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Knowledge-Based Enterprise Framework: A Management Control View

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1. Introduction

Contemporary organizations need to manage not only data, but the whole data-information-knowledge continuum; this is why the role and structure of the enterprise repository or enterprise knowledge base have to change adequately too. The concept of computerised knowledge base becomes important with the emergence of such intensively computer-based organizational forms as supply chains, virtual organizations etc. Organizations require having not only data in virtual environment (i.e. shared data bases), but also digital knowledge about those data, as well as about the data structure and semantics; knowledge about enterprise infrastructure and processes; process management up to strategic intentions (Gudas, 2009a).

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

The main goal of the knowledge management in enterprises is to create organizational context for effective creation, store, dissemination and use of enterprise knowledge, which are essential for enterprise competitiveness in changing business environment.

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 "Business and IT alignment" (Henderson, Venkatraman 1990). The investigations in knowledge management area are closely related to developments in the field of enterprise architecture (EA) frameworks (J.Schekkerman, 2003), enterprise modelling (EM) frameworks (Zachman, Sowa, 1992; Maes, et al., 2000; Ulrich, 2002) and languages (Vernadat, 2002). Enterprise domains and aspects of the enterprise knowledge identified in the various EM and EA methodologies and frameworks reflect the semantics of the concept "enterprise knowledge component".

The most IT-based enterprises today are data-driven: enterprise management activities are supported by management (functional) IS based on the Data Base Management Systems services. 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 IT-based support of business management activities.

There are three concepts related to the knowledge processes in enterprise: "knowledge-intensive", "knowledge-centric" and "knowledge-based". Appropriate name for any enterprise, based on knowledge intensive work, or knowledge intensive products is a "knowledge-intensive" organization or firm (Zack, 2003).

Even if the definition of the knowledge-centric enterprise does not emphasize the use of the information technologies (IT) in the enterprise, it should be noted, that research presented here is concerned with the contemporary enterprise, which uses IT extensively for the support of the management of its business processes. On the basis of the literature analysis "knowledge-based" enterprise is defined as an enterprise, which integrates enterprise knowledge base into the overall framework of business management and development.

The newest vision of the Real Time Enterprise (RTE) as the most adaptive and responsive enterprise is expressed by Gartner Group (Gartner Group, 1999). Y. Malhotra (Malhotra, 2005) has analysed the knowledge gaps which arise when implementing knowledge management in Real Time Enterprises and has pointed out the two main KM models: strategy-pull and technology-push models, thus indicating two interrelated RTE domains: business (strategy) domain and technology domain. Henderson and Venkatraman (Henderson, Venkatraman, 1990) have also analysed business-IT alignment problem and proposed a seminal Strategic Alignment Model (SAM) for business-IT alignment; the model was aimed to support the integration of information technology (IT) into business strategy by advocating alignment between and within four domains. In the SAM two interrelated aspects of computerised enterprise are defined: 1) business domain and 2) IT domain, decomposed into two levels of detail: 1) infrastructure and processes level, 2) strategic level.

Two types of knowledge inherent to the Knowledge-Based Enterprise should be pointed out. The first type of knowledge comprises all the organizational memory, which consists of various types of human knowledge, handled by managers daily to perform and manage organizational activities. This type of knowledge is referred to as *organizational knowledge*.

Another type of knowledge is a subset of knowledge stored in the Enterprise KB, and is named *enterprise knowledge*. It comprises virtual (digital) knowledge about the problem domain, i.e. digital knowledge about activities of Knowledge-Based Enterprise.

The Knowledge-Based Enterprise (KBE) framework is based on the internal modeling paradigm applied for enterprise management modeling (Gudas, 2009), (Gudas, 2008), (Gudas, Brundzaite, 2006a). The dependency map of the major concepts involved in the development of KBE framework (i.e. external modeling, internal modeling, knowledge, control, management system, management function, elementary management cycle, knowledge management framework, etc.) is presented and major concepts are described.

The control view-based perspective is applied for analysis of enterprise modeling methods (Gudas, 1991), (Gudas, et al., 2005) aimed for refinement of knowledge modeling aspects and management layers.

The M. Porter's Value Chain model (Porter, 1985), as well as Strategic Alignment Framework (Henderson, Venkatraman, 1990), is modified and used for the analysis and structuring of enterprise domains, management information transactions and content of information, developing the control view-based definition of enterprise management

function, identification of enterprise components, related to knowledge management. The internal structure of enterprise knowledge component is motivated and defined. The Enterprise Knowledge Space is defined, delineating the boundaries and granularity of enterprise knowledge layers and components.

2. Concepts of enterprise knowledge management modeling

A rough overview of the concepts and their dependencies involved for development of the control view-based approach to Enterprise Knowledge Management modeling is given in Fig. 1.

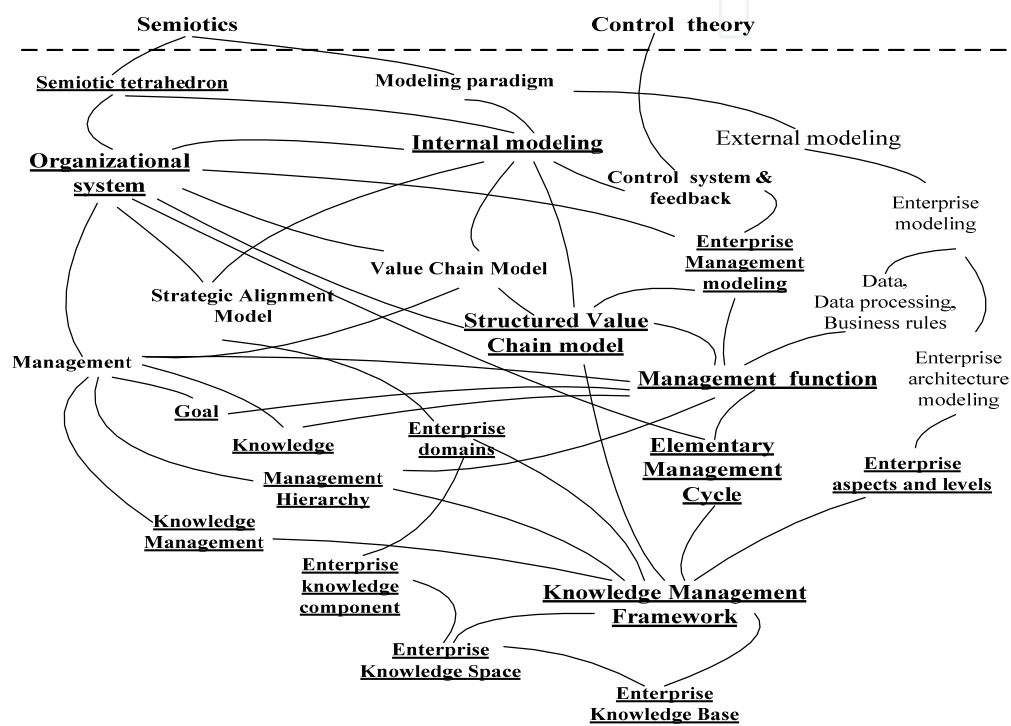


Fig. 1. Dependency map of major concepts involved for development of Enterprise Knowledge Management framework

Semiotics and *Control theory*. The top two concepts in Fig. 1 are on the level of theories, namely, „*Semiotics*“ and „*Control theory*“. *Semiotics* gives for Enterprise Knowledge Management modeling the concept of *Semiotic tetrahedron* of FRISCO [Falkenberg et al., 1998], which affords a predefined methodological structure for *Organizational System* modeling using *Internal modeling* paradigm.

The *Control theory* gives the concept “*Control System*” for developing the *control view* approach to *Organizational System* management modeling. The concept “*Control System*” is a background for developing the feed back loop of the *Management Control System*, formally defining the Enterprise Management as a hierarchy of *Management Functions* comprised of *Data*, *Knowledge* and *Goal* components and interactions in the information feedback loop. The internal structure of *Management Function* is information processing framework defined as *Elementary Management Cycle* (Gudas, et al., 2005).

The *External modeling* paradigm. The *External modeling* paradigm denotes the branch of empirical Enterprise modeling methodologies and methods, relevant and formally

described by “Black Box” approach [Gudas, 2009]. Enterprise modeling is a well developed field of business process modeling, closely related with Business Process Re-engineering (BPR) and Information System Engineering (ISE), development of CASE methods and tools. Enterprise modeling affords a set of methodologies, enterprise architecture modeling frameworks, methods, standards and languages for manifestation (representation) of empirical information acquired by system analyst in the business domain. Enterprise models developed for BPR and ISE needs correctly empirically represents the identified data (information flows), processes, events, organizational units, workflows or few other component types (constraints, business rules, etc.) of business domain. The development of Knowledge -Based Modeling methods is related with understanding differences of two modeling paradigms: *an external modeling paradigm* and *internal modeling paradigm*. An external modeling paradigm is based on the Black Box model of W. Ross Ashby (Fig. 2). A Black Box model highlights the origin of empirical models: components and (functional) behaviour of a system are acquired by external (empirical) analysis and represented by analyst using definite modeling language (notation).

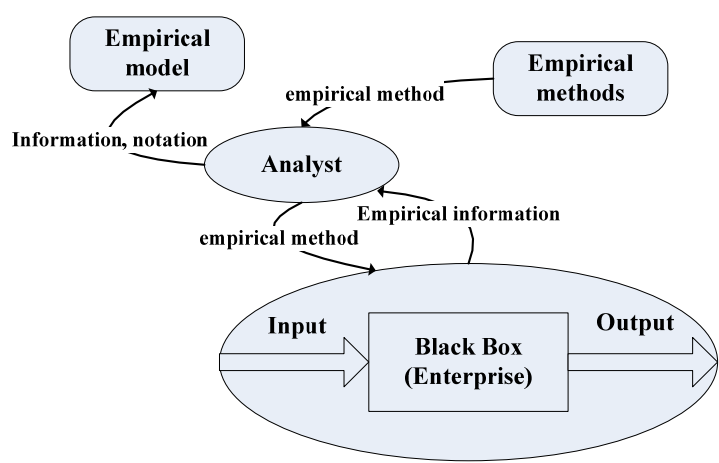


Fig. 2. The External modeling paradigm is relevant to Black Box model

The *Internal modeling paradigm*. The *Internal modeling paradigm* denotes the branch of *Knowledge-based approaches* to modeling, relevant and formally described by “White Box” approach [Gudas, 2009]. The *Internal modeling paradigm* gives background to extend Enterprise modeling views and aspects, a set of Enterprise components’ types and interactions. An *Internal modeling paradigm* is based on the White Box principle (Fig. 3). A *White Box* principle highlights the origin of knowledge-based approaches - the representation (model components, structure and the operation of a system) are validated by analyst against some predefined knowledge (theory) related to the internal transformations of *Domain*. For instance, the high level *business model* - Value Chain Model (VCM) (Porter, 1985), as well as the Strategic Business&IT Alignment Model (SAM) (Henderson, Venkatraman, 1990), is classified as internal models of Enterprise. A *Control view-based* approach to Enterprise management and knowledge modeling (Gudas, et al., 2005) fits to *Internal modeling paradigm* based on the White Box principle. The Internal modeling paradigm (Fig. 3) highlights the formal model of *Domain* as the essential component of knowledge-based modeling.

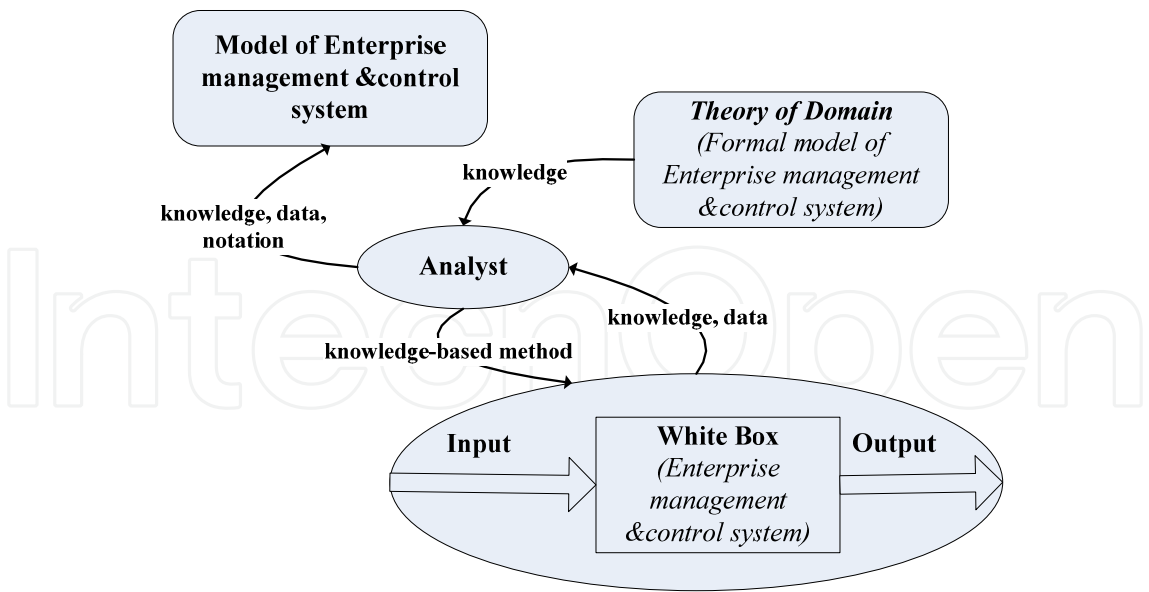


Fig. 3. The Internal modeling paradigm is relevant to White Box principle

The Semiotic tetrahedron of FRISCO. The concept of *semiotic tetrahedron* is a methodological structure for understanding the relation between “model”and "business domain" („the relation of symbols to reality“) (Falkenberg, et al., 1998).

The *semiotic tetrahedron* in the Fig.4 (Domain, Conception, Actor (Interpreter&Representer), Representation) is key predefined structure for understanding the *internal modeling* paradigm and its application for *Organizational System* management modeling as well as for understanding the concepts *Interpretation* and *Elementary Management Cycle* (Gudas et al, 2005).

The Semiotic tetrahedron reflects the view of FRISCO to the relation of reality (*Domain*) and model (*Representation*): there is a *domain* (the Real World) observed by analyst called the *Actor*. As a result of these activities (namely, *perception* and *interpretation*), the *Actor* forms *A Conception* (an internal semantic model of Real World) and *A Representation* (an external semantic model of Real World).

The semiotic triangle is a helpful tool for explaining the enterprise management as a semiotic process – a sequence of steps and transformations of information (data, knowledge and goals).

