets of the enterprise knowledge base (Gudas, Brundzaite 2006)

the enterprise knowledge generalized by the following concepts: the Enterprise Knowledge Component (*B*, *T*, *K*), and the modified VCM including knowledge management layer.

The process-oriented Knowledge-based Enterprise Model (KBEM) is presented by modifying Porter's Value Chain Model (VCM). The peculiarity of this KBEM is the identification of Knowledge management layer next to Business process management layer. Interactions among layers of the KBEM are the following formally described as semantically different control loops: the Process Management Cycle (*EMCp)* and the Knowledge Management Cycle (*EMCz*). The Knowledge-based Enterprise is represented as a modified value chain model featuring the knowledge management component.

The Enterprise Knowledge Space supports analysis and integration of knowledge about different domains and aspects of Enterprise management activities. The described Enterprise Knowledge Modelling framework is aimed to develop the enterprise knowledge modelling method and a knowledge management tool.

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VEIKLOS ŽINIŲ MODELIAVIMAS: DOMENAI IR ASPEKTAI

S. Gudas

Santrauka

Pateiktas apibendrintas žiniomis grįstos veiklos modelis, skirtas žinių valdymui analizuoti ir kurti organizacijos (veiklos) žinių bazę. Aptarti veiklos domenų ir aspektų modeliavimo būdai, remiantis šia analize suformuluotas veiklos žinių komponento konceptas. Veiklos žinių komponentas (*B*, *T*, *K*) yra apibrėžtas kaip būtina trijų dalių visuma: žinių valdymo metodai (*K*), žinios apie IT paslaugas ir priemones (*T*) bei veiklos valdymo žinios (*B*). Sudaryta formali modeliavimo konstrukcija – organizacijos (veiklos) žinių erdvė (*B*, *T*, *K*), kuri atskleidžia veiklos žinių elementus. Apibendrintas žiniomis grįstos veiklos modelis pavaizduotas remiantis modifikuotos vertės grandinės modeliu, papildytu žinių valdymo sluoksniu ir IT komponentu. Identifikuoti pagrindiniai veiklos žinių bazės žinių poaibiai.

Reikšminiai žodžiai: veiklos domenas, žinių aspektai, veiklos žinių komponentas, organizacijos (veiklos) žinių erdvė, žiniomis grįstos veiklos modelis.

Saulius GUDAS. Born on 10 June 1952. Nationality: Lithuanian. Degree: Doctor (HP); Title: Professor Position: Professor, Vilnius University, Kaunas Faculty of Humanities, Department of Informatics. Education: 1969–74 Kaunas University of Technology, 1982 – PhD on the topic „Synthesis of algorithmic structure of Information Systems for Manufacturing objects"; 2005 – Habilitation procedure on the topic „Modelling of Knowledge-based Information Systems engineering processes". Research directions: knowledge-based enterprise modelling, knowledge-based CASE methods.