Intelligent Service-Oriented Enterprise Architecting for Knowledge Portals Design: Fusion of Approaches

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***Abstract*—Knowledge portal is an important element within corporate knowledge management. Currently there is plentyful tools and software for knowledge portal construction, but it is not yet evident how to select, compose and configure them for any specific company and business situation. The paper describes basic principles of a new methodology PROTESYS (PROject-TEchnology-SYStem) for knowledge portal design, implementation and support. This methodology helps knowledge managers, business analysts and enterprise architects to (re)design and support knowledge portal. The foundational triad of this methodology includes three pillars: service orientation, enterprise architecture management and intelligent support.**

I. Introduction

Knowledge management system (KMS) is an essential attribute of any company in knowledge-based economy of XXI century. KMS is a class of information systems applied to managing organizational knowledge [1]. Knowledge portal [2] is a popular type of KMS implementation. Intelligent services and ontologies has a high potential for improving effectiveness of knowledge portals, but their usage in industrial applications is still limited [3], [4], [5].

The suggested PROTESYS methodology for knowledge portal design is meant for knowledge managers, business analysts and enterprise architect, which are responsible for KMS requirements analysis, conceptual design, deployment and support. This methodology helps to develop requirements and design specifications for knowledge portal both from business and IT perspective. PROTESYS methodology is being developed within RFBR project InS-PORT (Intelligent Services for ontology-based knowledge PORTal support). The goal of InS-PORT project is to develop methodology and technology, which help to build and deploy knowledge portals for commercial companies, research institutions and other organizations.

The PROTESYS methodology uses service-oriented approach, enterprise architecture management methods and intelligent support. Service orientation gives agility since it provides implementation-independent building blocks for KMS design and composition. Enterprise architecture management supports holistic design of socio-technical business systems, provides coherent languages for KMS specification and enable to move beyond IT perspective. Intelligent rule-based component supports novice knowledge managers and helps to formalize best-practices for KMS design and composition in efficient and consistent way.

II. Service-orientation and enterprise architecting for Knowledge Portal Design

A. *Service-oriented approach and its application in KMS design*

Since software engineering was founded as a discipline in the 70s, computer scientists have searched for ways to describe basic or advanced building blocks out of which software systems can be composed. The main advantages are reduced cost and time as well as improved quality through modularization, reusability, stability and interoperability of the resulting software systems. There are a number of different terms for building blocks, e.g., functions, procedures, modules, classes or components. Recently, service has been the central concept for a redefinition of the technical and conceptual foundation for these main building blocks from a more business-oriented perspective [6], [7], [8].

A service is defined as a unit of functionality that some entity (e.g., a system, organization, or department) makes available to its environment, and which has some value for certain entities in the environment (typically the 'service users'). Service orientation supports current trends ranging from the service-based network economy to ICT integration with Web services. These examples already show that services of a very different nature and granularity can be discerned: they can be provided by organizations to their customers, by applications to business processes, or by technological facilities (e.g., communication networks) to applications [9].

In today's literature the term "Knowledge Management Service" (KM service) is used differently ranging from KM service as a synonym for "product in the area of KM" to an implemented Web Service in the context of KM like a search engine. Service-oriented approach to KMS design can be found in [10], [11], [12]; [13], which partially intersects with the current research.

B. *Enterprise architecture and its application in KMS design*

Enterprise Architecture (EA) is an emerging cross-

disciplinary field concerned with the design, management and transformation of a modern enterprise as complex system (business and IT) to ensure values of the key stakeholders [9], 14]. According to TOGAF, enterprise management provides a strategic context for the evolution of the IT system in response to the constantly changing needs of the business environment [14].

Enterprise architecting includes development of visual multi-aspect models of the business and its IT-architecture. Such models describes business capabilities, functions, organizational structure, business processes, information systems, data and technical infrastructure [9]. Special modeling languages, like Archimate [15], are used in order to develop such models. There are three levels of architecture description in ArchiMate: business ("level of human activities"), applications ("level of software") and technologies ("level of hardware/equipment").