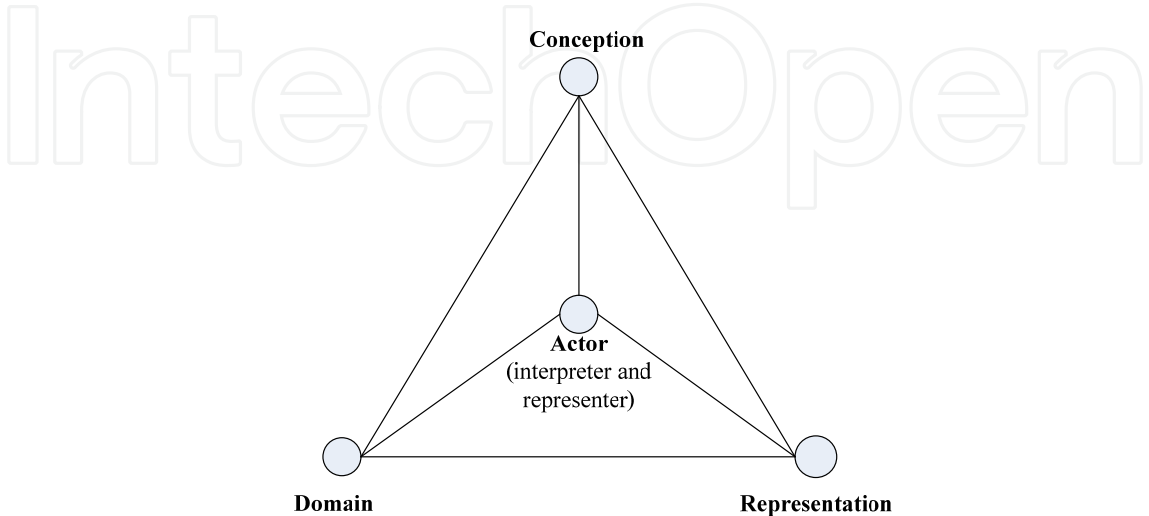


Fig. 4. The semiotic tetrahedron of FRISCO (Falkenberg et al., 1998)

Enterprise management&control as White Box. A *control* is an activity of managing or making control over some another activity. A *control system* is a system for controlling the operation of another system. A feedback control concept is applied to technical, social, economic systems modeling as well as to enterprise management and knowledge management modeling (Gudas, et al., 2005).

Definitions of management mostly include activities as follows: *planning, organizing, directing, and controlling* of the enterprise's operation so that objectives can be economically and efficiently achieved through others. So, the definition of the *management* includes the *control* concept.

Enterprise (Organizational System) is managed by management and control system, which performs a definite set of *Management Functions {Fj}* aimed to control enterprise *Processes {Pi}* (Fig. 5). Any *Management Function* is comprised of two components, namely, *Information Processing* (goal driven data processing and decision making) activity and *Information Feedback loop*.

Enterprise (management and control) modeling is based on the assumption as follows: any Enterprise is under control if each Enterprise *Management Function* includes the closed loop cycle of information transitions: a) takes (makes measurements of) a *Process state attributes*, b) calculates and decides a *Process control attributes* and in that way c) influences the *state of a Process*.

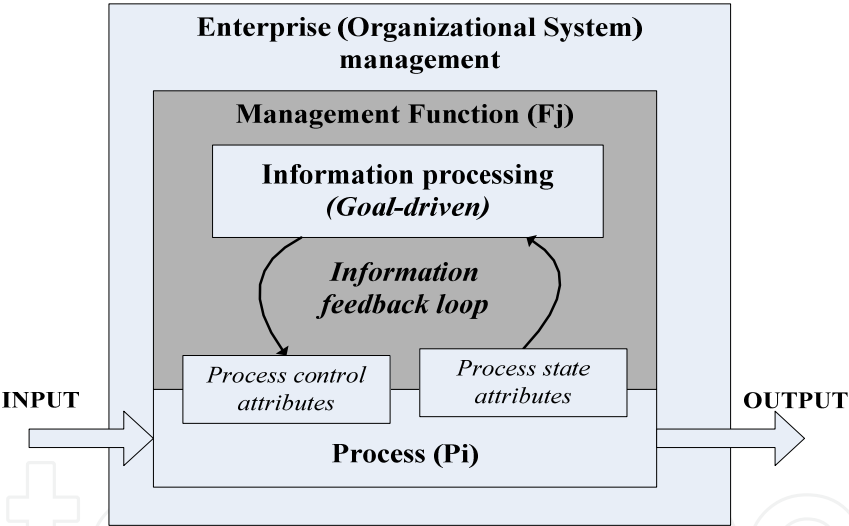


Fig. 5. The White Box model of Enterprise Management Function

According to Firestone (Firestone, 1999), organizational knowledge management activity “is aimed at integrating the various organizational agents, components, and activities of the organizational knowledge management system into a planned, directed process producing, maintaining and enhancing an organization's knowledge base”. The enterprise knowledge base along with its organizational and technological components constitutes enterprise knowledge management system (KMS). Knowledge management activity, as any other enterprise activity, is arranged in a hierarchy, which can have some reasonable number of interrelated levels.

Data, information, and knowledge. The analysis of *knowledge management* area requires well defined conceptual basis – relevant definitions at least for *management, data, information, knowledge, goal/objective* concepts. “The lack of consistent definitions for data, information,

and knowledge make rigorous discussions of Knowledge Management difficult” (Hicks, et al., 2006).

One major problem related with enterprise management and knowledge management is a problem of understanding *data*, *information*, *knowledge*, *goals* and their inter-relationships (Muller, Schappert, 1999), (Liew, 2007), (Hicks, et al., 2006). In the classical interpretation (based on the semiotic triangle) the concept “data”is associated with syntax (has no meaning), information corresponds to semantic (*information* is context interpreted *data*) and *knowledge* takes the pragmatic part (*knowledge* is action interpreted information) (Muller, Schappert, 1999).

The definitions of data, information, and knowledge could be concerned as problem, because data and information, as well as information and knowledge are perceived as interchangeable, it depends on activities and situations (Muller, Schappert, 1999).

And what about one more type of information – a *goal* (*an objective*), representing the key feature of Organizational Systems and management activities – a goal-driven behaviour? The semiotic tetrahedron of FRISCO extends the content of semiotic triangle including an *Actor* (interpreter and representer of perceived (acquired) *Data*) related with *Knowledge* and *Information* components. An *Actor* must be considered as an active component of *Organizational System* (as goal driven component), i.e. an Actor is considered as a goal seeking component of semiotic triangle. Consequently, the modified semiotic triangle that includes a *Goal* component interrelated with *Data*, *Information* and *Knowledge* components is presented in Fig. 6.

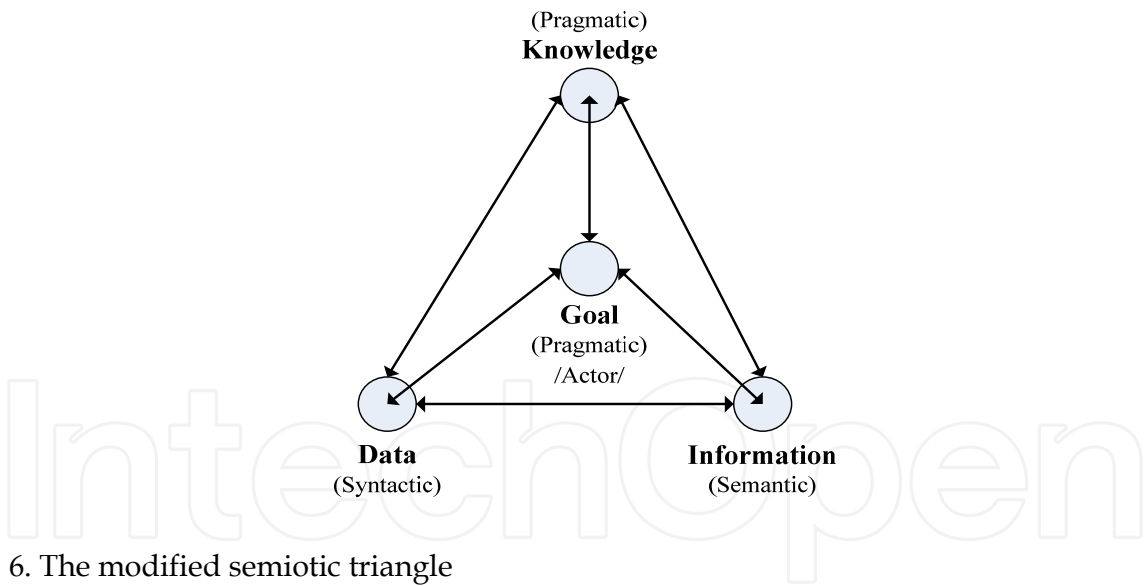


Fig. 6. The modified semiotic triangle

The inter-relationships of *Data*, *Knowledge*, *Goal*, *Information* and *Real World* (RW) are presented in the Fig. 7. A *Goal* is considered as domain interpreted information (pragmatic aspect – RW related). *Knowledge* is considered as action interpreted information (pragmatic aspect – management related, predefined (constrained) by *Goal*)).

Enterprise modelling. Enterprise modelling usually involves the definite set of aspects: function, behaviour, information, resource and organization (Vernadat, 2002) (GERAM, 1999). In addition, it is possible to distinguish one more aspect of an Enterprise modelling, defined as *the management point of view*. From this point of view, the new major Enterprise modelling constructs are identified. In the management control systems’ literature, similar

aspect is called *the management control perspective* (Anthony, Govindarajan, 2003), (Merchant, 1999). The management control perspective focuses on the organisation management and control issues; meanwhile the particularity of *the management-control point of view* is the refinement of information processing constructs and their interactions in the Enterprise. Some business systems are able to choose their own behaviour. Business processes in such systems are guided by the *decision-making mechanism*. That is why the modelling of *management process* and *management information flows* must be taken into account as mandatory aspects of Enterprise modelling. The scope of management process modelling is the internal structure of management information (Enterprise knowledge, data, objectives) and the management information processing as well.

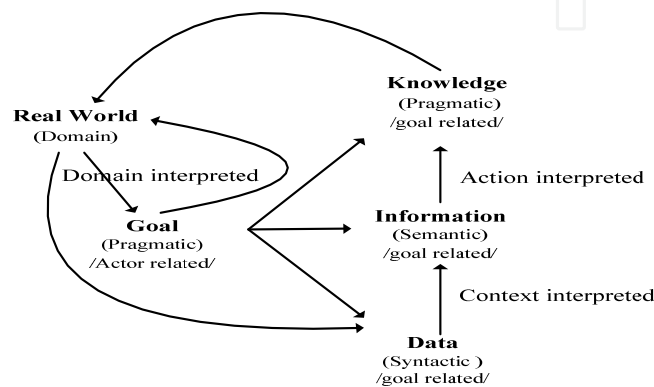


Fig. 7. Inter-relationships of data, information, knowledge, goal, and reality (domain)

It is claimed in Systems and Control Theory that a system can be controlled effectively only if some *feedback loops* (also called *control loops*) are implemented. Consequently, the components of the control loop should be included into Enterprise model.

It should be pointed out that the term *Control flow* (in the sense of *workflow*) is associated with the concept *Activity* in the UEML 1.0 (Vernadat, 2001). However, the earlier version of UEML core (UEML, 1999) includes separate modelling constructs *Function* and *Process*, and that makes this UEML core closer to the Enterprise modelling from the management point of view.

Further, the Control Theory defines the typical structure of a *System* – a real world System with internal “mechanism” of control. A *System* involves the following mandatory (complex) constructs: a real world *Process*, a *Control System* and a *Feedback Loop* which creates an *Information flow* (*Control flow*) between a *Process* and a *Control System* (Gupta and Sinha, 1996). A *Control System* performs a definite set of activities (*Functions*, related to a definite *criterion*) aimed to control a *Process*. Any *Function* takes (makes measurements of) a *Process state attributes*, calculates a *Process control attributes*, in this way making influence on the state of a *Process*.

Before we go further, let us define that any item (structural unit) of a *System* is named an *object*. An *object* could be conceptualised as an *entity* or a *class* (of the UML), or in some other way in accordance with particular modelling methodology.

3. Four domains of enterprise strategic alignment

Henderson and Venkatraman have analysed business-IT alignment issue and proposed a Strategic Alignment Model (SAM) (Henderson, J., Venkatraman, N., 1990).

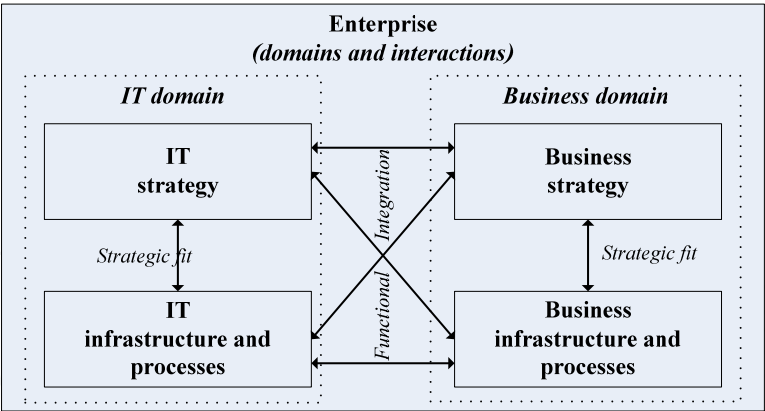


Fig. 8. Domains of Enterprise in the Strategic Alignment Model (SAM) (Henderson, Venkatraman, 1990)

The model is aimed to support the integration of information technology (IT) into business strategy by advocating alignment between and within four enterprise domains and is classified as internal model of Organizational System (Fig. 8).

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 the major concepts of various Enterprise Modeling and Enterprise Architecture methodologies and frameworks (see Table 1).

The interactions of Business and IT domains and views, namely *functional integration* and *strategic fit* are considered as knowledge manipulation processes, supported or not supported by enterprise information systems (data bases and knowledge bases). Alignment of business strategy and IT strategy is an intensive knowledge process, it requires particular knowledge about at least four views: *Business strategy*, *Business infrastructure*, *IT strategy*, *IT infrastructure* of enterprise.

Knowledge -Centric Enterprise Structure. The knowledge-centric organization, regardless of whether its products are tangible or not, here is defined according to the concept of knowledge-based organization, presented by M.H.Zack (Zack, 2003) and is based on the resource-based view of the firm; namely, knowledge-centric organization: a) recognizes knowledge as a key strategic resource, b) rethinks their business 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." (Zack, 2003), c) aligns its knowledge management activity with its strategy.

Even if the definition of the knowledge-centric enterprise do not emphasizes the use of the information technologies (IT) in the enterprise, it should be noted, that research presented here is concerned with the contemporary enterprise, which extensively uses IT for the support of the management of its business processes.

