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Operationalization SECI Model of Knowledge Management by Enterprise Ontology

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Abstract

The paper contains the proposition of solving the problem of operationalization of the SECI model of knowledge creation in a new scope — i.e., in relation to knowledge about managing an SME enterprise in conditions of uncertainty. This knowledge includes the assessment of the enterprise in the potential — risk space of operational activity. This problem was solved theoretically by developing the original A–E–AE enterprise ontology and practically by constructing the SOK-P1 system, which was used in the advisory practice for SME sector enterprises in the Lubelskie and Podkarpackie Voivodships.

Keywords: operationalization of the SECI model, A-E-AE enterprise ontology, CBR system, semantic knowledge management model

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Introduction

On the basis of the analysis of knowledge management models and my own practical experience resulting from the implementation of the several projects, I proposed the postulate of the need to develop a model taking into account the SECI knowledge creation cycle by the enterprise ontology focused on assessing the ability of small enterprises to continue as a going concern.

Postulate 1

The knowledge creation model SECI can be operationalized by introduction of the enterprise ontology to create a mechanism for creating new knowledge about an enterprise.

In the cycle of publications, I showed particular stages of creation of a semantical knowledge management model and its concretization by means of the KB DSS system called SOK-P1, developed and implemented in the consulting practice in the e-barometr portal (Łoboda et al. 2008).

The main issue of my analysis is the area of ontology, with particular emphasis on the design of domain ontologies. Links between philosophically developed ontologies and applied ontologies used in systems with knowledge base systems were reported by Garbacz and Trypuz (2012). The scope of ontology as a philosophy of being includes: being, not being, nothing, everything, things, ways of things, substance, accidents, principles of human cognition (Stróżewski 2006). Jashapara (2014) gives a series of definitions of knowledge which originate from philosophical trends from Platon to Polanyi who introduced the concept of tacit knowledge. Blackman and Henderson (2017) analyzed three philosophical schools in terms of knowledge management: the Earl's school (capturing and processing knowledge that is available to specialists), the Popper's school (knowledge organized in three worlds: physical, experimental, objective knowledge independent of the knower),

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the Heidegger's school (knowledge as a series of interpretations of different persons with different emotional behaviors). Jashapara defines knowledge management as "an effective learning process related to the searching, application and dissemination of knowledge (explicit and tacit), using appropriate technologies and a cultural environment, aimed at increasing intellectual capital and organizational efficiency." In relation to this definition, the subject of my analyses was to search for a model for enterprise knowledge presentation allowing its codification in order to be entered in a language recognized by the computers. Ontology in information systems is defined in terms of the structural aspect (for designing data bases, business logic, user interfaces). Ontology is a formal specification of a shared conceptualization. According to Garbacz and Trypuz: "The basic role of applied ontology is to separate the knowledge processed by the system from the methods (algorithms) of this processing and to represent such separated knowledge in a way that is understandable for both the computer and its user."

The enterprise ontology, from the philosophical point of view, was defined by Bocheński (1993) and Adamczyk (2003). Bocheński defines an enterprise as a system consisting of internal elements (capital, labor, invention) and external elements (clients, region, state). Adamczyk determines the enterprise ontology from the sociological point of view: "An enterprise is a functionally dependent subsystem consisting of two kinds of elements: material objects which exist in real-life and conceptual objects which are the products of the human mind, hereinafter referred to as culture, and the various interactions which take place between them, which are relatively stable." Adamczyk defines the categories: form (structure, thing, process, relation, influences, features, change, phenomenon, sets, synergistic effect), material content of an enterprise (background, people, division of labor), indigenous content (culture, conceptual objects), moment of structural change (change, occurrence, survival, improvement), cohesiveness, functionality, essence of an enterprise, values.

In the paper "Ontologiczne podstawy oceny przedsiębiorstwa" (Andreasik 2007; reprinted in: Andreasik 2013, 45–53), I presented my own conception of the enterprise ontology in which, starting from the Bergson's scheme of object recognition (Bergson 2006), I listed the following categories of the ontology:

A. Assessment spaces: potential space, risk space.

B. A set of potential types defined in the potential space: capital potential, stakeholder potential, innovation potential, relational potential — environment, relational potential — neighborhood, process potential.

C. A set of risk consequence types defined in the risk space: risk consequences in capital acquisition, risk consequences from stakeholders, risk consequences in realization of innovation and investment projects, environment risk consequences, macroeconomic neighborhood risk consequences, risk consequences in realization of processes.