From business point of view, KMS is a socio-technical system of systems, which integrates multiple business and information systems of the enterprise in order to improve knowledge processes. Since KMS is not only about IT, enterprise architecting is a promising discipline for KMS design and deployment. There are already some works that point to this potential, e.g. [16].

C. *Combining service orientation with enterprise architecture methods for knowledge portal design*

PROTESYS methodology combines service-orientation and enterprise architecting for knowledge portal design. It employs existing service-oriented EA methodologies (e.g. Archimate [15]) and suggests architecture building blocks for KMS / knowledge portal design. There are many KM tools [17], which are typically implemented in a comprehensive corporate KMS / knowledge portal, for example, community of practice, After-Action Review, idea capture and management. Within PROTESYS methodology KM tools [17] are considered as both providers and consumers of KM services.

Service orientation may typically lead to a layered view of EA models, where the service concept is one of the main linking pins between the different layers [9], [15]. Service layers, which are made available to higher layers, are interleaved with implementation layers that realize them. Within a layer, there may also be internal services, e.g., services of supporting applications that are used by the end-user applications. How this leads to a stack of service layers and implementation layers is shown in Fig. 1. These are linked by "used by" relations, showing how the implementation layers make use of the services of other (typically 'lower') layers, and realization relations, showing how services are executed on an implementation layer. Business service: a service that fulfills a business need for a customer (internal or external to the organization). Application service: a service that exposes automated behaviour. Infrastructure service: externally visible unit of functionality, provided by one or more computational resource, exposed through well-defined interfaces, and meaningful to the environment.

So, according to Archimate layered approach, KM tools are providers and consumers of KM business, application and infrastructure services of KMS / knowledge portal within PROTESYS methodology.

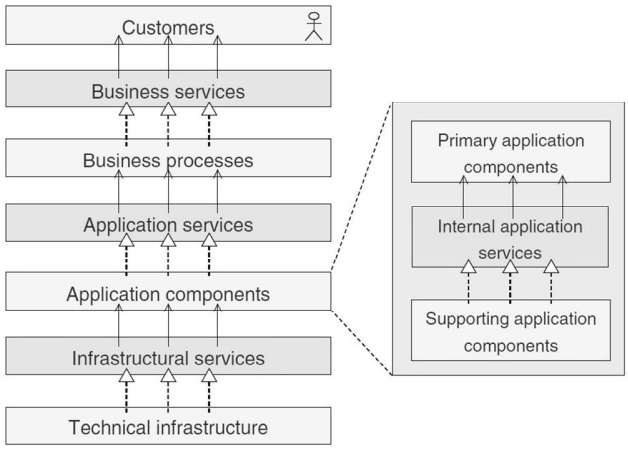

Fig. 1. Layered system of services in Archimate language [9]

Business services are based on corresponding business functions and processes, organizational roles and use various application services. Fig. 2 contains service-oriented description of one of KM tools, namely, the community of practice developed in accordance with the architectural approach [9] in the Archimate language [15] using Archi software [18]. Application services depicted at Fig. 2 may be also used for realization of various business services. For instance, "Information Storage" and "Forums" may be also used for ideas management business services. Such modular approach provides both efficiency by means of separate services operation improvement, and flexibility by means of quick assembly of new services based on combination of existing ones (same with Lego blocks).

D. *"Building blocks" application for knowledge portal design*

PROTESYS methodology formalizes and systematizes "building blocks" for conceptual (re)design of corporate KMS / knowledge portals and promotes knowledge reuse ideas [19]. These "building blocks" include service-oriented descriptions of popular KM tools [17] (patterns) and are based on catalogues (reference classifications) of KM services, application components and information resources. Such catalogues help to standardize "building blocks" descriptions and facilitate search, selection and configuration of KM services and components during knowledge portals design. In order to support semantic portal design "building blocks" will include services and components, which are specific for semantic web applications [3]. The selection of "building blocks" is supported by the special intelligent service (see section III).

Since KMS design (containing IT and organization parts) may be considered as a part of enterprise architecture design, the PROTESYS prototype for KMS design support will supplement functions of standard enterprise architecture management tools [22], [23], involving basic means to work with catalogues (reference classification) and "building blocks".