Contemporary organizations use the integrated data repositories which have to be identified within the enterprise model (the *Data Base* and *Data Warehouse* components in Fig. 9).

In order to illustrate the conception of the contemporary enterprise, which is knowledge-centric enterprise, the SAM model has to be complemented by additional components. According to the definition of the knowledge-centric organization, it rethinks its processes in the knowledge-oriented sense and aligns its *knowledge management activity* with its strategy. Consequently, in the knowledge-centric enterprise there exist some infrastructure for the knowledge management – the knowledge management (KM) layer; thus SAM model

is complemented with additional structural elements – business *knowledge and IT knowledge management components* (see Fig. 9).

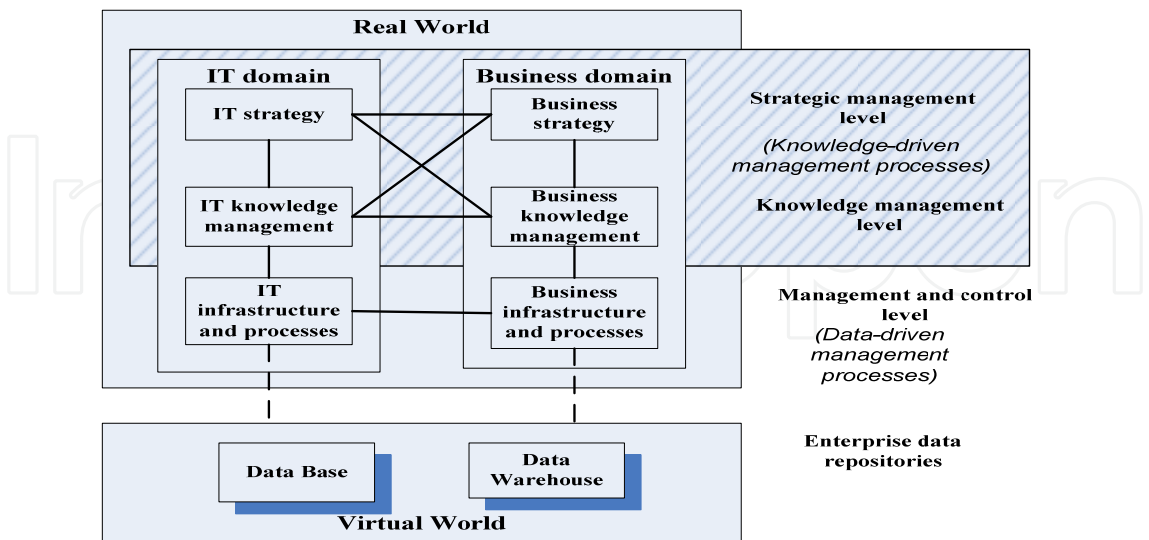


Fig. 9. The Knowledge-Centric Enterprise structure

To sum up, business and IT domains of SAM can be decomposed into three levels of management hierarchy: strategic management level, knowledge management level, and business management&control level.

The management processes on the strategic level and knowledge management level are *knowledge -driven* because these top level management activities require particular knowledge about strategies and management methods, and etc. The management processes on the business and IT management and control level require definite (time related) data about the state of business and IT processes, thus this level of management essentially is *data-driven*.

Knowledge-centric enterprise, as any other contemporary organization, possibly uses the integrated data repositories which are presented in the SAM as the *Enterprise Data repositories* component (Fig.9).

Even if knowledge management activities of Knowledge-Centric Enterprise are under control, there is a possibility for the knowledge flow bottlenecks left, because the valuable knowledge two interrelated enterprise domains required for the management solutions about (*i.e. Business domain, IT domain*) typically resides in the heads of the managers and employees, in the unstructured documents etc. As the business-IT alignment is continuous decision making process, it should be supported with reliable information (*Real World data and digital data*) and knowledge (*Real World knowledge only*) accessible across the enterprise.

4. Two worlds of the knowledge-based enterprise

In Strategic Alignment Model (Henderson, Venkatraman, 1990) two interrelated components of the enterprise are defined: 1) Business domain and 2) IT domain. According to the definition of the Knowledge-Based Enterprise, another two important components of the enterprise management are identified: Knowledge domain and Data domain. All these four components are interrelated domains (see Fig. 16), which have to be taken into account

when transforming business enterprise into Knowledge-Based Business Enterprise (Gudas, Brundzaite, 2006a).

The scheme presented in Fig. 10 sums up findings made in the chapter. The peculiarity of this abstraction is that it clearly separates the Knowledge domain from Data domain, in contrast to other conceptual enterprise models (e.g. presented in (Hettinger, 2003) or (Iyer, Gottlieb, 2004). For instance, the well-known ISA framework (Zachman, Sowa, 1992) does not concern knowledge domain at all. Though comparing ISA model with the presented abstraction of the Knowledge-Based Enterprise domains, different purposes and tasks of the ISA and Enterprise Knowledge Modelling framework should be noted.

The concept of the *knowledge base* is also used in the sense of computerized meta-data repository when implementing large-scale data management and business intelligence systems in the contemporary organizations. Meta-data repository helps to provide business data as well as data about data for business and for IT departments and to make adequate decisions regarding data management in organizations. Contemporary organizations need to manage not only data, but the whole data-information-knowledge continuum; this is why the role and structure of the enterprise repository or enterprise knowledge base have to change adequately too (Gudas, Brundzaite, 2006a).

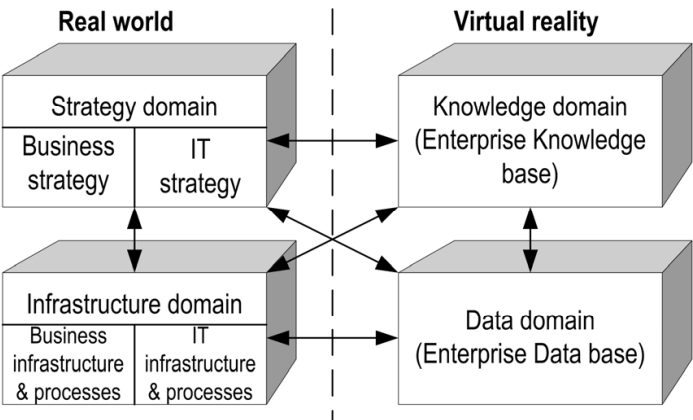


Fig. 10. Two worlds of the knowledge-based enterprise

The concept of computerized knowledge base become important with the emergence of such intensively computer-based organizational forms as supply chains, virtual organizations etc. Organizations require for having not only shared data bases in virtual environment, but also knowledge about those data, as well as about the data structure and semantics; knowledge about its infrastructure and processes; process management up to strategic intentions.

The solid lines in Fig. 10 represent the knowledge management activities which are used to assure integration of the enterprise knowledge base into overall enterprise management and development framework, as well as support of inter-domain alignment tasks. Knowledge management activity has to be managed and explicitly modelled either (Gudas, Brundzaite, 2006a).

5. Knowledge-based enterprise structure

The scope and structure of the organizational knowledge in the knowledge management literature is investigated. This structure has the name of *organizational memory* or *corporate*

memory. The organizational memory is concerned with the organizational learning processes. Organizational memory comprises all the possible forms of organizational knowledge: tacit, explicit, computerized, not-computerized, etc (Zack, 2003).

There are a lot of possible facets for characterising knowledge (Zack, 2003), although it is important in this situation to analyse knowledge in the sense of its “objective” and “subjective” characteristics. According to J.M. Firestone (Firestone, 1999), there are two kinds of knowledge:

1. “Knowledge viewed as belief... Such knowledge is “subjective” in the sense that it is agent-specific, whether the agent is an individual, group, team, or organization”.
2. “Knowledge viewed as validated models, theories, arguments, descriptions, problem statements etc. This kind of knowledge, further, is “objective.” It is objective in the sense that it is not agent specific and is shared among agents. Finally, it is objective because, since it is sharable, we can sensibly talk about community validation of this kind of knowledge.”

Business-IT alignment is a continuous decision making process and it should be supported with reliable information and knowledge. As it was noted in the beginning of the article, enterprise knowledge base is intended to be used as the source of knowledge about the problem domain (i.e.) also for IS engineering tasks in the IS requirements’ development stage. Resuming it should be stated that enterprise knowledge base is shared and it stores the enterprise knowledge (*digital knowledge*) in the form of validated Enterprise Knowledge Models. According to the Knowledge-Based Modeling (internal modeling) paradigm enterprise knowledge models have to be validated according to the formal model of enterprise management&control thus ensuring reliability of the acquired knowledge about problem domain.

Besides, it is suggested, that Knowledge-Based Enterprise uses Enterprise Knowledge Base (KB) together with explicitly modelled knowledge management activity as obligatory enterprise management component.

The concept of the Knowledge-Based Enterprise is illustrated further by using **Strategic Alignment Model (SAM)** (Henderson, Venkatraman, 1990). Therefore, Strategic Alignment Model is complemented by one more additional structural element – Enterprise Knowledge Base (see Fig. 11), which supports enterprise knowledge management activities and allows continuous cross-domain alignment process and also helps to eliminate knowledge flow bottleneck across enterprise.

Consequently, *Knowledge-Based Enterprise* here is defined by enhancing the Knowledge-Centric Enterprise (as defined above) with Enterprise knowledge repository. The *Knowledge-Based Enterprise* uses Enterprise Knowledge Base as obligatory enterprise management, as well as information system development component.

In Fig. 11 the structural element *Enterprise Goal’s Base* is abstracted, which could be as the part of the Enterprise knowledge base too.

Contemporary enterprise modelling methods are conceptual methods in the sense how the models are created and what knowledge they represent; they allow to acquire empirical knowledge about the problem domain (i.e. enterprise), which can be hardly validated. Enterprise Knowledge Base (EKB) here is considered as the computerised Enterprise Knowledge Model, which consist of integrated set of enterprise knowledge sub-models and is validated against the formalized enterprise knowledge model. Thus, EKB is the reliable knowledge source for a support of business management decision making, business and IT alignment, as well as for support of knowledge management and information systems development processes.

The peculiarity of the abstraction, presented in Fig. 11 is that it clearly separates the Knowledge domain and Data domain, in contrast to other conceptual enterprise models (e.g. presented in (Iyer, Gottlieb, 2004)).

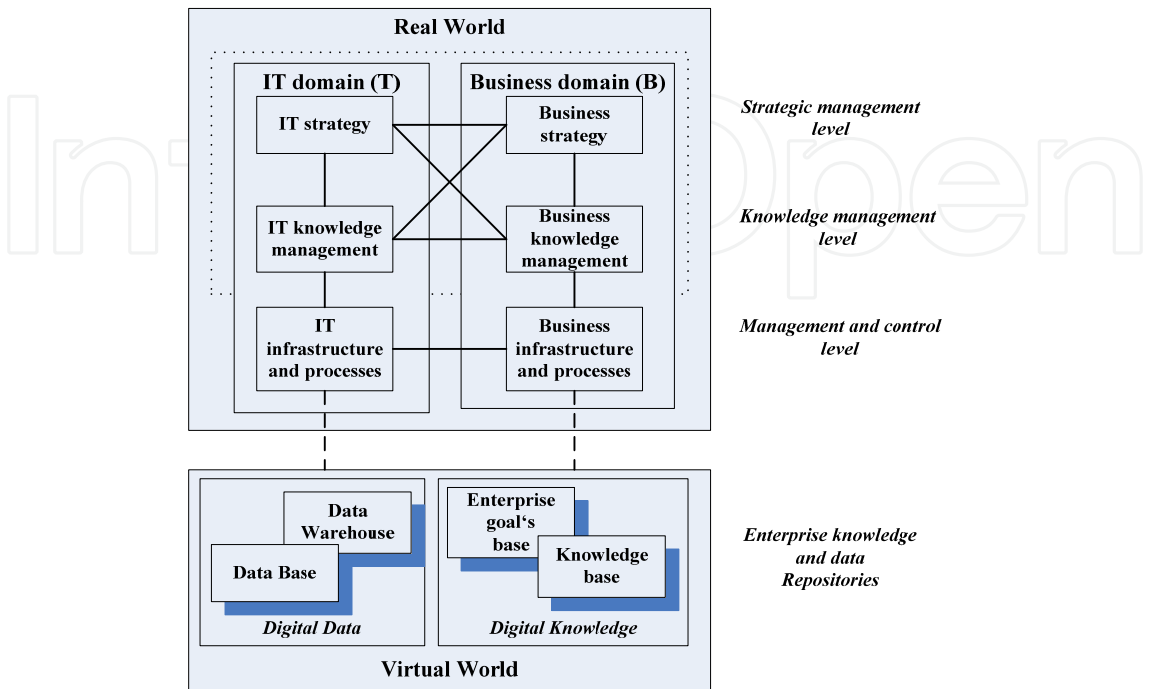


Fig. 11. Knowledge-Based Enterprise structure

Knowledge-Based Enterprise uses knowledge as a key strategic resource, as it was said before (see also Fig. 11). It became evident that the *organizational knowledge* (*non-digital knowledge*) is human knowledge used (and hidden in the Fig. 11) in the *business* and *IT domains* as integral components of any enterprise. Meanwhile, *enterprise knowledge* (virtual, digital knowledge stored in the Enterprise KB) is an obligatory component of Knowledge-Based Enterprise, integrated with all enterprise domains. Accordingly, three tiers Knowledge-Based Enterprise Architecture (in the Fig.12), it includes Enterprise KB as key component, integrated with knowledge management systems (Gudas, Brundzaite, 2007a).

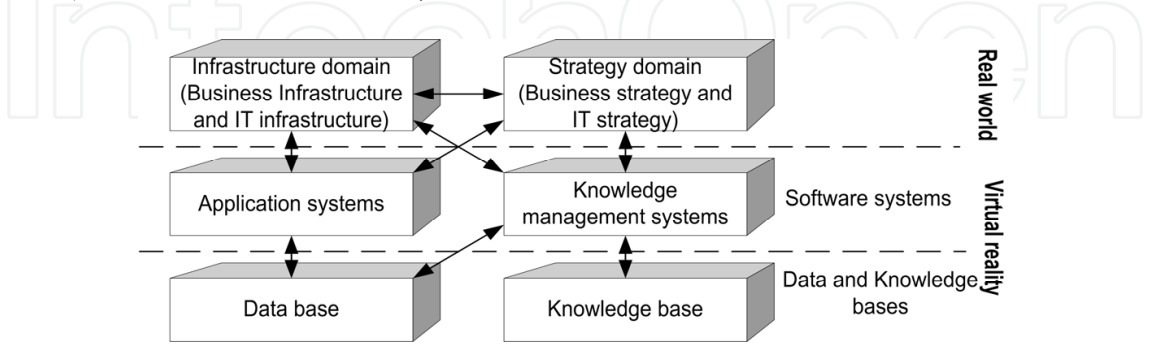


Fig. 12. Knowledge-based Enterprise Architecture

The Knowledge-Based Enterprise Architecture co-relates with the A Multi-Layer Architecture for Knowledge Management Systems (*Strategy; Organization; Information System*) presented by Ulrich Frank (Ulrich, 2002).