To codify the tacit knowledge, the formal model must be determined (in terms of set theory) that can be used for algorithmization. Such a model, based on the Ingarden's formal ontology, is presented by Krzyżanowski (1999). An object, that is defined by a state of thing, is in this model. The state of thing is defined by Krzyżanowski as follows:

"By the state ST of any object P at the moment "t" we mean the set of certain investigated features to which the object is entitled at this moment, $C_b, ST(P)_t = \{C_b(P,t)\}$."

In my approach to creation of the enterprise ontology, I assumed, according to the Ingarden's ontology, two states of the object: "positive state" and "negative state" (Ingarden 1987). The positive state is a characteristic of the enterprise potential, and a negative state is a characteristic of the risk of the enterprise activity. Features in "states of things" are assessments of the enterprise potential and assessments of influence of risk on the enterprise activity which are made by experts.

On the basis of analysis of different philosophical approaches, I proposed the following postulate:

Postulate 2

The knowledge about an enterprise can be codified on the basis of a formal model created with the use of the concept of an individual subject according to Ingarden (partly redefined by Krzyżanowski) and the definition of an enterprise according to Bocheński.

The goals of the monothematic publication cycle comes from two postulates presented earlier. I formulate the goals as follows:

- Designing a semantical knowledge management model including procedures of automatic knowledge creation on the basis of information provided by experts.
- Defining the new enterprise ontology on the basis of the domain knowledge model concerning an ability of small enterprises to continue as a going concern. A function of the ontology is to cover knowledge in the codified form according to modern standards of ontology recording in the Ontology Web Language (OWL).
- Presentation of the semantical knowledge management model in the operationalized form—i.e., the form including algorithms of data and information processing as well as generation of new knowledge.
- Designing the system consistent with the Case Based Reasoning (CBR) methodology allowing indexation of cases to retain them in the base and to search for similar cases. Such a system will be used in the process of knowledge distribution to beneficiaries.
- Conducting research by experts in the SME sector enterprises in order to capture knowledge about the state of potential and risk of operational activity. The obtained information will be put to the designed system to determine parameters of the sorting system (according to multicriteria decision making methods). The goal of research is to determine a position of an enterprise in the potential-risk space for new enterprises for which expert advice will be prepared.

1 Characteristics of research methods

According to research methodology in management sciences, I adopted multicriteria decision analysis methods (Wachowicz 2016): EUCLID, ELECTRE TRI, AHP, which I used in creation of the semantic knowledge management model oriented to capturing domain knowledge in the range of assessment of the SME sector enterprises. The EUCLID method was designed by Tavana (2002). This method allows sorting decision options into four classes. The method is similar to the TOPSIS method (Kobryń 2014, 167)—similarity to ideal solution. TOPSIS is a method for creation synthetic assessment that consists in determining the distance of each variant from the pattern (ideal variant) and from the anti-pattern (anti-ideal variant). The ideal variant is defined on the basis of the values which are the best ones in the whole set of values available under each criterion. On the other hand, the anti-ideal variant is defined on the basis of the worst values. The criteria may be of the stimulant and destimulant character. To aggregate the assessments I used the ELECTRE TRI method. In order to set up a sorting model, I developed a research programme to evaluate small enterprises in the SME sector by expert groups.

For the purposes of the research carried out under the project "System przeciwdziałania powstawaniu bezrobocia na obszarach słabo zurbanizowanych" (System of counteracting the occurrence of unemployment in poorly urbanized areas), data on small, unidentifiable enterprises (employing up to 50 people) from the Lubelskie Voivodship (3 926 enterprises) and the Podkarpackie Voivodship (3 638 enterprises) were purchased from statistical offices. Enterprises in the period 1999–2004 reported in two consecutive years and they were not in liquidation or bankruptcy at that time. These data were used in many researches, including determining the variability of employment. The coefficient of employment variation was used to calculate a sample size of small enterprises, which were then drawn for detailed interviews.

The calculation of the sample size was based on a simple random sampling scheme without replacement which ensured for large populations that the average value of the examined feature (employment) has distribution close to normal distribution, which in turn allowed using the following formula:

$$n^* = \frac{N k_{1-\alpha/2}^2 V^2}{N\delta^2 + k_{1-\alpha/2} V^2}, \tag{1}$$

where:
$n = \lfloor n^* + 1 \rfloor$ — the sample size,
δ — the relative estimation error,
V — the coefficient of employment variation,
N — the population size,
$k_{0,95} = 1{,}645$ for $\alpha = 0{,}1$ (Bracha 1998, 53).