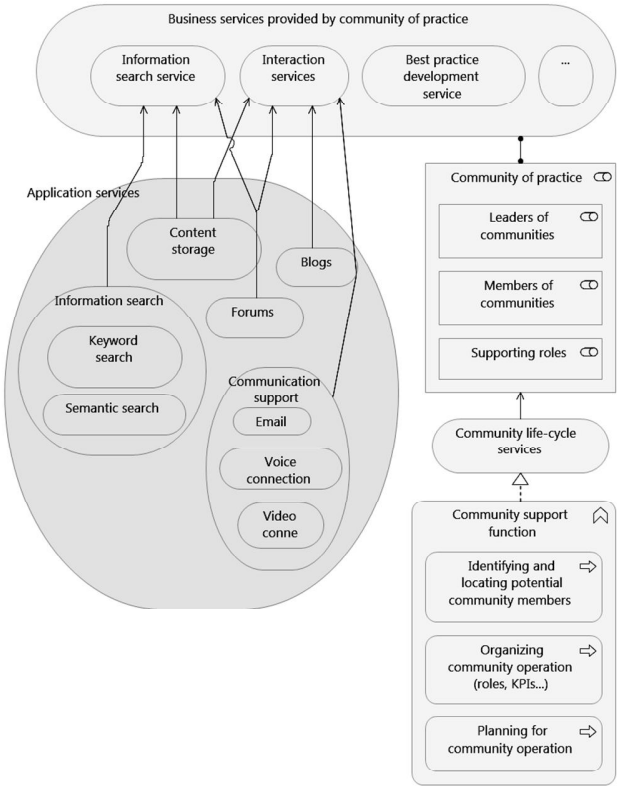

Fig. 2. Service-based description of community of practice (fragment)

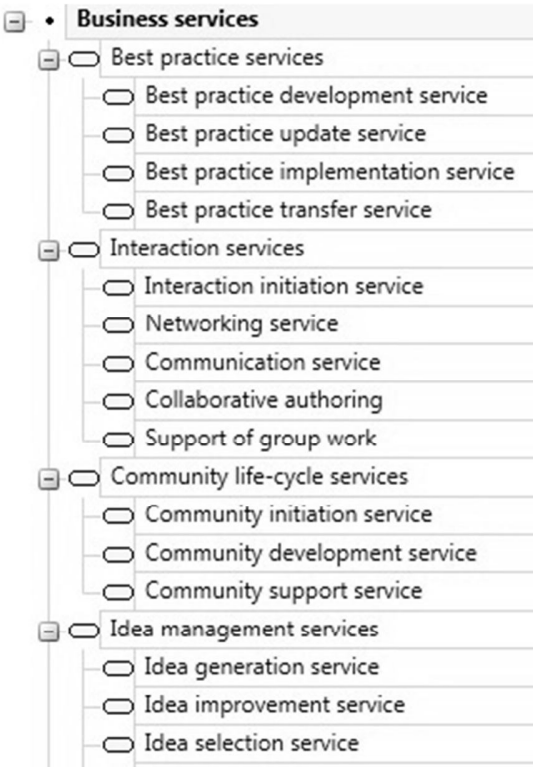

Fig. 3. Fragment of preliminary KM business services catalogue

III. Intelligent rule-based support for KM service selection

The selection of KM services for knowledge portal design is supported by the special intelligent (meta)service (or knowledge-based system), which is based on the extensible rule base. This intelligent (meta)service provides recommendations on some design strategic issues, namely, suggests KM tools, methods and services ("building blocks") for knowledge managers and business analysts based on some input parameters which describe the enterprise, its knowledge-critical domains and "as is" KM state.