6. Enterprise domains and aspects of the knowledge

Having defined Knowledge-Based Enterprise architecture independently from the products the enterprise produces, the following knowledge management modeling approach is concerned with the identification of the types and actual content of the enterprise knowledge.

Modelling Framework	Enterprise 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 (Zachman, Sowa, 1992)	Business domain; Motivation, Time	Business domain; Processes/Functions, Data, People, Network	IT domain; Goals/Objectives, Time, Peoples	IT domain; Functions, Data structure, Network,
B. Iyer, R. Gottlieb, 2004	Business process domain	Organization domain	Information/ knowledge domain	IT infrastructure domain
M.Porter's value chain model (Porter, 1985)	Business domain, Support activities	Business domain, Primary activities		
GERAM (GERAM, 1999), (Williams, Li, 1995)	Business domain; Management & control, Customer service	Business domain; Resource, Organization, Information, Function	IT domain; Human, Machine	IT domain; Software, Hardware
Multi-Perspective Enterprise Modeling (MEMO) (Ulrich, 2002a)	Business domain; Goal(competitiveness), Resource (Human resource technology), Structure(Strategic Business 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, R., Rijsenbrij, D., Truijens, O., Goedvolk, H. (2000).	Business domain; Strategy, Structure	Business domain; Information and communications; Operations	Technology domain; Strategy, systems, structure	Technology domain; Infrastructure, Operations
ARIS (EPC) (Scheer, 1999)	Business domain; Event, Function, Work, Control flow	Business domain; Information flow, Resources, Organization unit, Role,		
UEML (Vernadat, 2002)	Business domain; Event, Process, Activity, Role	Business domain; Organization unit, Enterprise object (Product, Order, Resource (Human, Machine));	IT domain; Resource (Human)	IT domain; Enterprise object Resource (Application, Machine)

Table 1. Enterprise domains and aspects of the Enterprise knowledge

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

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

Enterprise modelling (EM) and Enterprise architecture (EA) frameworks underlies our theoretical findings. In the contemporary EM and EA methods the three basic aspects of the enterprise knowledge (*business strategy; business; information systems and technologies*) are separated, and used to construct layered architecture. The analysis of the EM methods is presented in (Gudas, Brundzaite, 2006).

7. Structured value chain model

The Value Chain model comes from M. Porter's book (Porter, 1985). A Value Chain is a high level business model, a model that breaks down an organization into a series of value-generating activities. Two major interacting parts of VCM are *Support Activities* and *Primary Activities* (Porter, 1985).

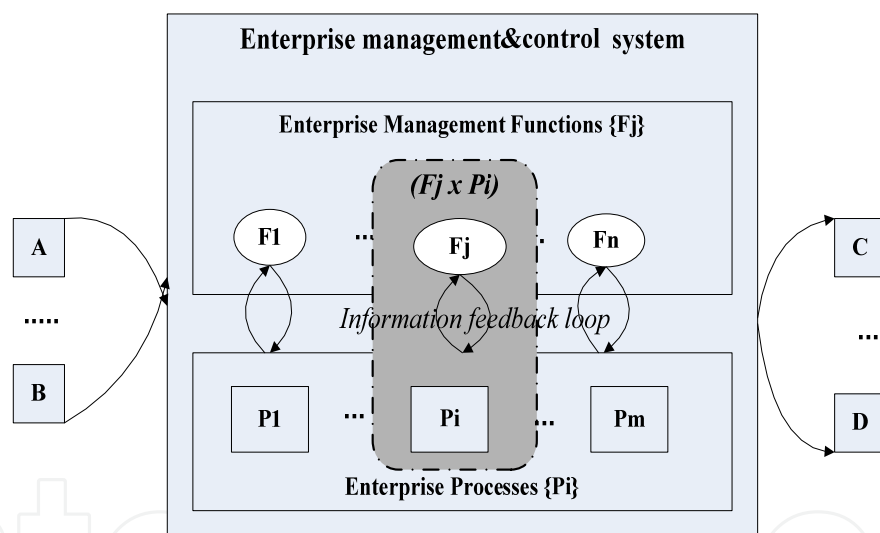


Fig. 13. The structured Value Chain Model (SVCVM)

The analysis of the Enterprise modelling from *the management (control) point of view* gives some new aspects for the Enterprise modelling itself (Gudas et al., 2005):

- The matter under investigation is a content of information, information processing and decision-making activities in the Organizational System (Enterprise).
- It is aimed at the enhancement of the Enterprise model that can be used as a source of domain knowledge for business management analysis and development of advanced IS engineering methods;
- A set of EM constructs and their types of relation should be revised *from the management point of view*. These constructs should include a definite set of structural elements and relations for the modelling of Enterprise management functions and information interactions.

From the management (control) perspective the major parts of M.Porter’s Value Chain Model are renamed as follows (Fig. 13):

- Support Activities are information processing activities (for instance data processing, decision making), consequently they are renamed as Management Functions {Fj};
- Primary Activities are material flow processing activities (for instance, manufacturing), consequently they are renamed as Enterprise Processes {Pi};
- The interaction of Management Functions {Fj} and Enterprise Processes {Pi} is considered as information feedback, it is the obligatory component of enterprise management (control) system.

The Structured Value Chain model is used to identify the information transactions between Management Functions and Enterprise Processes. The Structured VCM refines the enterprise management & control as a system of closed loop interactions of Management Functions {Fj} and Enterprise Processes {Pi}:

$$SVC\!M = \{Function\ (F_j) \times Process\ (P_i)\}. \quad i = 1,m; j = 1,n;$$

The interaction of Function and Process. The interaction of Enterprise model core elements Process and Function is formally assumed as a Control Process. It is defined as a Feedback Loop between Process P(i) and Function F(j). The analysis of the Function- Process interaction is a background of the formalized model of the organizational system (an Enterprise model) described in (Gudas, 1991).

Fig. 4 presents the structured model of the Function-Process interaction. The concept Process is assumed as “a Black Box”. The internal structure of Process is unstudied, the concept Process is characterized by a set of Process state attributes (this set comprises subsets of Input flow attributes, Output flow attributes and Process attributes) and it is influenced by the output of a management Function – a set of Process control attributes (Gudas et al., 2005).

From the management point of view, Process P(i) is defined by two sets of attributes: a set of Process state attributes and a set of Process control attributes. A set of Process state attributes includes the Process input (material flow) attributes, Process output (material flow) attributes and the attributes of the particular Process P(i).

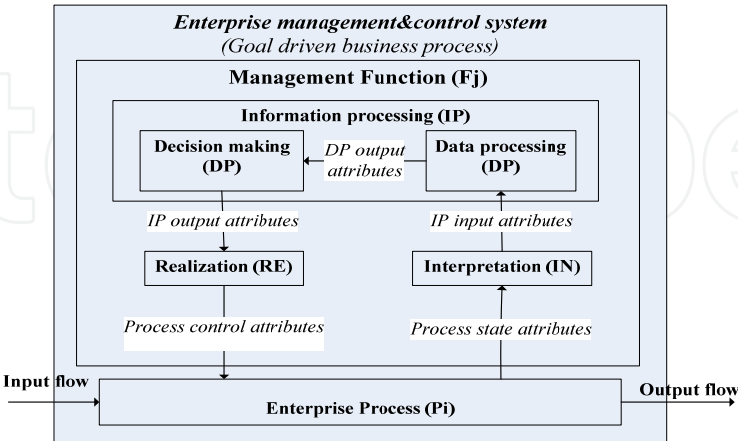


Fig. 14. The structured model of the Function-Process interaction

A management Function consists of the predefined sequence of mandatory steps of information transformation (Interpretation, Information Processing, Realization); these steps compose a management cycle (a feedback loop). A definite set of attributes (a set of

information items) is formed and transmitted during each management step. A management *Function* $F(j)$ is initiated by some *Event* – a fact or a message associated with some internal or external (environmental) object. This definition of *Function* is close to the definition of function presented in (ENV 40003, 1990). This paper presents more detailed content of *Function* $F(j)$ since it defines a sequence of definite types of interacting information activities (*Interpretation*, *Information Processing*, *Realization*) directed to control *Process* $P(i)$ (Fig. 13).

All other constructs of *Function-Process* interaction (except constructs *Process*, *Input flow* and *Output flow*) in the structured model are assumed to be the components of the construct *Enterprise Management Function* (Fig. 15).

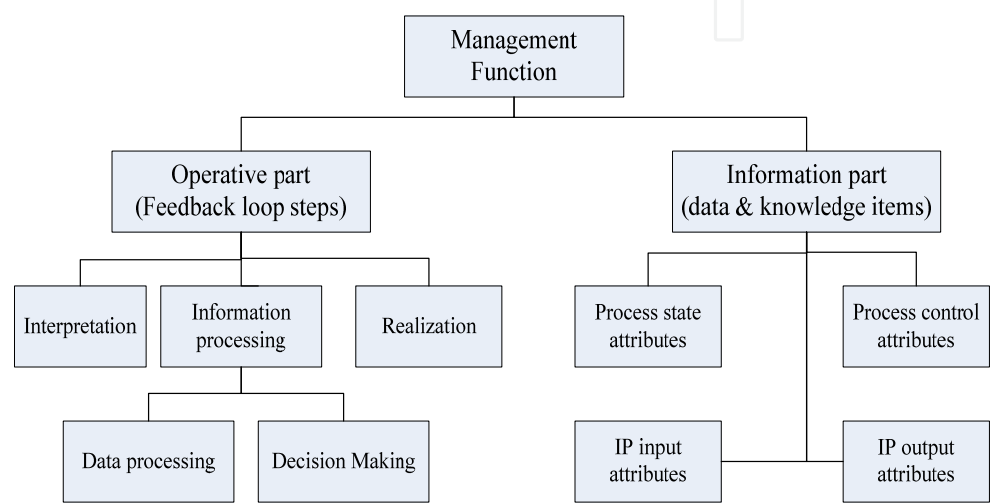


Fig. 15. The control view based structure of Management Function (Gudas et al., 2005).

It is assumed, that *Process* and *Management Function* are activated by some *Event*. A definite set of *state attributes* of an activated *Process* is the information flow defined as an input of (one or more) specific management *Function* that is activated by some particular *Event*. It should be pointed out, that the set of attributes of management *Function* is closely related to the description of function presented by CIMOSA (ENV 40003, 1990). The CIMOSA specification of function includes the structural part (the list of sub-functions is used), the functional part (goals, limitations, functional description, necessary equipment, input, output) and the part of an attitude (goals, limitations, procedural rules, events, end state).

The Elementary Management Cycle (EMC). The structured model of the *Function-Process* interaction (Fig. 14) is formally specified as **Elementary Management Cycle (EMC)** at Fig. 16. The Elementary Management Cycle (EMC) is the basic construct of Enterprise management modelling, refines the components of management (control) cycle as well as content of management information transformations (Gudas, 1991), (Gudas et al., 2005).

The semantics of *Elementary Management Cycle (EMC)* transactions at Fig. 16 are co-related with the description of modified semiotic tetrahedron of FRISCO (Fig. 4, Fig. 6).

A new perspective - control view perspective of Enterprise management modeling is beneficial and constructive for advancing of Business Process modeling and IS engineering methods. An Enterprise Management Model provides the theoretical background for system analysis of management information processes, identification and more detailed decomposition of enterprise data and knowledge components *Function*, *Process*, *Activity*, *Information flow*, *Control flow*, etc.

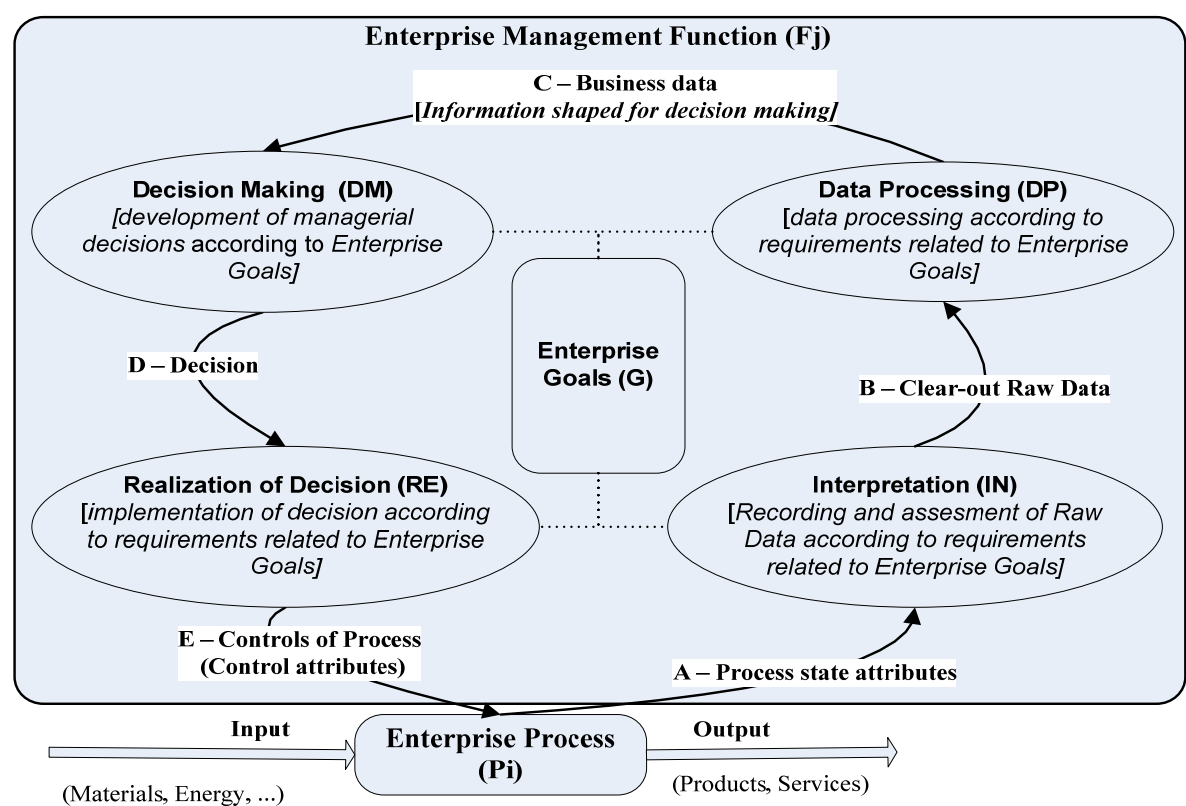


Fig. 16. The Elementary Management Cycle (EMC) – specification of *Function-Process* interaction

8. Enterprise knowledge component

Enterprise domains and aspects of the enterprise knowledge identified in the various Enterprise Modeling (EM) and Enterprise Architecture (EA) methodologies and frameworks (Table 1) reflect the semantics of the concept “enterprise knowledge component” (Gudas, Brundzaite, 2006).

