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Knowledge Management Models. State of the Art

Jan Andreasik
University of Information Technology and Management in Rzeszow, Poland

Abstract

In this article knowledge management models are classified into the following groups: 1. Resource models. 1.1. Holistic models. 1.2. Pyramidal models. 2.Process models. 2.1. Knowledge value chain models. 2.2. Branch models of organizational processes. 2.3. Spiral models. 3. Knowledge creation models. 4. Semantic models. As the summary the operationalization of knowledge management models is presented.

Keywords: knowledge management models, resource models, process models, knowledge creation models, semantic models, operationalization of knowledge management models

JEL: M15, O32

Introduction

The subject matter of knowledge management models is mentioned by Lee and Chen (2012) in the list of scientific papers devoted to knowledge management in the years 2001 to 2005 at position 13, and in the next years (i.e., 2006–2010) at position 3. Kor (2017) included in the main topics of analyzed publications: presentations of research results, IT systems, innovation issues, knowledge management processes and organizational learning. Among applied theories, the author listed the theory of company resources and the theory of knowledge creation according to Nonaka, Takeuchi. In Ramy's et al. literature review, the most frequently mentioned topics are listed: knowledge sharing process, intellectual capital, knowledge creation, knowledge transfer, knowledge management culture (Ramy et al. 2018). Wang et al. (2018) worked out the cluster of the most frequently mentioned concepts in the literature: knowledge management, knowledge sharing, innovations, knowledge transfer, organizational learning, knowledge, ontology, knowledge creation, knowledge management systems, learning, information systems, tacit knowledge, collaboration, information management, information technology, intellectual capital, knowledge acquisition, knowledge presentation (results), semantic web, communication practice, social capital.

It results from the above literature reviews that the current trend in knowledge management is to create semantic models with domain ontologies which are the basis for designing the Knowledge Based System (KBS) systems. In such systems, there are distinguished the following modules: knowledge acquisition in the collective system, knowledge creation using the SECI model (Nonaka and Takeuchi 2000), and a knowledge sharing module as a conversation module.

I classify knowledge management models into the following groups:

1. Resource models
   1.1. Holistic models
   1.2. Pyramidal models

E-mail addresses of the authors
Jan Andreasik: jandreasik@wsiz.rzeszow.pl

2. Process models
   2.1. Spiral models
   2.2. Branch models of organizational processes
   2.3. Knowledge value chain models
3. Knowledge creation models
4. Semantic models

1 Resource models

Resource models are of an integrative character of the whole environment that influences knowledge creation. Flaszewska (2016) presents the Leonard-Barton's resource model. In this model, the key competences of an enterprise are influenced by: collective problem solving, implementation and integration of new tools, experimenting to solve problems more quickly in the future, and effective importing of the knowledge from an environment.

1.1 Holistic models

The Global Knowledge Management Framework (GKMF) model designed by Pawłowski and Bick (2012) is an example of a holistic model. In this model, knowledge creation processes are influenced by: strategy of an organization (problems, resources), stakeholders (communities, organization, natural persons), infrastructure (technologies and machines, tools), and organization culture. Sztangret (2015, 2016) presents a holistic model of marketing knowledge management based on the example of the IT sector. The model has a tabular form. The author distinguishes four levels of knowledge management: Level I — a system of qualified/certified cooperation with partners, competitors and stakeholders, Level II — instructions and recommendations/communication and promotion, Level III — creation of synergistic/new knowledge bases with a qualified access, Level IV — Interprocessing the knowledge in an organization and its networks. In columns of the table, the following particular elements are distinguished: knowledge spiral, impact on the customer. Oztemel, Arslankaya and KorkuszPolat (2011) presented the Enterprise Knowledge Management Model (EKMM) with Strategic Enterprise Resource Management (SERM) included. Basic elements of this model are as follows: strategy (economic policy, risk management, strategic planning), the ERP systems, technology (information systems, research and development R&D, assessing the invention's technological readiness), relationships with customers, result management. Jashapara (2006) presents a holistic knowledge management model that includes the following elements: strategy (intellectual capital, organizational efficiency and effectiveness), systems and technologies, culture (change management, implementation), organizational learning (knowledge acquisition, knowledge exploitation, knowledge dissemination). Cahyaningsih et al. (2017) define a holistic knowledge management model in public administration. The NUSANTARA models consist of eight levels: vision and mission, key success factors, knowledge management processes, information systems for knowledge acquisition and sharing, knowledge management cycle, knowledge creation cycle, intellectual capital management structure of an organization, and public administration services. Krenz et al. (2014) designed an integrated knowledge management model implemented in the cluster of aviation enterprises. In the model called "Hamburg Model of Knowledge Management," they distinguished: influence sphere (actors, relationships between actors, sector/global environment), development sphere (culture, processes, structures), and action sphere (actions related to knowledge creation).