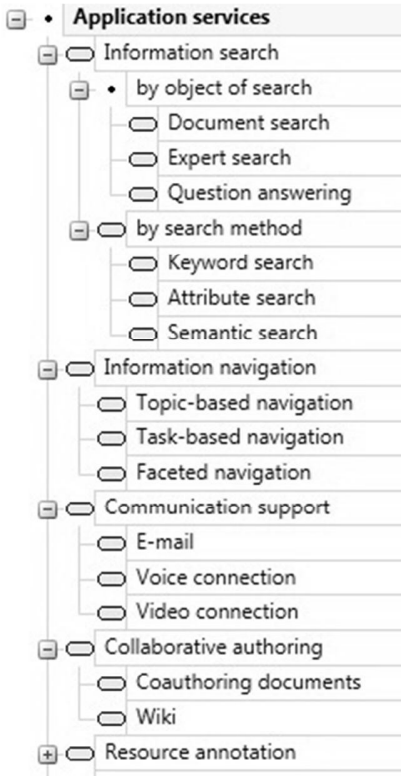

Fig. 4. Fragment of preliminary KM application services catalogue

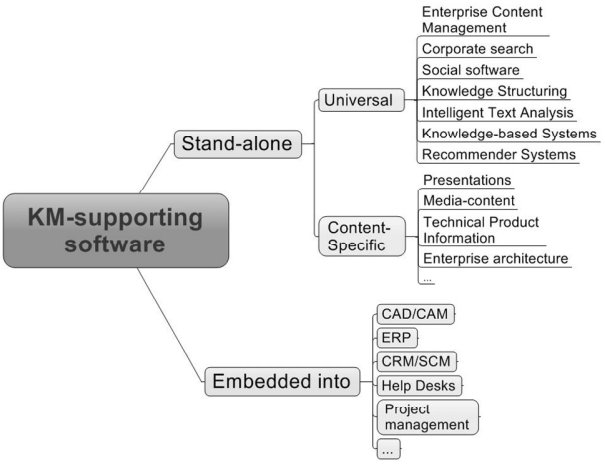

Fig. 5. Catalogue of software a required for KMS (upper level)

Knowledge Based Systems (KBS) are developed with an aim of providing assistance to the user to retrieve, analyze and make decisions within a particular knowledge domain. A rule-based system uses rules and facts to provide recommendations or diagnoses, or to solve a particular problem. The knowledge-base would contain a set of rules that represent the knowledge of the system [24], [25]. The rules are conceptually represented as IF/THEN statements with logical form: IF <predicate> THEN <consequent>. Using such statements the knowledge for a particular environment could be captured and they could be represented as set of rules.

Example rules for intelligent KM service selection (meta)service:

Rule1: IF Company's strategy is Operational excellence THEN Best practice development may work [26].
Rule 2: IF Knowledge in the domain of interest is Ambiguous and equivocal THEN Interaction services (Interaction initiation, Networking, Communication, Collaborative authoring, Support of group work service) AND Expert search service may work [27].

The decision table is used in order to represent, integrate and run these rules– see Table I. This table has three constituents: conditions, actions and decision rules [28]. Each condition has a condition stub and a condition entry. Each action has an action stub and action entry. A decision rule, which is represented as a table column, is a combination of a set of conditions and actions.

TABLE I. DECISION TABLE FRAGMENT FOR INTELLIGENT KM SERVICE SELECTION

	Rule 1	Rule 2	etc.
Conditions			
Company's strategy	Operational excellence		…
Knowledge properties		Ambiguity and equivocality	…
Knowledge process task			…
etc.			…
Actions			
KM methods and tools	Best practices;		…
KM business services	Best practice development service	Interaction services; Expert search service	…
KM application services		Communication support (sending/ receiving e-mails, voice communication, video conferences)	…
Source	[26]	[27]	

Input parameters (conditions) are identified by knowledge managers during KMS / knowledge portal development or support - knowledge audit and diagnostics (organizational context analysis) is the initial stage of any project on KMS development; it helps to understand company's strategy, activities and processes, key knowledge, its level, etc.

In order to improve consistency and reduce ambiguity we specified sets of conditions and actions together with their possible values and represented it in Tables II and III.

These results are based on expert knowledge and global experience, for instance, [17], [26], [27], as well as on the analysis of MAKE [21] and successful KMS implementations [29].