Summarizing the above given overview of enterprise modelling domains and aspects (Table 1), we make a premise, that there are three integrated aspects of the Enterprise management activities modeling (Henderson, Venkatraman, 1990):

- Modeling of business strategy, infrastructure and processes;
- Modeling of IT strategy, infrastructure and processes;
- Modeling of Enterprise Business and IT integration (Business and IT alignment activities).

Performance of all these Enterprise management activities require adequate diverse knowledge, namely, first type of knowledge is knowledge about business processes (B), second type - knowledge about information technologies (T) and, finally, knowledge about enterprise management (K) (Gudas, Brundzaite, 2006).

So, the key enterprise management activities are supported by the differing types of interrelated knowledge, depicted as *enterprise knowledge component* in Fig. 17. Enterprise management activities required to be supplied as well by actual data stored in the enterprise data repositories (data base). Hence, the enterprise knowledge component $e(b, t, k)$ is associated with *data* items as well (see Fig. 18).

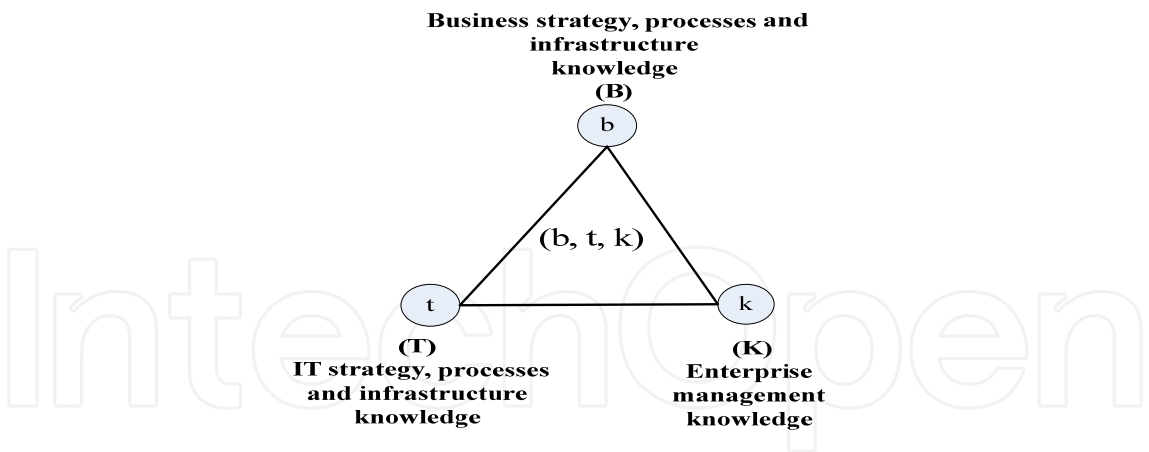


Fig. 17. Knowledge component e (b, t, k) for enterprise management activities

The internal structure of the enterprise knowledge component (b, t, k) (see Fig. 17) represents a new viewpoint to enterprise knowledge modelling: the enterprise management facilities (decision making units of organizational structure) should be supplied and operate with *complex integrated knowledge* about different Enterprise domains as follows: business knowledge (B), IT knowledge (T) and knowledge about enterprise management modeling (K) (Gudas, Brundzaite, 2006).

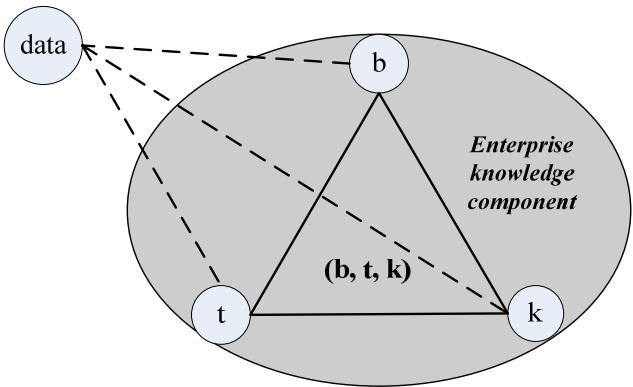


Fig. 18. Enterprise knowledge component e (b, t, k) is integrated with enterprise data items

The depicted enterprise knowledge component (Fig. 18) represents a structural viewpoint to enterprise knowledge modeling: the Knowledge Base should include *integrated enterprise knowledge* (validated models, theories, arguments, descriptions, problem statements) about business strategy and infrastructure (B), IT strategy and infrastructure (T), enterprise management modelling knowledge and knowledge management methods (K).

On the basis of the internal structure of enterprise knowledge component (b, t, k) the abstract space (the Universe of Discourse) for Enterprise knowledge modeling is defined as follows (Fig. 19): Enterprise Knowledge Space (B, T, K), in which B – axis of business process knowledge hierarchy; T – axis for IT management knowledge hierarchy, K – axis of enterprise management knowledge hierarchy (Gudas, Brundzaite, 2006).

The Enterprise Knowledge Space axes (B, T, K) reflect the different management knowledge types, each axis having its own hierarchical structure. Semantics of the enterprise knowledge hierarchy levels (partition of the axes B, T, and K) is discussed in the following chapter.

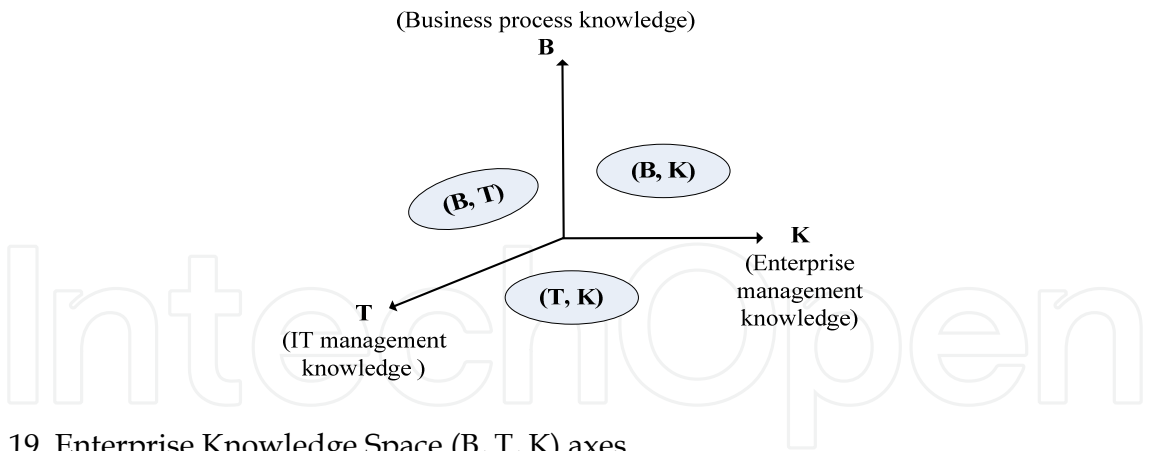


Fig. 19. Enterprise Knowledge Space (B, T, K) axes

9. The enterprise knowledge space

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

The contemporary organizational theories distinguish between four hierarchical levels in organizations: strategic level, tactical level, knowledge level and operational level (Laudon, Laudon, 2004). On the basis of such hierarchical system, it is possible to define four adequate levels in organizational information management processes. We have modified a slightly ordinary hierarchical structure by placing knowledge management in the second level of the business management hierarchy (axes B), because of the overall nature of the knowledge management processes. The Enterprise Knowledge Space (Fig. 20) was derived by fitting integrated knowledge model component (see Fig. 18) with the hierarchical information structure of the organizational systems (Gudas, Brundzaite, 2006).

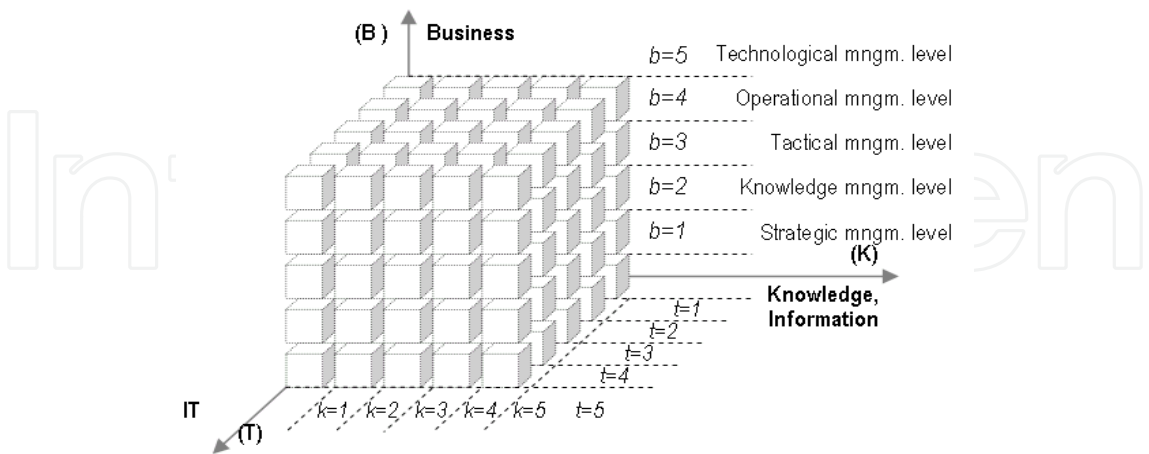


Fig. 20. Enterprise knowledge space $E(B,T,K)$

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:

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

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 $e111$ 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:

$E2 = (B = \{B1 - \text{Strategic management level (this level embraces strategic management methods), } B2 - \text{Knowledge management level (this level embraces knowledge management methods), } B3 - \text{Tactical management level (this level includes tactical management methods), } B4 - \text{Operation management level (this level concerns operational management methods), } B5 - \text{Technological process control level (this level embraces process control and management methods)}\}; K = \{K1 - \text{Ontological modelling level; } K2 - \text{Meta-meta-modelling level, } K3 - \text{Meta-modelling level, } K4 - \text{Conceptual modelling level, } K5 - \text{Particular (instant) modelling level}\})$.

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

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

Maes *et al.* (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 ((Henderson, Venkatraman, 1990).

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

The identifiers of enterprise knowledge item. The formal description of the Modified Value Chain Model M with the knowledge management function K can be expressed as the Cartesian product in the following way:

$$M = (K) \times (F_1, \dots, F_n) \times (P) \times (R) \times (R), \quad (2)$$

Where K - knowledge management function, F_1, \dots, F_n - business management functions, P - business processes, R - business resources.

This means, that each enterprise knowledge model item $m \in M$ in the modified value chain model is related to the appropriate knowledge management function g ($k \in K$), business management function f ($f \in F$), business process p ($p \in P$), and resources r ($r \in R$). To put it in other terms, the enterprise knowledge model item is identified by a set of identifiers:

$$m(g; f; p; r) \in M. \quad (3)$$

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:

$$m_e(b; t; k; g; f; p; r; l) \in M_e; \quad (4)$$

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

The Enterprise Knowledge Model Me 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. 20).

10. Enterprise management layers and knowledge

An Enterprise Management System is a multilevel hierarchical structure. Enterprise management levels, knowledge hierarchy, semantics of the enterprise knowledge layers are investigated in (GERAM), (MOF, 2011), (Roboam et al., 1990) (Gudas, 2008), (Gudas, Brundzaite, 2006b), (Ulrich, 2002), (Laudon, Laudon, 2004), (Muller, Schappert, 1999). Semantics of Enterprise knowledge and management levels depends on the purpose of modeling, enterprise modeling point of view (Table 2).

Management layers of traditional Enterprise are as follows: strategic management, managerial, operational management. In case of Knowledge-Based Enterprise (KBE) semantics of Enterprise knowledge and management levels depends on the purpose of modeling and modeling point of view (see Table 1). Semantics of the enterprise Knowledge management layers in the different frameworks and models depends on the definite purpose (intention) of modeling as well as on the requirements of business control process and IT related requirements for enterprise management systems (Gudas, 2009).

For instance, the Enterprise model aimed for business and IT strategic alignment includes only two layer: strategy layer (business strategy and IT strategy) and infrastructure layer (business infrastructure and IT infrastructure) (Henderson, Venkatraman, 1990).

The management system of the IT-based enterprise includes layers as follows: strategic management, knowledge management, managerial, operational management layer (Laudon, Laudon, 2002).

According to J.M.Firestone (Firestone, 1999), organizational knowledge management activity “is aimed at integrating the various organizational agents, components, and activities of the organizational knowledge management system into a planned, directed process producing, maintaining and enhancing an organization's knowledge base”.

The enterprise knowledge base along with its organizational and technological components constitutes enterprise knowledge management system (KMS). A key aspect in defining the KMS is that both its components and interactions must be fully designed. Knowledge management activity, as any other enterprise activity is arranged in a hierarchy, which can have infinite number of levels.

The first task is to identify finite number of design levels. According to MDA architecture, four modeling levels are recommended in Meta-Object Facility (MOF) (Christian, 2005), (MOF, 2011).

On the basis of these recommendations four hierarchically interrelated knowledge management levels (see Fig. 26) were identified. (Gudas, Brundzaite, 2006a).

Meta-modeling approach	Modeling purpose, intention	Abstraction levels or views
GERAM (GERAM, 1999)	Enterprise architecture model development	Generic; Partial;Particular
Meta-modeling approach to adaptive knowledge management (Süß, 2000)	Knowledge management	Abstract meta-model; Application specific model; Domain-specific models; Hypermedia information space; Real world
The Knowledge Factory (Müller, 1999)	Knowledge management	Knowledge; Information; Data
A. Liew (Liew, 2007)	Understanding Data, Information, Knowledge	Wisdom; Knowledge; Information; Data
A Multi-Layer Architecture for Knowledge Management Systems (Ulrich, 2002)	Architecture for Knowledge Management Systems	Views of a Knowledge Management System: Strategy view; Organizational view; Information System view. Abstraction levels:Generic knowledge; Specific knowledge.
Meta-Object Facility (MOF, 2011)	Object-oriented language description	Meta-meta model; Meta-model; Model; Information
Knowledge-Based Enterprise framework [5, 6, 8]	Architecture for Knowledge-Based Enterprise Management Systems	Enterprise strategic management ; Enterprise meta-knowledge management ; Enterprise knowledge management ; Enterprise management Business process management ;Manufacturing process management and control

Table 2. The overview of Enterprise management levels and knowledge

As it could be concluded from the overview of Enterprise modeling approaches (see the column “Abstraction levels or views” in Table 2), the enterprise management hierarchy levels and knowledge abstraction hierarchy are co-related. For instance, abstraction levels of knowledge could be *Generic knowledge*; *Specific knowledge*, *Partial knowledge*, *Domain-specific*, *Application specific*, *Meta-*, *Meta-Meta-*, and etc. (see Table 2).