1.2 Pyramidal models

Pyramidal models cover knowledge generation in the cause-effect relationship, from data, through information, to knowledge, and next wisdom. One of the first models of this type was the DIKW (Data, Information, Knowledge, Wisdom) model designed by Ackoff (1989). Jashapara (2006) extends this relationship from wisdom to the truth and then to intentional action. Jennex and Bartczak (2013) extends the model, in terms of organizational learning, to the hierarchical structure: reality → signals from sensors → data → information → knowledge → intelligence. Zins (2007) presents a study of the definition of concepts covered by a pyramidal model. A study concerning

definitions of concepts of relation: data → information → knowledge → wisdom (in Polish) was elaborated by Stefanowicz (2013). Ermine (2018) presented a pyramidal model designed in the French Knowledge Management Club.[1] The model consists of five levels: data → information → knowledge (from tacit to explicit) → individual competences → team skills → value added. This model is called KMAV (KM Added Value) — i.e., the knowledge management model that create value added. In the model, 21 criteria related to transitions between particular levels are determined.

2 Process models

Process models are the biggest group of knowledge management models. Flaszewska (2016) compiles a number of process models developed from 1994 to 2012, distinguishing seven phases: Phase 1 (knowledge creation, acquisition and location); Phase 2 (knowledge development, exploration, acquisition and codification); Phase 3 (knowledge transfer, exchange and development); Phase 4 (knowledge provision, distribution, sharing); Phase 5 (knowledge dissemination and exploitation); Phase 6 (knowledge storage); Phase 7 (knowledge transfer). Makeshwarkar and Sohani (2014) listed 28 process models. Shongwe (2016) synthesized the names of knowledge management processes on the basis of literature analysis in terms of the frequency of occurrence of process names in models: knowledge transfer, knowledge application, knowledge storage, knowledge creation, knowledge acquisition, knowledge organization, knowledge identification, learning, and analysis.

2.1 Spiral models

Spiral models are captured in the form of a value chain, a linear sequence (phases, stages, subprocesses) and in the form of the so-called knowledge life cycle. Grudzewski and Hejduk (2004) presented four cycles of knowledge circulation in an intelligent organization: cognition cycle (assimilation, understanding, knowledge), innovation cycle (thinking, communication, knowledge), realization cycle (retaining, value and knowledge), adaptation cycle (learning, solving, knowledge). Evans, Dalkir and Bidian (2014) presents a knowledge management cycle with feedback from a learning stage to a creation stage, through stages: knowledge identification, retaining, sharing, application and learning. Zhao, de Pablos and Qi (2012) presented the wheel of knowledge management: knowledge acquisition, integration, storage, sharing, transfer, application, and innovation. Cordova, Duran and Galindo (2015) presented a knowledge management cycle model consisting of six elements (projects): conversation system, knowledge inventory (document base), transformation of tacit knowledge (discovered by experts), competence identification, document management, and social network usage (web portals). Shongwe (2016) analyzed 20 knowledge management cycle models. The most frequently distinguished processes were as follows: knowledge transfer, knowledge storage, knowledge application, knowledge creation, and knowledge acquisition. Torraco (2000) defined a knowledge management model with two cycles: the internal cycle (knowledge creation, learning, application) and the external cycle (a model of knowledge codification, methods and systems for knowledge management, a module of knowledge sharing, creation of knowledge management culture). Zawiła-Niedźwiecki (2014, 2015a, 2015b) designed a knowledge management model consisting of three spirals: spiral of perfecting the collection of knowledge (SPC), spiral of the perfecting of the formulation of knowledge (SPF), spiral of perfecting the utilization of knowledge (SPU). He defined 22 stages of knowledge management: 1. (SPU) needs, 2. (SPC) identification of needs, 3. (SPC) identifying the sources of needs, 4. (SPC) indicating the potential places of tacit knowledge, 5. (SPC) identification of beneficiaries of knowledge, 6. (SPC) identification of the form of transfer, codification, storage, verification, actualization, 7. (SPC) classification of knowledge, 8. (SPC) the organization of the obtaining of knowledge, 9. (SPF) designation of the form of transfer, codification, storage, verification, actualization, 10. (SPF) selection of the method and tools of search, 11. (SPF) descriptions of areas of knowledge, 12. (SPF) descriptions of issues in the framework of areas, 13. (SPF) descriptions of problems in the context of issues, 14. (SPF) formulating answers to questions in the framework of problems, 15. (SPF) atypical proceedings, 16. (SPF) archiving knowledge, 17. (SPU)