In 2005, in the REGON data base in Lubelskie Voivodship, 126 600 small enterprises were registered. According to 10% assumed, 115 enterprises should have been drawn. In the Podkarpackie Voivodship, from 116000 small enterprises, 105 enterprises should have been drawn. However, a significant number of refusals of participation by enterprises in surveys were expected. That is why it was assumed that there would be a need to draw 500 enterprises in each of the voivodships. The drawing was commissioned from statistical offices in Lublin and Rzeszów, which applied a systematic sampling scheme (every 250th enterprise in the Lubelskie Voivodship and every 230th enterprise in the Podkarpackie Voivodship). In this way, the following data about enterprises were obtained: REGON number, legal form (basic and special), form of ownership, date of establishment, name, address of registered office (contact details), employment ranges.

Companies were approached in the order of the statistical offices, and if a company refused to respond, it was replaced by another one on the list. The AHP method (Prusak and Stefanów 2014) was used to assess potential in the particular ranges and to estimate weights. It is a method of comparing in pairs variants according to criteria, which are arranged in a hierarchical order.

I designed the original enterprise ontology on the basis of theories: the Ingarden's formal ontology (Ingarden 1987), the Bocheński's enterprise philosophy (Bocheński 1993), and the Krzyżanowski's organization ontology (Krzyżanowski 1999). Selection of these theories was preceded by the analysis of various concepts on which the constructions of the enterprise ontology were based, which I described earlier.

2 Characteristics of operationalization SECI model of knowledge management by enterprise ontology

Process of operationalization SECI model of knowledge management is presented in following publications.

Publication 1

Andreasik, J. 2019. "Knowledge Management Model Based on the Enterprise Ontology for the KB DSS System of Enterprise Situation Assessment in the SME Sector." *Advances in Artificial Intelligence, Software and Systems Engineering* 787: 146–156. doi: 10.1007/978-3-319-94229-2_15.

In the paper, I presented a structure of the semantic knowledge management model for assessment of enterprises in the SME (small and medium sized enterprises) sector. This model is shown in figure 1. The model consists of four layers. Layer 1 includes four modules realizing the SECI model processes:

A1. The module of interpretation of data obtained on the basis of enterprise documents and assessment estimation in distinguished ranges of potential and assessment estimation in distinguished ranges of risk.
A2. The module including the classification system procedure.
A3. The module of assignment of characteristic patterns of results according to the Argenti's conception.
A4. The module of making the knowledge generated in modules A2 and A3 available.

The modules in Layer 1 refer to elements of the SECI model — i.e., module A1 refers to the externalization process (extraction of tacit knowledge and its codification), module A2 refers to the combination process (transformation of codified knowledge into aggregated knowledge in the form rules indicating assessment of an enterprise position in the potential-risk space), module A3 refers