Therefore the knowledge management modeling requires some complex hierarchical structures to be identified for adequate representation of the knowledge management activities and organizational units.

11. The knowledge-based enterprise framework

In the knowledge modelling field the process-oriented view is recognized as a success factor [18]. In the organizational management practice widely recognized the Porter's (VCM) represents a process-oriented view to business. The Porter's Value Chain Model (VCM) here is used as a basis for the enterprise knowledge modelling (Gudas, Brundzaite, 2006b).

The control view-based approach (Gudas et al., 2005) is focused on the informational interactions between two kinds of VCM activities -primary and support activities. The different nature of these two kinds of activities is revealed: support activities are information processing activities and are referred to as *Business Process Management Functions*; primary activities typically are material processing (technological) and are named *Processes*.

The interrelated elements *Function* and *Process* form the construct *Business Process* (B). The interaction of the elements *Process* and *Function* is formally assumed as a *Control Process* with the *Feedback Loop*, i.e. *Elementary Management Cycle* (EMCp). As the *Function* and *Process* interaction is already discussed in detail in (Gudas et al., 2005), let us concentrate on enterprise model constructs, which are related to the knowledge management.

The similar insights are represented in the organizational control systems modelling (OCSM) framework developed in (Kampfner, 1999).

According to the knowledge-based enterprise definition and structure (see Fig. 11, 12) there is a type of business activity – *knowledge management activity*, which is hidden within M.Porter's Value Chain Model. On the basis of these findings and other methods discussed above, the Value Chain Model is modified and Knowledge-Based Enterprise model is developed (see Fig. 21). Whereas the modified Value Chain Model is focused on the enterprise knowledge management activities and components, it is named *Knowledge-Based Enterprise Model*.

For the completeness of the model two important components of enterprise systems are included: *resources* (R) component and *information technology* (IT) component (Gudas, 2009).

The Knowledge-Based Enterprise model (KBEM) is a process-oriented model and it refines three different layers of enterprise management hierarchy (Fig. 21):

- knowledge management layer;
- business process management layer;
- infrastructure (management) layer.

The Knowledge-Based Enterprise (KBE) model is constructed from the following main components: *Business process* (B), *Knowledge management function* (K) component, *Information technology* (T) component and the *Resources* component (R).

The interaction of the components from different layers of the KBEM (management transaction) is considered as control loop (informational feedback) formally described in

(Gudas, Brundzaite, 2007) as *EMC* (*Elementary Management Cycle*). There are two different management transactions (*Elementary Management Cycles*) identified in the KBEM (Fig. 21): *Knowledge management cycle* (*EMCz*) and *Process management cycle* (*EMCp*) (Gudas, 2009).

The peculiarity of the developed model comparing with the M.Porter's Value Chain Model is that the developed model distinguishes between qualitatively different business management activities (*F*, *P* and *K* constructs in the Fig. 21) and allows formally represent interactions between these activities by using two types of the control activities (*EMCz* and *EMCp* with different semantics) (Gudas, 2009).

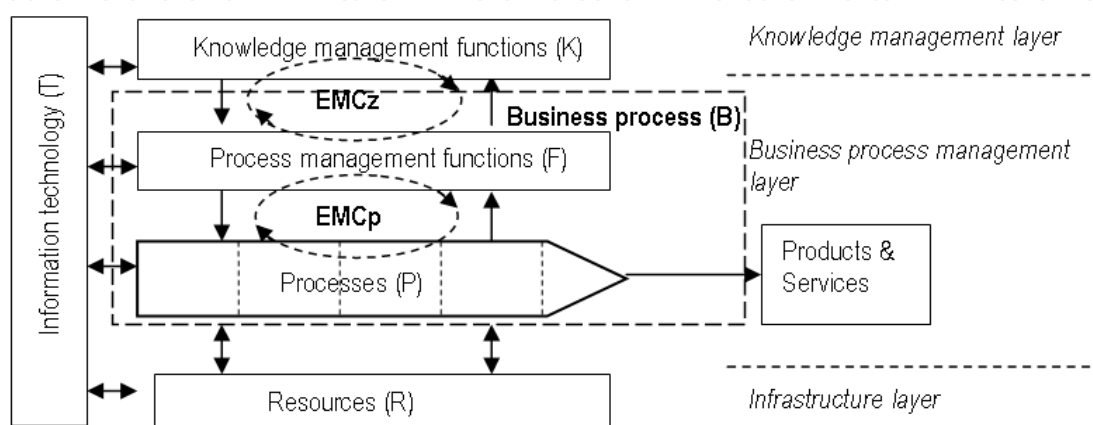


Fig. 21. Knowledge-Based Enterprise model

The semantics 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 control of the component *Processes (P)* – primary activities of enterprise (development of products and services in the proper way (Quality, Time schedule, etc));
- *Knowledge management cycle EMCz* – is the higher level EMC, its component *Knowledge management functions* 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.

By definition (Gudas, Brundzaite, 2006b), an Elementary Management Cycle (*EMC*) consists of the predefined sequence of mandatory steps of information transformation (*Interpretation, Information Processing, Realization*); these steps compose a management cycle (a feedback loop). The content of information and semantics of transformation of these mandatory steps of *EMC* depends on the subject area (domain of the enterprise). 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 *Process management cycle EMCp*. The *EMCz* deals with the information about the characteristics of management functions (quality, effectiveness, etc.), meanwhile the *Process management cycle EMCp* controls characteristics of products, services and state of a *Process* (i.e. technological process).

Therefore, the content (semantics) of information (data, knowledge, goals) processed in these two management cycles (*EMCz* and *EMCp*) is unlike 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*.

As it was concluded from the overview of Enterprise modeling approaches (see the column “Abstraction levels or views” in Table 2), representation of the enterprise knowledge management activities requires some hierarchical structure to be defined.

Therefore, the *Knowledge management component (K)* in the Fig. 25 is decomposed as hierarchical system and the Knowledge-Based Enterprise (KBE) framework (Fig. 26) developed (Gudas, Brundzaite, 2006, 2006a, 2006b).

The *Knowledge management component (K)* consist of the internal components as follows (Fig. 29): Business Process (BP), Resources (R), BP knowledge management (K4), Enterprise knowledge management (K3), Knowledge Base management (K2) and Business/IT strategic alignment (K1). These components shape a hierarchy of KBE management levels as follows:

Level 1 .Enterprise strategic management (Business and IT strategic alignment activities);

Level 2. Enterprise meta-knowledge management (Enterprise meta-modeling activities);

Level 3. Enterprise knowledge management (Enterprise knowledge for BP management);

Level 4. Enterprise management (BP knowledge management: knowledge acquisition for BP management, required by Enterprise strategy, defined at level 1);

Level 5. Business process management (managerial activities: Implementation of management functions, directing and controlling (manufacturing) Process);

Level 6. Process management and control (manufacturing control activities).

These enterprise management levels differ in the content of knowledge, required for KBE components for implementation of management activities.

The *KBE framework* is a process-oriented model and it refines two different layers (Fig. 26) of enterprise management hierarchy. The *Knowledge management domain (K)* is aimed to control activities of the component *Business domain (B)*. The *Business domain (B)* includes management and control of manufacturing activities (the component *Processes (P)*).

The Knowledge-Based Enterprise framework is based on the management (control) view (Gudas, et al., 2005), formally defined using the concept of Elementary Management Cycle (EMC). In brief, the concept EMC is a formalized description of the Enterprise management control as interaction of *Process* and *Function* – as two core components of enterprise from the control point of view (Gudas, 1991), (Gudas et al., 2005). The interaction of core elements *Management Function* and *Process* is formally assumed as a *Control Process* with the *Feedback Loop* between *Process P(j)* and *Management Function F(i)*.

The interactions of the different management levels (including levels 1 – 6) of the *KBE framework* are management transactions, which are considered as control loops (informational feedback) between corresponding KBE components, that is formally described as *EMC* (the *Elementary Management Cycle*). The semantics 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. The *EMCp* is responsible for control of the component *Processes (P)* – primary activities of enterprise (development of products and services in the proper way (Quality, Time schedule, etc));
- Knowledge management cycle *EMCz* is a higher level EMC, its component *Knowledge management functions* is responsible for the adequate activities of the *KBE framework* component *Process management functions (F)*. The *EMCz* is focused on the alignment of *Business process (B)* with the Enterprise strategic goals.

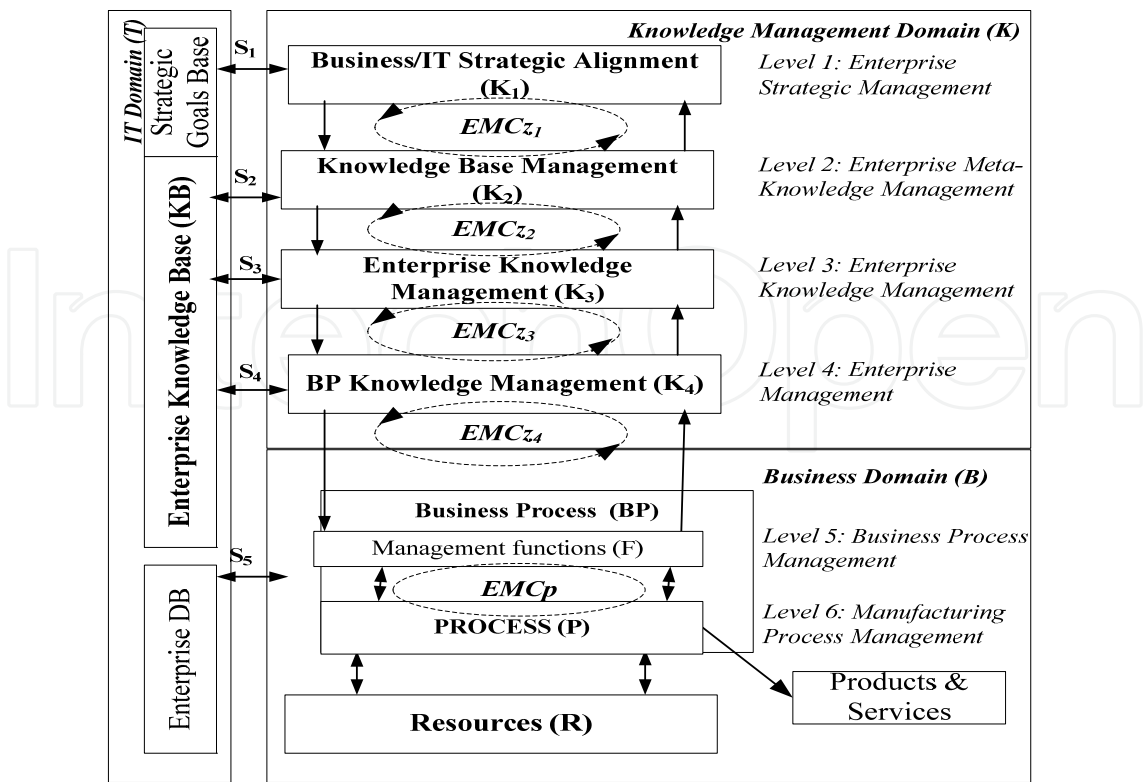


Fig. 22. Knowledge-Based Enterprise management framework

Every higher management level is related with the lower level by the Elementary Management Cycles (*EMC_{z1}, EMC_{z2}, EMC_{z3}, and EMC_{z4}*) [8]. Each *EMC_z* has different semantics.

Thus, from the management control point of view, *Knowledge Management Layer* of the Knowledge-Based Enterprise [Gudas, 2009), (Gudas, 2009a) is decomposed into four structural elements as follows:

- The component *K4 - Business Process Knowledge Management Functions* (KM level 4 – *Enterprise Management Level*). *K4* forms management control attributes for Business Process (*B*) level. *K4* uses interface *S4* with the *Enterprise Knowledge Base (KB)* for the exchange knowledge about business processes management.
- Third component *K3 - Enterprise Knowledge Management* (KM level 3 - *Enterprise Knowledge Management Level*) is aimed to complement knowledge of structural element *K4* by using knowledge, stored in *Enterprise Knowledge base (KB)* through interface *S3*. *K3* is related with KM level *K4* by feedback loop *EMC_{z3}*.
- The component *K2 - Knowledge Base Management* (KM level 2 - *Enterprise-Meta Knowledge Management Level*) is aimed to improve the structure and content of the *Enterprise Knowledge Base (KB)*, i. e. to adjust *KB* content with the business goals through the interface *S2*; Level *K2* in turn is related with third KM *K3* level by feedback loop *EMC_{z2}*.
- Knowledge management is driven by organizational goals and objectives. In the highest KM level – (KM level 1 - *Enterprise Strategic Management Level*) the component *Business/IT Strategic Alignment (K1)* defines strategic requirements for the *Enterprise Knowledge Base meta-modeling*. Components *K1* and *K2* are interrelated by the feedback loop *EMC_{z1}*.

Summing up, four management transactions (formally described as *EMC*), which have different semantics, are identified (Fig. 26):

- *EMCz1* – Enterprise Meta-Knowledge Management Cycle;
- *EMCz2* – Enterprise Knowledge Management Cycle;
- *EMCz3* – Business Process Knowledge Management Cycle;
- *EMCz4* – Business Process Management Cycle.

The semantics of structural components of these Enterprise Management Cycles further are described in detail.

12. Management transactions of Knowledge-Based Enterprise

The semantics of structural components of the Knowledge-Based Enterprise management framework are further described in detail (Gudas, Brundzaite, 2007), (Gudas, 2008), (Gudas, 2009), (Gudas, 2009a), (Gudas, 2010).

Business process management cycle (*EMCz4*). The component *BP Knowledge Management (K4)* is aimed to complement knowledge of the component *Business process (BP)* required by the *Management functions (F)* for management and control of the *Process (P)* on the level 6. „*Manufacturing Process management*“ (see Fig. 22). This knowledge management transaction in the KBE framework is named *EMCz4* – Business Process Management Cycle. Business process management cycle (*EMCz4*) is presented in Fig. 23.