TABLE II. INPUT PARAMETERS (CONDITIONS) OF KM SERVICE SELECTION DECISION-MAKING MODEL

Conditions (Input parameters)	Possible values
Knowledge process task	Knowledge generation; Knowledge accumulation; Knowledge allocation; Knowledge exchange
Company's strategy	Operation excellence; Innovation and product leadership; Customer intimacy; Business growth and extension
Knowledge-related goals	Reduced time for required information search; Keeping critical knowledge; Improved knowledge exchange; Transmission of advances experience/practices; Application of accumulated knowledge, etc.
KM maturity level	Depends on the chosen model
Functional areas and processes	Production, Procurement, Sales, Finances, Human resources management
Areas of knowledge	Customer knowledge; Knowledge of company's products/services; Process knowledge; Knowledge of the company and business organization
Knowledge types and properties	Explicit knowledge; Implicit knowledge; Modality (texts, drawings, tables, diagrams, formulas); Uncertainty, Complexity, Ambiguity, Equivocality
Quantitative benefits	Increase in revenues, costs reduction
Duration of implementation	Natural number
Implementation costs	Natural number
Company size	Natural number
Influence degree	Team; Department; Enterprise

TABLE III. OUTPUT PARAMETERS (ACTIONS) OF KM SERVICE SELECTION DECISION-MAKING MODEL

Actions (Output parameters)	Possible values
KM tools and methods	Knowledge base (library, corporate memory); Best practices; Communities of practice; Lessons learned; Expertise locator; Ideas bank (ideas accumulation and management); Questions and answers service, etc.
KM business services	Best practice services (development, update, implementation, transfer service); Interaction services (Interaction initiation, Networking, Communication, Collaborative authoring, Support of group work service); Etc.
KMS application (software) services	Information search (key words, attributes, semantic); Information storage (kinds: texts, drawings, audio, video, etc.); Navigation (topics, tasks); Information recommendation; Communication support (sending/receiving e-mails, voice communication, video conferences); Forum; Blog, etc.

IV. Related work

There are some existing works, which consider KMS or knowledge portal design from service-oriented and are intended for similar purposes.

The process-oriented knowledge management of PROMOTE® has been used as a concept to define knowledge management requirements on the basis of business needs [10], [11]. The KM-Services approach has been introduced to implement the KM-system on the basis of process oriented knowledge management. The KM-Service framework has been introduced to enable analysis, simulation and evaluation of KM-requirements and KM-solutions. Current research of these authors in this area focuses on semantic business process management and service implementation within workflow execution [30]. Although authors provided KM-Service Selection algorithm, it does not address the question of annotating KM-Services with elements of the suggested semantic framework (e.g. origin or dynamic of knowledge) and other contextual factors (e.g. company's strategy). So the rule-based method of our PROTESYS methodology, which links KM services with different contextual factors (see Section III), may extend the work [11]. Additionally their work didn't differentiate business- and application KM services and is mostly about application level services.

Maier R. and his colleagues [12], [13] proposed a three-layered service infrastructure that composes services from heterogeneous applications into specific KM services. The infrastructure supports discovery, call, and provision of KM services from activities within business processes. It argues that integration of KM services in organizations requires alignment of the IT infrastructure, particularly its knowledge-oriented part, with the KM portion of business strategy, that is, KM strategy. This alignment can be achieved by introducing a service infrastructure that uses the concept of KM service. Current research of on this topic links KM services with knowledge maturing process [31] and knowledge maturing activities [32]. The authors of this approach differentiate business and application-level KM services (as we do), but their service selection mechanism is mostly based on the concept of knowledge maturing. Besides the approach of Maier and his colleagues is not explicitly aligned with current methodologies and languages for enterprise architecture management.

EA modeling for KMS implementation is also suggested in [16]. Although this research provides a case study, that demonstrates applicability of the approach, it does not provide any generalized reusable models.