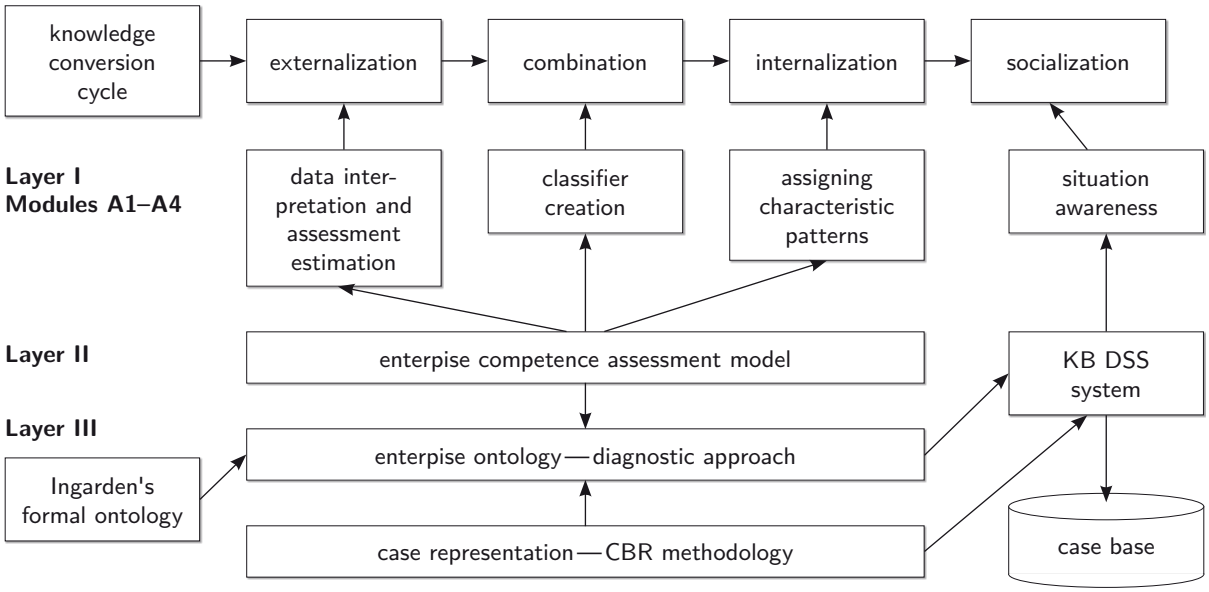

Fig. 1. The semantic knowledge management model for assessment of the SME sector enterprises

to the internalization process — i.e., to assignment of a characteristic pattern of enterprise results in order to evoke at recipients a proper reaction to transferred knowledge about an enterprise situation, module A4 refers to the socialization process, i.e., transferring knowledge in the specific form on the Web portal to initiate discussion and to transfer opinions between authorized persons.

Module A1 of data interpretation and assessment estimation constitutes an interface of the designed SOK-P1 system, which is based on the enterprise competence assessment model defined in Layer II. This model is based on the Hamel-Prahalad's core competence theory (Prahalad and Hamel 1990). In the conception of enterprise assessment assumed by me, the core competences are: maintenance and development of the enterprise potential and awareness of the impact of risk on the business. "The enterprise potential is a multidimensional category and concerns specific possibilities, determined in various ways, built on special capacities, abilities contained in possessed resources, as well as in skillful use of environment resources" according to Lichtarski (2001). The risk is understood as an operational risk. The definition of an operational risk is given by Zawiła-Niedźwiecki (2013): "An operational risk is the risk of material and reputational damages and legal liability resulting from inadequate or failed processes and resources necessary for them (personal, material, informational and financial), and arising from disturbances caused by internal and external threats." He defined the following operational risks: risk of natural disasters, risk of terrorism, risk of external disruption of the functional working environment, risk of internal disruption of the functional working environment, risk of disruption of the physical working environment, risk of disruption of the technical working environment, risk of disruption of the computer working environment, risk of lack of competence, risk of lack of personal reserves, risk of staff turnover, risk of relativism of interpretation, risk of bad will of the employee, routine risk, risk of lack of functionality, risk of lack of material reserves, risk of side effects, risk of wear and tear, risk of misuse of funds, risk of exhaustion of funds, risk of lack of full content of information, risk of information lagging behind the development, risk of information unavailability, risk of information distortion, risk of incident (failure), risk of lack of organizational potential, risk of primacy of safety over effectiveness. All types of risk are taken into consideration, in assessment of activity risk of an enterprise, by experts who assess influence of risk on enterprise activity in particular ranges defined in the ontology presented further.

Module A2 is the module of assessment aggregation and determining a sorting system for four classes: threat class (low potential, high risk), high risk warning class, good condition class (high potential, low risk), low risk warning class. I selected the Euclid method designed by Tavana (2002) from among multicriteria decision making methods. I designed algorithms for determining

parameters of the sorting system in five spaces: capital potential — financial risk, innovation/investment potential — investment risk, stakeholder potential — stakeholder cost risk, relation potential (neighborhood) — relation risk (neighborhood), relation potential (environment) — relation risk (environment). Module A2 realizes the internalization process of the SECI model — i.e., transformation of codified expert knowledge in the explicit form (numerical grades from the interval (0, 1)) and assessment weights (numerical values from the interval (0, 1)) into parameters of the sorting system. As a result of the project realized under the EQUAL programme, I collected expert assessments for a representative sample of the SME sector enterprises from the Lubelskie and Podkarpackie Voivodeships. These assessments have been aggregated into a set of parameters of the sorting system according to the algorithms presented in the next articles.