The work flow and semantics of Business Process Management Cycle *EMCz4* is as follows. The purpose of Business process management cycle (*EMCz4*) is the development (generation) of a particular knowledge to control an enterprise component *Business process (BP)*. The component BP is comprised of a set of *Management functions (F)* and *Process (P)*. The component BP is at *Business domain (B)*, it is outside of the *Knowledge management domain (K)*.

The semantics of steps of the *Business process management cycle (EMCz4)* (Fig. 27) are as follows: *IN4* – interpretation of some facts (characteristics) related with the controlled object – an activity BP; *IP4* – processing of interpreted information (data, knowledge) and decision making (it is aimed to control an activity BP); *RE4* – realization of decision (management control making, including transferring of manipulated variables (a particular decision) and influencing a controlled object – the component “Business process (BP)”.

The constraints on the Business process management cycle (*EMCz4*) are output of the component *K3* (Enterprise knowledge management) and input of the interface *S4* from Knowledge base (KB).

The activity *IN4* performs an interpretation of the actual knowledge about the features (state) of the Business process (BP). Characteristics (data and knowledge about a state) of Management Functions (F) and Process (P) are captured, transferred and conceptualized, using some criterions from the Enterprise Knowledge Base (EKB). This captured actual semantics of the Business process (BP) is an input of the component BP knowledge management functions (*K4*). The activity *IN4* comprises of a set of rules and procedures for transformation of the actual data and knowledge about a state of Business process (BP).

The step *IP4* is knowledge processing activity, aimed to define a set of manipulated variables – decision to control Business process (BP). The activity *IP4* is a system of data and knowledge manipulation procedures focused for alignment of the content of component Business process (BP) (i.e. *IP4* modify a list and logic of management functions F) in accordance with requirements of the higher level component *K3* (these requirements are the

output of the step RE3 of the higher level management EMCz3) and actual knowledge accessed by interface S4 from the Enterprise knowledge base.

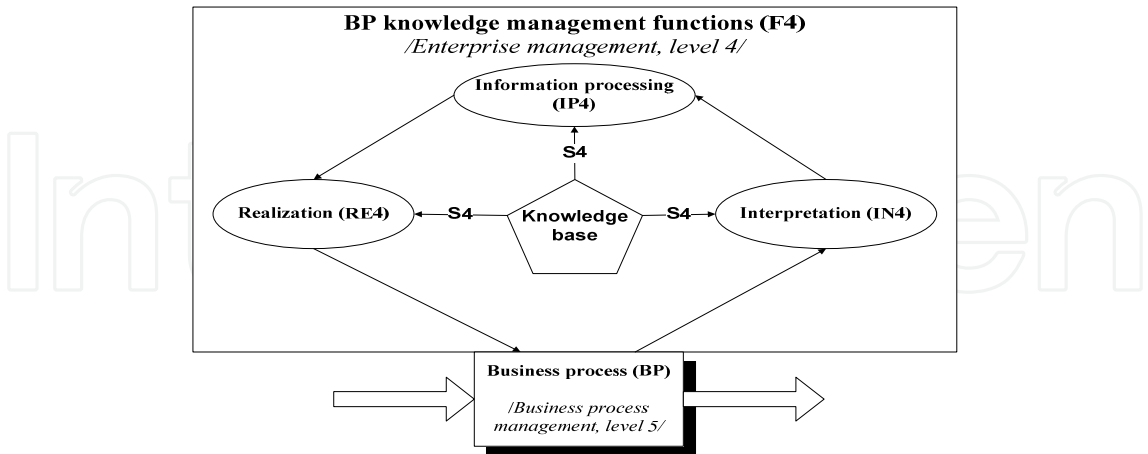


Fig. 23. Business process management cycle (EMCz4)

The step RE4 is the co-ordination activity, the feedback from higher level knowledge management component K4 to business process management level 5. The RE4 is aimed to transfer manipulated variables (decision) and to influence the component Business process (BP), namely to modify Management functions (F).

Business Process Knowledge Management Cycle (EMCz3). The Business Process Knowledge Management Cycle (the management control EMCz3 in Fig. 22) is *knowledge adaptation cycle* (Fig. 28) aimed to integrate the component “BP knowledge management” (K4) with the actual content of the component “Enterprise Knowledge Base” (KB).

The Enterprise knowledge management cycle EMCz3 is aimed to development (generation) of particular new knowledge for business process management functions, which are depicted as the component K4 (“Business process management”) in Fig. 26.

The semantics of steps of the Business process knowledge management cycle (EMCz3) are as follows (Fig. 24): IN3 – interpretation of facts (characteristics) related with the controlled object – an activity of the component K4, IP3 – processing of interpreted information (data, knowledge) and decision making (aimed to control the component K4), RE3 – realization of decision (making management control, including transferring of manipulated variables (a particular decision) and influencing a controlled object – the component K4. The constraints on the Business process knowledge management cycle (EMCz3) are output of the component K2 (Knowledge base management) and input of the interface S3 from Knowledge base (KB).

The activity IN3 performs an interpretation of the actual knowledge about the features (state) of BP knowledge management functions (F4). The step IN3 comprises of a set of interpretation rules and procedures for transformation of the actual data and knowledge about a state BP knowledge management functions (F4) for the integration with the step IP3. These transformations are aimed to fit the requirements of the IP3 – the next step of the enterprise knowledge management cycle EMCz3.

The step IP3 – knowledge processing activity, aimed to form a set of manipulated variables – decision to implement new features of the BP knowledge management functions. The IP3 is a system of data and knowledge manipulation procedures focused for modification of the content of component K4 with the requirements of the higher level component K2 (these

requirements are the output the step RE2 of the higher level management EMCz2) and actual knowledge accessed by interface S3 from the Enterprise knowledge base.

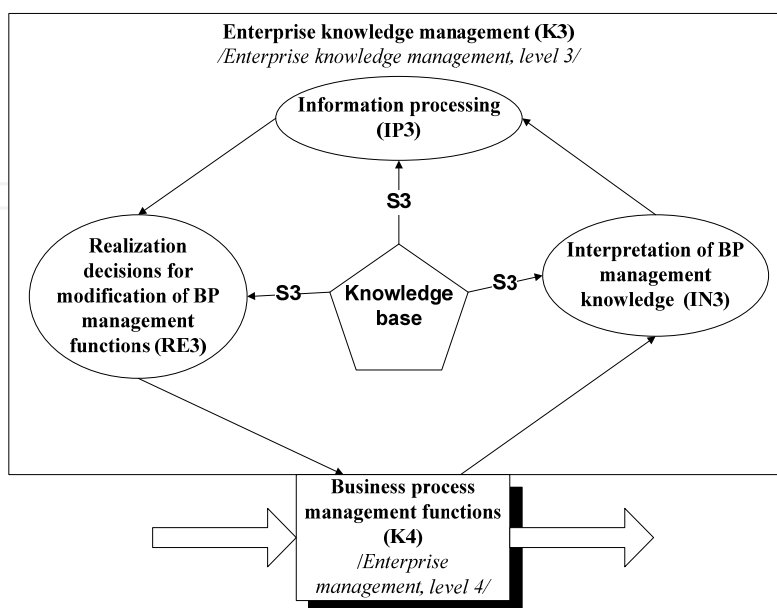


Fig. 24. The Business process knowledge management cycle (EMCz3)

The step RE3 – the co-ordination activity, the feedback from higher level Knowledge management component K3 to Business process knowledge management functions (K4). The step RE3 is aimed to transfer manipulated variables (decision) and to influence the component K4, namely to modify Business process knowledge management functions (F4). Enterprise Knowledge Management Cycle (EMCz2.)

The component K3 “Enterprise Knowledge Management” (KM level 3 - Enterprise Knowledge Management Level) is aimed to complement knowledge of the component K4 „BP Knowledge Management” by required knowledge, stored in Enterprise Knowledge base (KB) using interface S3. The component K3 is related with the next knowledge management level 4 by feedback loop EMCz3 (related with component K4).

The component Enterprise Knowledge Management (K3) is interrelated with other knowledge management system components as follows:

- EMCz2 – the Enterprise Knowledge (content) Management Cycle; based on the Enterprise meta-knowledge (Ontology) stored at the EKB (supported by the interface S2);
- The interface S2 – service to component K2 for using meta-knowledge, stored in Enterprise Knowledge base (KB);
- EMCz3 – the Business Process Knowledge (content) Management Cycle; based on the Enterprise knowledge stored at the Enterprise Knowledge Base EKB (supported by the interface S3);
- The interface S3 – service to component K3 for using knowledge, stored at the Enterprise Knowledge Base (EKB).

The Enterprise Knowledge Management Cycle (the management control EMCz2 in Fig. 22) is a *higher level knowledge adaptation cycle* aimed to modify the component “Enterprise knowledge management” (K3) of Knowledge management (K) domain. The Enterprise knowledge management cycle EMCz2 is aimed to development (generation) of definite

knowledge required to adapt a set of Enterprise knowledge Management functions to the new requirements of the Knowledge Base meta-model.

The semantics of steps of the Enterprise knowledge management cycle (EMCz2) are as follows (see Fig. 25): IN2 – interpretation of facts (characteristics) related with the controlled object – an activity of the component K3; IP2 – processing of interpreted information (data, knowledge) and decision making (aimed to control an activity of the component K3); RE2 – the step of realization (implementation) of decision aimed to influence a controlled object Enterprise management – the component K3.

The constraints on the Enterprise knowledge management cycle (EMCz2) are output of the component K1 (“Business and IT strategic alignment”) and input of the interface S2 of Enterprise Knowledge base (KB).

The activity IN2 performs an interpretation of the actual knowledge about the features (state) of Enterprise knowledge management functions (F3). The step IN2 comprises of a set of interpretation rules and procedures for transformation the actual data and knowledge about a state of Enterprise knowledge management functions (F3) for the integration with the step IP2. These transformations are aimed to fit the requirements of the IP2 – the next step of the enterprise knowledge management cycle EMCz2.

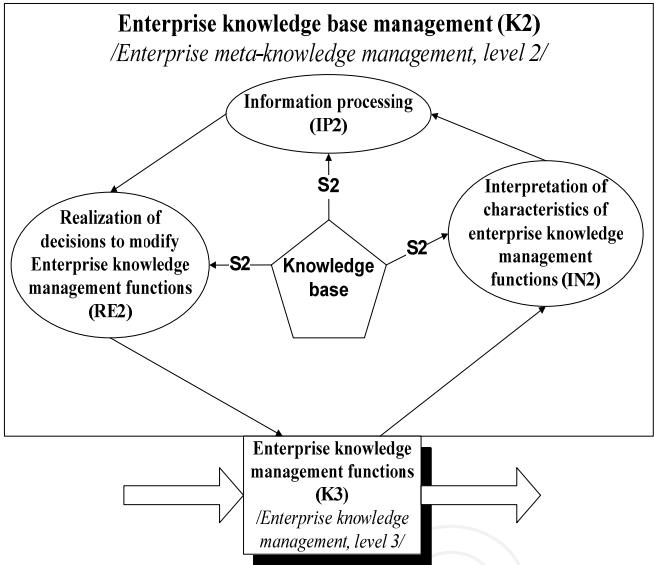


Fig. 25. The Enterprise knowledge management cycle (EMCz2)

The step IP2 – knowledge processing activity, aimed to form a set of manipulated variables – decision to modify the component Enterprise knowledge management (K3). The IP2 is a system of knowledge manipulation procedures focused for alignment of the content of component K3 with the requirements of the higher level component K1 (these requirements are the output the step RE1 of the higher level management EMCz1) and actual knowledge accessed by interface S2 from the Enterprise Knowledge Base.

The step RE2 is the co-ordination activity, the feedback from higher level component Knowledge base management (K2) to the component Enterprise knowledge management (K3). The step RE2 is aimed to transfer manipulated variables (decision) and to influence the component K3, namely to modify Enterprise knowledge management functions (F3) (Gudas, 2009).

Enterprise Meta-Knowledge Management Cycle (EMCz1)

Enterprise management as well as knowledge management is driven by organizational goals and objectives. At the highest level of knowledge management of the KBE framework (*Enterprise Strategic Management Level*) the component *Business/IT Strategic Alignment* (K1) defines strategic requirements for the Enterprise Knowledge Base management component (K2) and controls it by the feedback loop EMCz1.

The EMCz1 is *Enterprise meta-knowledge management cycle*, focused on the alignment of the enterprise knowledge base content (i.e. enterprise meta-knowledge model) and business/ IT strategic goals (Gudas, Brundzaite, 2007).

The management control EMCz1 is the *top level knowledge management activity* focused on the requirements for the scope and content of Enterprise knowledge base (meta-knowledge). The component Knowledge base management (K2) is responsible for the meta-knowledge management (at level 2 of Knowledge management domain.).

The purpose of Enterprise meta-knowledge management cycle EMCz1 is development (generation) of a definite knowledge to modify the enterprise component Knowledge base management (K2) which is comprised of a set of Enterprise knowledge base management functions (F2).

The semantics of steps of the Enterprise meta-knowledge management cycle (EMCz1) are as follows (Fig. 26):

IN1 – interpretation of facts (characteristics) related with the controlled object – an activity of the component K2;

IP1 – processing of interpreted information (data, knowledge) and decision making (aimed to change the knowledge base meta-structure);

RE1 – realization of decision (a strategic decision) aimed to influence a controlled object – the component K2.

The constraints on the Enterprise meta-knowledge management cycle (EMCz1) are input of the interface S1 from the knowledge base *Strategic Goals*.

The activity IN1 performs an interpretation of the actual knowledge about the features (state) of enterprise knowledge base management functions (F2).

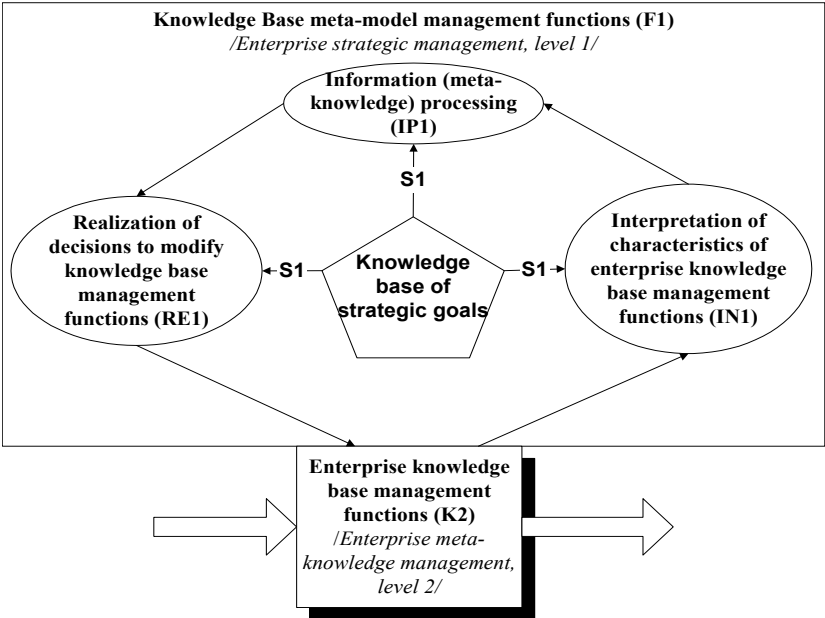


Fig. 26. Enterprise meta-knowledge management cycle (EMCz1)

The step IN1 comprises of a set of interpretation rules and procedures for transformation of the actual data and knowledge about a state enterprise knowledge base management functions (F2) for the integration with the step IP1. These transformations are aimed to fit the requirements of the IP1 – the next step of the enterprise knowledge management cycle EMCz1.