There is also Semantic Web Framework for designing ontology-based applications (including semantic/knowledge portals) [33]. It is a component-based framework for analyzing rapidly the required components, the dependencies between them, and selecting existing solutions. Immediate uses of the Semantic Web Framework include the identification of the components needed for a Semantic Web application in the software design phase or the identification of existing implementations of components to be reused. The main difference of this Semantic Web Framework from the PROTESYS methodology is that it is for software developers, while PROTESYS methodology is intended for knowledge managers. This difference induces many internal differences.

V. Conclusion and future work

The paper described PROTESYS (PROject-TEchnology-SYStem) methodology for knowledge portal design, implementation and support. It merges service orientation, enterprise architecting and intelligent support for design of knowledge portals.

The idea of KM-services is to enable a clear description of KM tools, existing software and functionality of knowledge portal on a conceptual level that is independent of the underlying technology. Such a service-based view would facilitate the selection and composition of KM tools and application (software) components and stimulate reuse of proven patterns and solutions. Enterprise architectural approach is specifically relevant for KMS design that is actually a socio-technical system of systems, which integrates multiple business and information systems of the enterprise in order to improve knowledge processes efficiency. The selection of KM tools, methods and services for KMS / knowledge portal design is supported by the special intelligent (meta)service, which is based on the extensible rule base. This service integrates and formalizes good practices and expert knowledge about KMS/knowledge portal construction.

Future development of PROTESYS methodology includes the creation of reference model [34] for KM and extension of the rule-base for KM service selection. Reference model for KM will incorporate reference information both about the aforementioned KM tools, services and software (categories and typical modules), and also about reusable information resources [35], information and knowledge management processes, organizational roles and some other elements of comprehensive KMS (business and IT). Rule-base for KM service selection will be later extended using the literature survey and case study analysis. Empirical methodology justification and evaluation are also planned.

Acknowledgment

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References

[1] M. Alavi, D. Leidner, Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS quarterly*, 25(1), 2001. pp. 107-136.

[2] R. Mack, Y. Ravin, R. Byrd, "Knowledge portals and the emerging digital knowledge workplace". *IBM systems journal,* 40(4), 2001, pp. 925-955.

[3] J. Domingue, D. Fensel, J. Hendler eds. *Handbook of semantic web technologies.* Vol. 1. Springer Science & Business Media, 2011.

[4] C. Holsapple, ed. *Handbook on knowledge management 1: Knowledge matters. Vol. 1.* Springer Science & Business Media, 2013.

[5] T. Gavrilova, I. Leshcheva, "Building Collaborative Ontologies: A Human Factors Approach", Chapter in Book *"Collaborative*

Knowledge in Scientific Research Networks" (Eds. P. Diviacco, P. Fox, C. Pshenichny, A. Leadbetter), IGI publishing, USA. 2015. pp. 305-324.

[6] B. Hefly, W. Murphy, *Service Science, Management and Engineering Education for the 21st Century*. Springer, 2008.

[7] J. Spohrer, K. Stephen, "Service science, management, engineering, and design (SSMED): an emerging discipline", *Information Systems and New Applications in the Service Sector: Models and Methods: Models and Methods*, 2010. pp. 194–227.

[8] D. Koznov, A. Samochadin, A. Azarskov, and J. Chevzova, "Towards e-Government Services in Russia", in proc. of the *International Conference on Knowledge Management and Information Sharing (KMIS)*, Oct. 2011, pp. 294-301.

[9] M. Lankhorst et al., *Enterprise Architecture at Work: Modelling, Communication and Analysis* (The Enterprise Engineering Series). Springer, Third Edition. 2013.

[10] R. Woitsch, "Knowledge Management Services as a Basic Concept for Enterprise Knowledge Management System", *in proc. of I-Know*. Vol. 3. 2003.

[11] R. Woitsch, D. Karagiannis, "Process Oriented Knowledge Management: A Service Based Approach", *J. UCS*. 2005. 11 (4). pp. 565-588.

[12] R. Maier, U. Remus "Integrating knowledge management services: Strategy and infrastructure", *Knowledge Management and Business Strategies: Theoretical Frameworks and Empirical Research*, Hershey (PA, USA). 2007. pp. 209-229.

[13] R. Maier, T. Hädrich, R. Peinl, *Enterprise knowledge infrastructures*. Springer Science & Business Media, 2009.