Module A3 compiles time series of enterprise results (sales revenues, operating profit EBITDA, net profit). These results are characterized by typical result trajectories defined by Argenti (1976) and Richardson (Richardson, Nwankwo, and Richardson 1994). These typical trajectories are characteristic patterns for enterprises both in their development and in their bankruptcy phases. In the literature four patterns defined by metaphors related to behavior of frogs were characterized: boiled frog, bullfrog, drowned frog, and tadpole. Assigning one of these patterns to a particular enterprise is an act of clarifying the situation in terms of forecasting. In this way, the process of internalization of the SECI model is realized, which is connected with the transfer of explicit knowledge to tacit knowledge. The concept of the Argenti's patterns provides metaphorical images into the enterprise performance and position assessment in the space: potential — risk, for managers and owners, in order to change the strategy.

Module A4 constitutes the KB DSS (Knowledge Based Decision Support System) system — an decision support system with the knowledge base, which is based on the CBR (Case Base Reasoning) methodology. In my papers, there is defined only one element of the CBR cycle. It is the element connected with definition and indexation of cases. The remaining elements of the CBR cycle are realized using available software: myCBR (German Research Center for Artificial Intelligence)[1], jCOLIBRI 2 (developed in Facultad de Informática, Universidad Complutense Madrid)[2]. In the CBR cycle, the socialization process takes place that involves gaining experience in assessing the enterprise situation on the basis of an analysis of similar cases from a set of cases submitted from the system by means of automatic reasoning from the case database and defined similarity measures.

In Layer 3, I defined the original enterprise ontology, which includes the concept apparatus of potential and risk, as well as those concepts which are used in the procedures of aggregation of assessments and generation of rules for determining the position of an enterprise and the patterns of results.

In the paper, I also presented an evaluation of the presented knowledge management model in terms of the requirements for knowledge management models. These requirements were formulated by Ale, Toledo, Chiotti and Galli (2014). The requirements apply to the SECI model and the process model: a knowledge management model should be convergent with the strategy of the organization, knowledge should be the strategic asset of the organization, a model should include the process knowledge management in the organization, a model should include three categories of the knowledge management cycle: knowledge creation, knowledge communication, knowledge representation and review, a model should include the process of knowledge distribution in the organization (including creation of the knowledge repository), a model should take into consideration the social aspect (tacit knowledge transfer) and the technological aspect (declarative and procedural knowledge), a model should take into consideration the changes in the culture of the organization (using information systems). In the next publications, I determine ways to satisfy these requirements.

1. See: https://www.dfki.de/en/web/.
2. See: https://informatica.ucm.es/.

Publication 2

Andreasik, J. 2009. "The Knowledge Generation about an Enterprise in the KBS-AE (Knowledge-Based System — Acts of Explanation)." *New Challenges in Computational Collective Intelligence* 244: 85–94.

In the publication, I presented the general system of data, information and knowledge flow as the system Agent – Expert – the CBR (Case Based Reasoning) system (Watson 2003). In this system, the concept "agent" means all data recording systems operating in an enterprise, such as the systems of the ERP (Enterprise Resource Planning) class, the CRM (Customer Relationship Management) systems, the HR (Human Resources) systems, accounting software, the BPM (Business Process Modelling) systems, the WWW portals with document bases, the BSC strategic planning systems, the PM (Project Management) systems, help-desk applications (Tyndale 2002), etc. From these systems, the experts, using the query languages (SQL) or reporting interfaces, obtain data for the argumentation of assessments of particular types and kinds of enterprise activity potential and risk, respectively. Data are aggregated in appropriate argumentation protocols for potential assessments and for risk assessments. The second element of the information flow system are experts who perform evaluations on the basis of argumentation protocols and interviews with managers and owners of an enterprise. The third element is the CBR system, which gathers cases consisting of expert assessments and trajectory patterns of results (e.g., sales value in individual years). In subsequent publications, I present the model of aggregation of expert assessments. In this publication, I presented a diagram of communication (in UML) of the creation of a case database for the CBR system. I also presented a diagram of classes defining the data structure of the designed IT system SOK-P1.

Publication 3

Andreasik, J. 2009. "Decision Support System for Assessment of Enterprise Competence." In *Computer Recognition Systems 3*, edited by M. Kurzynski and M. Wozniak, 559–567. Berlin, Heidelberg: Springer Berlin Heidelberg.