The step IP1 – a meta-knowledge processing activity, aimed to form a set of manipulated variables – decision to control the component Knowledge base management (K2). The IP1 is a system of knowledge manipulation procedures focused for alignment of the content of component K2 with the requirements of the actual knowledge accessed by interface S1 from the Enterprise Strategic Goals' Base.

The step RE1 – the co-ordination activity, it is the feedback from higher level component Business and IT alignment (K1) to the component Enterprise knowledge base management (K3). The step RE1 is aimed to transfer manipulated variables (a strategic decision) and to influence the component K2, namely to modify Enterprise knowledge base meta-model and knowledge base management functions (F2).

13. Components of knowledge management system

Knowledge management *Use Cases* and interfaces. The major knowledge management *Use Cases* and interfaces at the Enterprise knowledge management (K) domain are depicted at the *Use Case diagram* (UML) in Fig. 31. There are four types of *Actors* associated with particular level of the enterprise Knowledge management (K) domain: a top manager (a chief executive), a Knowledge base administrator, an enterprise management expert, and a business process manager (Gudas, Brundzaite, 2007).

The enterprise knowledge self-organization activity is a responsibility of a chief executive. It includes interfaces with use cases Strategic knowledge management functions (F1) and Knowledge base management functions (F2).

Responsibilities of a knowledge base administrator includes interfaces for administration of use cases Strategic knowledge management functions (F1), Knowledge base management functions (F2), "enterprise knowledge management functions (F3), and BP knowledge management functions (F4).

The responsibilities of an enterprise management expert are focused on the development of a definite new knowledge and requirements for improvement of BP management functions (using interfaces with use cases Enterprise knowledge management functions (F3), BP knowledge management functions (F4), and Knowledge base management functions (F2)).

The BP managers access definite knowledge aimed to perform BP management and BP management control (using interfaces with the use case BP management functions (F)), and use interface with BP knowledge management functions (F4) to access definite knowledge for modification of BP management functions.

The major Classes of Enterprise Knowledge base. Enterprise knowledge modelling method could be used for construction of the integrated enterprise knowledge base, which is considered as the basic component of the knowledge-based enterprise. Enterprise knowledge base will enable transformation of the enterprise into knowledge-based business as well as to solve business and IT alignment and enterprise IT management problems.

The major classes of the enterprise knowledge base are derived from formal description of Enterprise Knowledge Space and are defined as Enterprise Knowledge Model M.

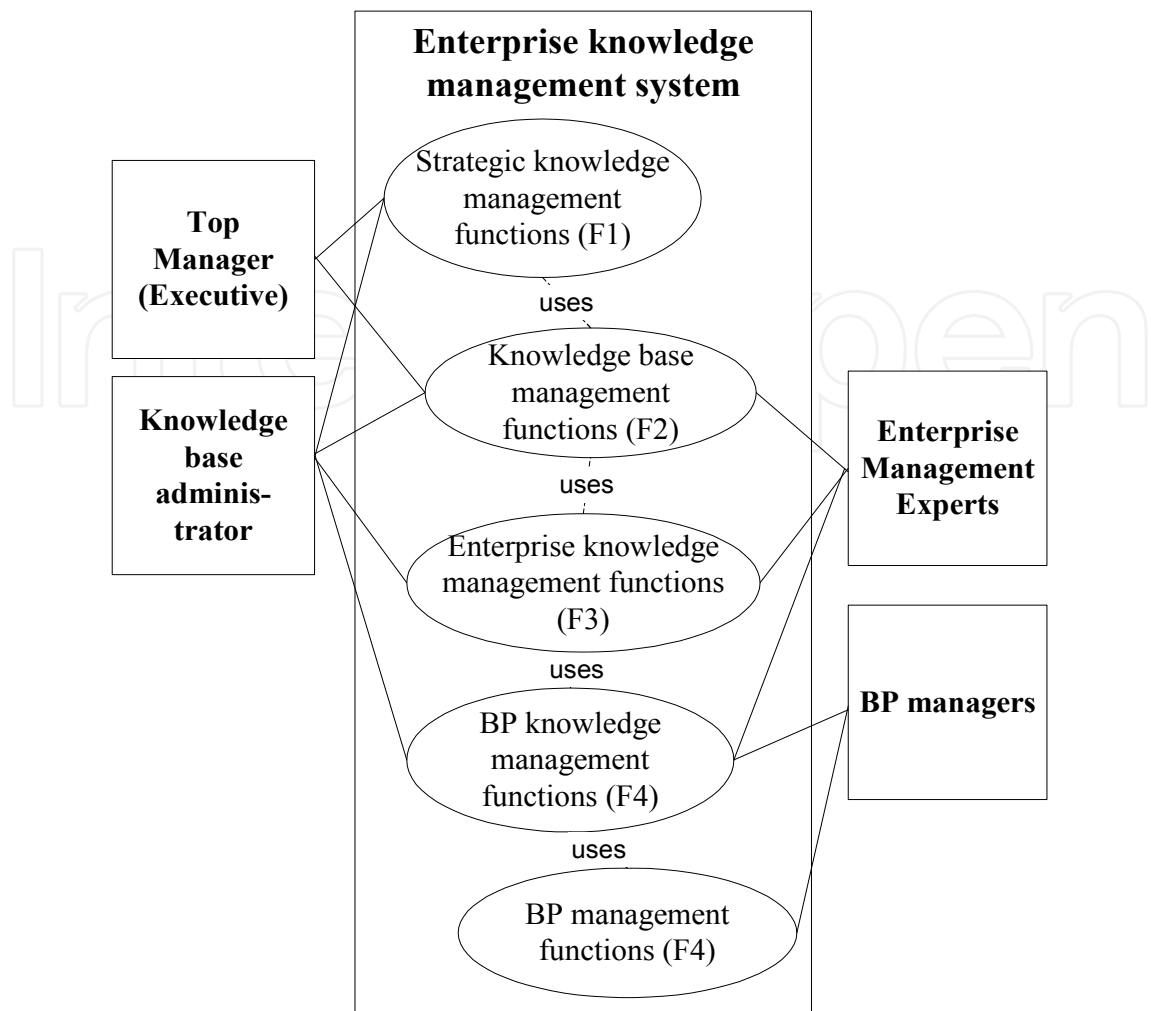


Fig. 27. The major interfaces of Enterprise knowledge management system

The formal description of the Enterprise Knowledge Model M can be expressed as the Cartesian product in the following way (Gudas, 2008):

$$M = (T) \times (K) \times (B) \times (R) \tag{5}$$

where T = information technology, K = knowledge, B = business process, R = business resources.

For the completeness of the model, *resources* (R) component was introduced into the model, as we consider knowledge as separate, but integrated enterprise aspect in contrary to the classical enterprise modelling methods which analyze knowledge alongside with other business resources.

This means, that each enterprise knowledge item m ($m \in M$) in Enterprise Knowledge Model M is related to the appropriate business process b ($b \in B$), knowledge k ($k \in K$), resources r ($r \in R$) and information technology t ($t \in T$). To put it in other terms, the enterprise knowledge model M item m is identified by a set of identifiers:

$$m(t;k;b;r;l) \in M \tag{6}$$

where l ($l \in L$) is time period index.

The Enterprise Knowledge Model M is composed of interrelated items m and enables modelling a knowledge-based business, as it considers enterprise modelling knowledge (identifier k), business processes (identifier b), IT (identifier t), and their interactions. Each aspect (b, t, k) is modelled into the 5 levels of detail in the Enterprise Knowledge Space (Fig. 20).

In Fig. 28, the Enterprise knowledge structure (subsets of knowledge) is presented by class diagram (UML).

Consequently, Enterprise Knowledge Base contains integrated knowledge about three enterprise domains: business (B), information technology (T) and knowledge (K), as well as various relationships of these domains.

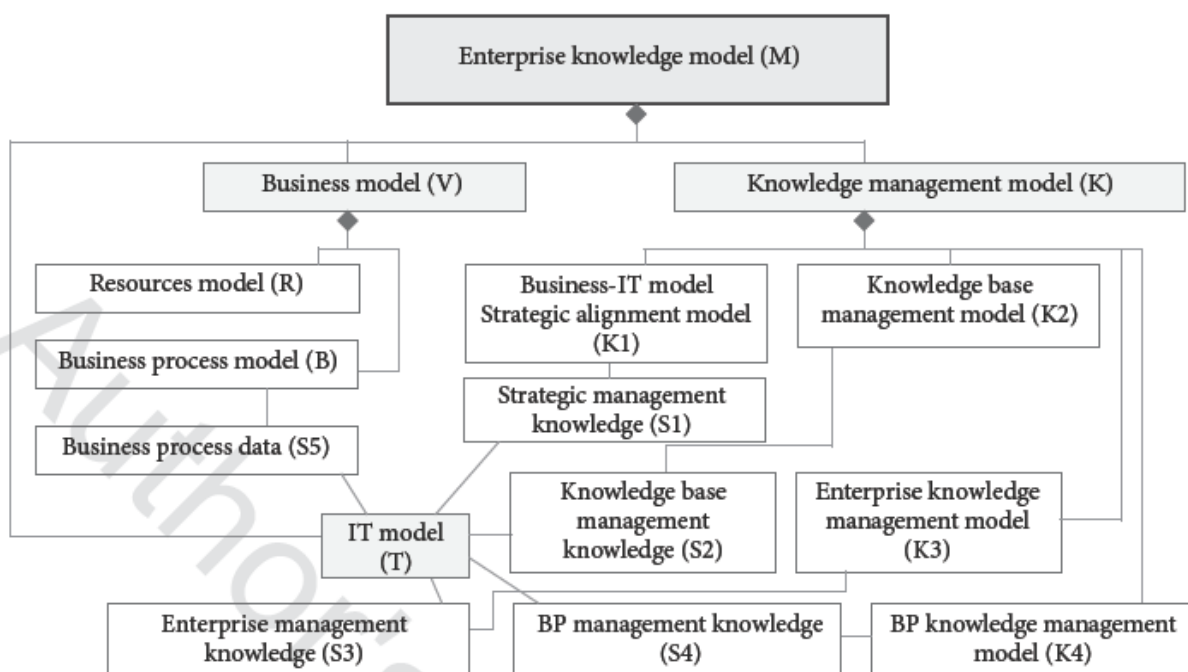


Fig. 28. The major knowledge subsets of the Enterprise Knowledge Base

14. Conclusions

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

From the knowledge management point of view, the conception of the Knowledge-Based Enterprise embodies the vision of the more mature and more advanced enterprise and is the step towards intelligent enterprise systems. Advancement is seen here as the high formalisation degree of the knowledge management activities which results in the more efficient management and automation of business process and knowledge processes in the enterprise (Gudas, 2009).

The 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 formally described as semantically different information feedback (control loops): the Process Management Cycle (*EMCp*) and the Knowledge Management Cycle (*EMCz*). The Knowledge-Based Enterprise model is represented as a modified value chain model featuring the knowledge management component.

The concepts of the *enterprise knowledge component* and *Enterprise Knowledge Space* delineates the boundaries and granularity of enterprise knowledge layers. The framework of the Enterprise Knowledge Space is based on the analysis of Enterprise domains and aspects of the various enterprise knowledge modelling approaches generalized by the following concept: the Enterprise Knowledge Component (B, T, K). 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 method of enterprise knowledge modelling.

The developed Knowledge-Based Enterprise (KBE) framework more formally refines knowledge management activity in the enterprise and is the basis for the development of the Enterprise knowledge base, which is concerned as the main component of the KBE. Interactions among the levels of knowledge management are based on the concept of Elementary Management Cycle (EMC). The EMC concept is derived (Gudas et al., 2005) from the classical concept of control loop as the formal background for description of management information processing in the hierarchical organizational systems (Gudas, 1991).

The presented framework of the Knowledge-Based Enterprise Management System's architecture is aimed to the development of the practical methods for the Knowledge-Based Enterprise modelling and implementation.

The peculiarity of the KBE model is that it reveals another - knowledge management level - and defines interactions between those two management levels of the enterprise, using the same EMC concept. The knowledge management layer of the KBE model contains a hierarchy of the knowledge management activities, defined as the particular types of the EMC. All defined types of the EMC have their own semantics (Gudas, Brundzaite, 2007).

Another important feature of the developed model is that the interactions (defined as interfaces S) between knowledge management domain and information technology domain (Enterprise Knowledge base) are defined formally too.

The presented framework of the Knowledge-Based Enterprise is the basis for the development of the practical methods for the Knowledge-Based Enterprise Modelling and implementation.

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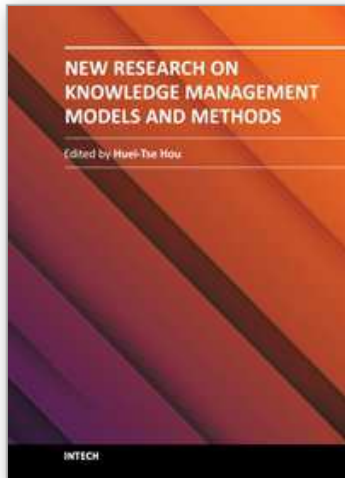
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New Research on Knowledge Management Models and Methods

Edited by Prof. Huei Tse Hou

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Due to the development of mobile and Web 2.0 technology, knowledge transfer, storage and retrieval have become much more rapid. In recent years, there have been more and more new and interesting findings in the research field of knowledge management. This book aims to introduce readers to the recent research topics, it is titled "New Research on Knowledge Management Models and Methods" and includes 19 chapters. Its focus is on the exploration of methods and models, covering the innovations of all knowledge management models and methods as well as deeper discussion. It is expected that this book provides relevant information about new research trends in comprehensive and novel knowledge management studies, and that it serves as an important resource for researchers, teachers and students, and for the development of practices in the knowledge management field.

How to reference

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