1. See: Club Gestion des Connaissances, [@:] http://www.club-gc.asso.fr/.

documentation of utilizing knowledge, 18. (SPU) training on the usage of knowledge, 19. (SPU) administration of tools of providing access to knowledge, 20. (SPU) administration of providing access to knowledge, 21. (SPC) audit of the adequacy of the content/form/method/tools, 22. (SPC) Audit of the organizational efficiency of knowledge management. The Zawiła-Niedźwiecki model is the operationalized model.

2.2 Branch models

Branch models set out pathways for knowledge creation. A model designed by Sopińska and Wachowiak (2006) is an example. In this model, two paths are distinguished: A: explicit knowledge acquisition → explicit knowledge processing → explicit knowledge sharing; B: tacit knowledge acquisition → tacit knowledge processing → tacit knowledge sharing. Paths A and B converge in the node: knowledge application (in decisions). Sopińska (2014) presented a knowledge and intellectual capital management model in the network organization. In this model, two paths from a node are distinguished: 1. Type of knowledge management strategy applied, 2. Description of the knowledge-sharing process, 3. Level of formalization and centralization of knowledge management. Path A: level of single link in the network. Path B: level of the whole network. Soniewicki (2017) presents a model consisting of one path, but with alternative branches in the node; knowledge application. A path of dynamic knowledge orientation: market orientation → system of activities in the range of organization knowledge → application of knowledge (new products or improvement of existing ones, new promotional activities or improvement of the existing ones, new distribution activities or improvement of the existing ones, new activities in other areas of the company operations or improvement of the existing ones) → short-term competitive advantage → loss of competitive advantage.

2.3 Knowledge chain models

Knowledge chain models are patterned on the Porter's value chain theory (Porter 1985). Holsapple and Singh (2001) presented a knowledge chain model, in which the basic actions are as follows: knowledge acquisition, knowledge selection, knowledge generation, knowledge internalization, and knowledge externalization. They list auxiliary actions: leadership, coordination, control and measurement of resources and contractors. A value chain is oriented to gaining a competitive advantage. Wang and Ahmed (2005) designed a value chain, in which the following knowledge management processes are distinguished: knowledge identification, knowledge acquisition, knowledge codification, knowledge storage, knowledge assessment, knowledge refinement, knowledge creation. They determined an environment enabling the organization of knowledge management processes: knowledge management system, knowledge management culture, organization memory system, and knowledge sharing. The value chain is oriented to new product development, flexibility of strategy, organization learning, and responsibility towards customers. Carlucci, Marr and Schiuma (2004) designed a value chain that starts with a knowledge creation process that is influenced by: physical enterprise infrastructure, virtual infrastructure, human resources, and relations with stakeholders. The next link in the chain is competence management, next is managing organizational processes of an enterprise. The value chain is oriented to improving the value of business results. Drewniak (2016) designed an integrated value chain model oriented to building strategic alliances. He integrated Porter's value chain with Wang and Ahmed's knowledge chain. Toszewska-Czerniej (2015) presented a value chain model in which there are distinguished: input (key service elements, key customers, strategic objectives), process (key human capital indicators), actions (effects of activities, reactions of service users, relations between results and activities), learning (what knowledge workers need to develop), output (what skills and knowledge should be improved, what observable results should be improved), and influence (what knowledge affects the services provided, how to change the culture of the organization).