[14] J. Ross, M. Mocker, I. Sebastian, Architect Your Business — Not Just IT! *MIT CISR Research briefing*, 2014.

[15] The Open Group, "ArchiMate® 2.1 Specification," 2013. Web: http://pubs.opengroup.org/architecture/archimate2-doc/.

[16] S. Lusa, D. Sensuse. "Enterprise architecture model for implementation knowledge management system (KMS)." *In Proc.ICT Convergence (ICTC)*, International Conference on. IEEE, 2011. pp. 208-212.

[17] R. Young (Editor) *Knowledge management tools and techniques manual*. Asian Productivity Organization. 2010.

[18] Archi website. The Free ArchiMate Modelling Tool. Accessed 20 October 2015, http://www.archimatetool.com.

[19] K. Sandkuhl, "Knowledge Reuse: Survey of Existing Techniques and Classification Approach", *Business Intelligence, Lecture Notes in Business Information Processing*, 2015, pp. 126-148.

[20] V. Pershukov et al. Experience from knowledge management system creation at the State Atomic Energy Corporation Rosatom, in *Rosatom is sharing knowledge*. HSE publishing house, 2012, pp. 61-122. (in Russian)

[21] Most Admired Knowledge Enterprises (MAKE) executive summaries. Web: http://www.knowledgebusiness.com/knowledgebusiness/templates/TextAndLinksList.aspx?siteId=1&menuItemId=133

[22] M. Berneaud, S. Buckl, A. Diaz-Fuentes, et. al. Berneaud, *Trends for Enterprise Architecture Management Tools Survey*. IBM report. 2012. May 16. 134 p.

[23] L. Grigoriev, D. Kudryavtsev, "Non-diagrammatic method and multi-representation tool for integrated enterprise architecture and business process engineering" *in Proc. of 15th IEEE Conference on Business Informatics (CBI 2013)*, 15–18 July, 2013. pp. 258–263.

[24] A. Abraham, *Rule-based expert systems. Handbook of measuring system design*. Wiley, 2005.

[25] J.C. Giarratano, *Expert Systems: Principles and Programming*. Brooks Cole, Pacific Grove, 1998.

[26] S. Barnes, N. Milton, *Designing a Successful KM Strategy-A Guide for the Knowledge Management Professional*. Information Today Incorporated. 2014.

[27] M. Zack, The role of decision support systems in an indeterminate world. *Decision Support Systems*, 43(4), 2007. pp. 1664-1674.

[28] P. Jorgensen, *Modeling Software Behavior: A Craftsman's Approach*. CRC Press, 2009.

[29] M. Hefke, A. Abecker, K. Jäger, "Portability of best practice cases for knowledge management introduction", *J. Univers. Knowl. Manag*, 1(3), 2006. pp. 235–254.

[30] R. Woitsch, D. Karagiannis, "Knowledge Engineering in Business Process Management", *in Handbook on Business Process Management 2*, Springer Berlin Heidelberg, 2015, pp. 623-648.

[31] R. Maier, A. Schmidt, "Explaining organizational knowledge creation with a knowledge maturing model", *Knowledge Management Research & Practice*, 13(4), 2015, pp. 361-381.

[32] A. Kaschig, R. Maier, A. Sandow, M. Lazoi, A. Schmidt, S. Barnes, A. Mazarakis, "Organizational learning from the perspective of knowledge maturing activities", *Learning Technologies, IEEE Transactions on*, 6(2), 2013, pp. 158-176.

[33] R. García-Castro et al., "Towards a component-based framework for developing Semantic Web applications", *The semantic web.* – Springer Berlin Heidelberg, 2008. pp. 197-211.

[34] P. Fettke, (Ed.). *Reference modeling for business systems analysis*. IGI Global. 2006.

[35] D. Kudryavtsev Systematization of ontological and non-ontological information resources for knowledge management system development, *in Proc. GSOM Emerging Markets Conference 2015*, Business and Government Perspectives, St.Petersburg, Russia, 2015, pp.213-222.