3 Knowledge creation models

In all of the types of knowledge management models presented earlier, a key stage is the knowledge creation stage. One of the first models of knowledge creation required for making strategic decisions

was the model of adaptive decision-making developed by Boyd as the OODA (Observe, Orient, Decide, Act) model.[2] The OODA model covers the decision-making loop starting with observation and data acquisition, orientation, decision making and action. Orientation is based on the analysis and synthesis of cultural backgrounds, innate and inherited characteristics of decision-makers and experience. The decision is linked to determining a specific hypothesis. The action requires testing of alternatives. Florek and Barczak (2004) applied the OODA model in in modelling the decision-making process in the exploitation of technical facilities.

The most well-known knowledge creation model is the SECI model designed by Nonaka and Takeuchi (2000). The model consists of four processes constituting a spiral: externalization — transforming the tacit knowledge to the explicit (formal) knowledge, combination — aggregation of the codified knowledge, internalization — transferring the created knowledge to beneficiaries for the purpose of acquiring experience, socialization — collective relationships between beneficiaries as the learning process. The processes of the SECI model are included, partially or totally, in the process models of knowledge management.

The extended SECI model is presented by Wierzbicki (2007) as a concept of creative space. The model is a net consisting of nodes and transitions — similarly to a Petri net (Szpyrka 2008). Three types of superior nodes are defined: real heritage — analogy to Popper's third world (Popper 2002) — intuitive heritage, and emotional heritage. The second group of nodes is composed of: collective emotions, collective intuition, collective activity in the real environment. The third group of nodes is composed of nodes related to individual emotions, individual intuition and individual activity in the real environment. There are transitions between nodes of the first and second group: mythologization, abstraction, and learning. There are transitions between the second and third group of nodes: indoctrination, socialization and combination.

Nanatsudaki's model (seven spirals of knowledge) was designed in the Japan Advanced Institute of Science and Technology. The model includes a synthesis of the models developed by Wierzbicki and Nakamori (2007). The model consists of seven spirals. The OPEC (Objectives – Process – Expansion – Closure) spiral (i.e., the spiral of goal distribution). The EAIR (Enlightenment – Analysis – Immersion – Reflection) spiral (i.e., the spiral of hermeneutics). The SECI (the Nonaka and Takeuchi's model: Socialization – Externalization – Combination – Internalization) spiral. The DCCV (Divergence – Convergence – Crystallization – Verification) spiral — i.e., the spiral of brainstorming. The EDIS (Enlightenment – Debate – Immersion – Selection) spiral (i.e., the spiral of debate). The I5 (Intervention – Integration – Imagination – Involvement – Intelligence) spiral that is the system called a roadmap of knowledge construction: identification of knowledge required to solve the problem — understanding the situation through analysis of data and information and through simulations — involvement in the process of knowledge exchange — creation of new ideas — integration of knowledge. The I5 is explained in the knowledge construction theory (Nakamori, Wierzbicki, and Zhu 2011). The EEIS (Enlightenment – Experiment – Interpretation – Selection) spiral refers to the testing of ideas and hypotheses in experimental research.

Oinas-Kukkonen (2005) presented a knowledge creation model in the collective intelligence environment. The model consists of seven processes: comprehension — the process of interaction with the external environment, the purpose of which is to transform tacit knowledge into explicit knowledge through various experiments; communication – the process of sharing experiences among people in order to create tacit knowledge in the form of mental models (metaphors); conceptualization — the process of codifying tacit knowledge to the form of conceptions and the systematization of conceptions (algorithms, requirements, specifications, computer software); collaboration — the process of collective interaction and collective conceptualization; collective intelligence — the process of organizational culture aimed at collective creation of knowledge assets (know-how, patents, procedures, specifications).

Koźmiński (2004) presented a knowledge creation model in which there are distinguished the following stages: the stage of knowledge development, where the most important problems of the company are diagnosed. The second stage is to create relational knowledge based on associations.

2. See: Slide 5 of the presentation "The Essence of Winning and Losing", 28 June 1995, by John R. Boyd [@:] https://www.danford.net/boyd/essence4.htm.

The third step is to identify situational knowledge based on "weak signals" from the company environment and interior. A crucial stage is the stage of associating relational and situational knowledge in the creative process. The next stage is the stage of synthesis of intellectual creation. After this stage, there is a stage of experimentation in which computer simulation methods can be used. The final stage is to update the state of technical, economic, legal and social knowledge.

Hejduk and Tomczyk (2015) presented a knowledge creation model in the field of occupational safety. The OSH standards and the base of events deliver the explicit knowledge. The tacit knowledge is related to: observing the OSH instructions, ability to observe dangerous situations, experience at the workplace, intuition and professionalism, chance to avoid risk. The explicit and tacit knowledge affects the attitude of employees to safety at the workplace, which translates into the level of OSH culture and occupational safety.

To identify situational knowledge the KAMET II method can be used (Cairo and Guardati 2012). The method includes the CML (Conceptual Modeling Language) language, in which there are distinguished: elements of the structure of the situation (problem, classification rules, act of division), components of the structure of the situation (symptom, predecessor, solution, time, value, inaccuracy, process, formula, exam), composition relations: division relation, conclusion relation, action relation, merger relation. All elements of the CML language have their own graphical symbols, by means of which it is possible to reproduce a situation in which tacit knowledge is acquired.

4 Semantic models

Semantic knowledge management models are connected with an architecture of the KBS (Knowledge Based System) systems (Akerkar and Sajja 2010). In this class of systems, knowledge bases, rested on ontologies (Staab and Studer 2009) written in the Ontology Web Language (OWL) language (Goczyła 2011), are defined. There can be distinguished two groups of systems, in which knowledge is codified by means of ontologies: the Knowledge Based Decision Support System (KB DSS) systems (Zaraté and Liu 2016) and the Knowledge Based Recommender System (KB RS) systems (Burke 2001). These systems have either graphical interfaces facilitating the insertion of knowledge in a codified form or mechanisms for the analysis of texts from text bases or Internet-based knowledge repositories (e.g., Wikipedia). The KnowBest (Di Iorio and Rossi 2018) platform is an example of the KB RS system using the knowledge conversion cycle according to the SECI model. The platform is oriented to recommendation of teaching materials from the WikiRecPley portal for students using e-learning courses. Another group of the KB DSS systems consists of systems, in which ontologies are created automatically on the basis of structures on distributed data bases. These systems allow creating complex queries in the SPARQL language to search for objects with a specific set of features (attributes).

4.1 Design of a system for semantic analysis of NHF databases

From 16 July 2009 to 31 March 2010, I designed, together with a team of IT workers (Sławomir Umpirowicz and Andrzej Ciebiera), the ControlSem system in a pilot version for the National Health Fund in Rzeszów. I developed the system architecture consisting of TopBraid Composer[3], the D2RQ converter (to RDFS) and relational data bases. The Top Braid Composer tool includes the ontology editor in the OWL language allowing automatic insertion of an ontology from the distributed data base structure, the international drug names data base, the ICD 9 (International Classification of Medical Procedures) dictionary, the ICD 10 (International Statistical Classification of Diseases and Related Health Problems) dictionary. The ControlSem system allows generation of the new knowledge related to analyses of cases of non-compliance with the NHF medical procedures. The query templates in the SPARQL language, for particular drugs (Clopidogrel, Tramadol), containing procedural conditions for the use of drugs for specific classes of patients, were constructed. The system generates the knowledge about cases of non-compliance in prescribing drugs by doctors of specific health care institutions. I presented two papers at two international conferences (Andreasik, Ciebiera, and Umpirowicz 2010, 2011).

3. See: https://www.topquadrant.com/.

Operationalization of knowledge management models

The key problem in application of knowledge management models in specific enterprises is a lack of their sufficient operationalization. Nowadays, there are published papers in which the authors present ways of operationalization of certain models. They can be divided into two groups: operationalization of knowledge management models without domain orientation and with domain orientation. In the first group, I distinguish the following operationalized models:

The Zawiła-Niedźwiecki model (Zawiła-Niedźwiecki 2015b). It covers four layers and formal approaches in in sustainable knowledge management: organizational layer (strategy, structure, audit), operational layer (knowledge disclosure and management), content layer (areas of knowledge), intellect layer (human relations and interpretation of content). In the model, the author presented operationalization of knowledge resources by defining the framework of knowledge resources in the organization and by defining the key for separation of knowledge management areas. Maps of knowledge resources and requirements in specific areas and ranges of knowledge have been provided. The indicators of effectiveness of knowledge management have been defined.

The Ermine model (Ermine 2018). It is based on the author's model of the knowledge value chain, in which the main chain consists of: data, information, knowledge creation process (tacit knowledge ← → explicit knowledge), competences, abilities. Auxiliary processes include: data management, information management, management of knowledge creation processes, competence management, ability management. The author defined the AIK model (A — the network of actors or knowledge community, I — information subsystem, K — knowledge capital). The mathematical model (Ermine 2005) based on the system theory was defined. The following operators were distinguished: the Wenger's operator (Rozkosz 2017) that is the operator of group learning in the actor community; the socialization process operator and the combination process operator (according to the SECI model). On the basis of the textbook of French Knowledge Management Club, the author presented the knowledge management plan with the analysis process of knowledge capital by means of the mind map. He gave a description of the implementation of the knowledge management plan, in which he defined the scope of the so-called knowledge books used to codify knowledge (e.g., phenomena, activities, history of activity, concepts, tasks, lines of evolution of objects or concepts).

The Arduin-Rosenthal-Sabroux-Grundstein model (Arduin, Rosenthal-Sabroux, and Grundstein 2014). The authors presented the concept scheme specifying terminology of tacit knowledge covered by the ISO/IEC 15504 standard. They introduced arguments and certificates for each level of tacit knowledge (level 0: incomplete knowledge, level 1: presented knowledge, level 2: knowledge to be introduced, level 3: precise knowledge, level 4: predicted knowledge, level 5: optimized knowledge).

The Rao-Nayak model (Rao and Nayak 2017). The authors introduced transactions defined in Dietz's enterprise ontology to operationalization of the externalization process of the SECI model. Eight transaction were defined: T1: case formulation, T2: case implementation, T3: case indexation, T4: tacit knowledge extraction, T5: knowledge synthesis, T6: knowledge evaluation, T7: case acceptance, T8: knowledge sharing. Transactions includes typical communication process schemes between actors of knowledge management systems with the knowledge base (Case Based Reasoning — CBR): requestor, expert, acceptor, solver, end user, reviewer.

The Wong-Tan-Lee-Wong model (Wong et al. 2015). The authors defined, on the basis of indicators of intellectual capital assessment, lists of indicators for processes in the process knowledge management model: knowledge extraction process, internalization process, knowledge creation process, knowledge management system implementation process, codification and evaluation process, knowledge transfer and sharing process.

In the literature, there is a series of descriptions of operationalized knowledge management models which are domain oriented. I can give here three examples. The first example concerns knowledge management for forecasting the time of the production cycle in the aviation industry (Quintana-Amate et al. 2017). The second example concerns the process of codification of tacit knowledge for the service department in a production enterprise (Dudek 2017). The third model was developed by SIEMENS.[4] The aim of knowledge management is to increase the value of stakeholders.

4. See: SEIMENS knowledge management portal at http://www.kmbestpractices.com/siemens.html.

The model is based on Young's manual ("Knowledge Management Tools..." 2010). It assigns knowledge management methods and tools to five processes: knowledge identification, knowledge creation, knowledge retaining, knowledge sharing, knowledge application.

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