In the publication, I defined the sorting system as the DSS (Decision Support System) system. The task of the DSS system is to calculate indexes for determining an enterprise position in the potential-risk space. Each enterprise is characterized by a pair of aggregated assessments of potential A(P) and risk A(R) in five spaces defined in the ontology. I distinguish the hierarchical system of potential (level I: potential types, level II: potential kinds, level III: potential ranges). Similarly, I distinguish the hierarchical system of threats (optionally risk) (level I: risk types, level II: risk kinds, level III: risk ranges). The experts make assessment of gains from potential in the specific range, kind, and type: $c(R^P_{ijk})$. The experts make assessment of risk in the specific range, kind, and type: $c(R^R_{ijk})$. Grades are numbers from the interval (0, 1). After analysis of different assessment scales, I assumed the following values of linguistic grades: impossible (potential, risk) — 0,00, small possibility (potential, risk) — 0,10, small chance of occurrence (potential, risk) — 0,20, doubtful (potential, risk) — 0,3, uncertain (potential, risk) — 0,4, possible (potential, risk) — 0,5, almost promising (potential, risk) — 0,6, promising (potential, risk) — 0,7, very promising (potential, risk) — 0,8, almost certain (potential, risk) — 0,90, certain (potential, risk) — 1,00.[3]

In the publication, I presented the procedure for determining borders of four classes of the sorting system: the average value $\Delta c(R^P_{ijk})$ and the average values $\Delta c(R^R_{ijk})$. The values of these parameters are determined experimentally on the basis of recorded grades of 220 SME sector enterprises from the Podkarpackie and Lubelskie voivodships. These parameters separate the system of potential assessment and risk assessment into four sorting classes:

I. Threat class (low potential, high risk)
II. High risk warning class
III. Good economic condition class (high potential, low risk)
IV. Low risk warning class

3. [In the journal European practice of number notation is followed — for example, 36 333,33 (European style) = 36 333.33 (Canadian style) = 36,333.33 (US and British style). — Ed.]

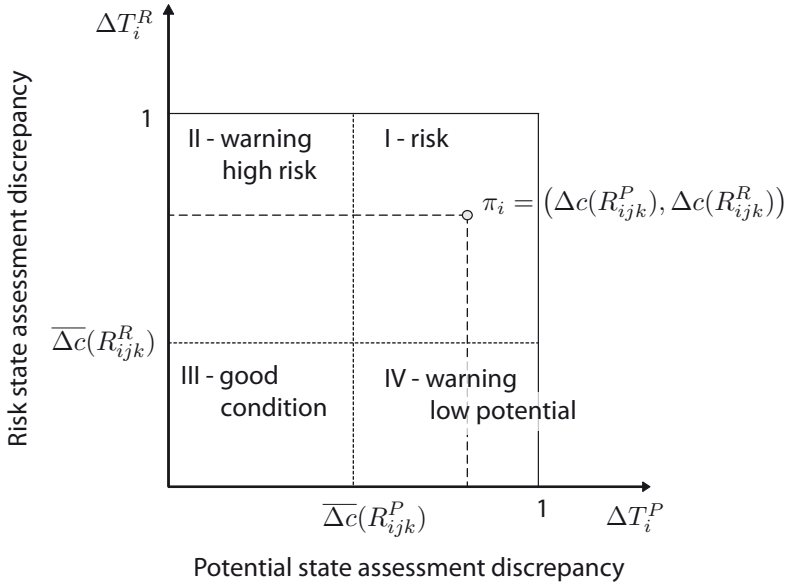

Fig. 2. The sorting system determined according to the EUCLID method

In the procedure, I used the EUCLID method designed by Tavana (2002). In the paper „Analiza decyzji strategicznych z uwzględnieniem ryzyka" (Andreasik 2003; reprinted in: Andreasik 2013, 179–191), I presented a case study for the EUCLID method concerning sorting of investment projects.

Due to the fact that there are five assessment systems, I introduced, into the procedure, an algorithm for determining one parameter to identify the position of the assessed enterprise, This parameter is the slope angle Θ of the radius vector of the point $(c(R_{ijk}^P), c(R_{ijk}^R))$. I used the sorting method, ELECTRE TRI (Mousseau, Slowinski, and Zielniewicz 2000), to create aggregation of the parameter Θ. In the method, values of profiles separating particular classes and thresholds (indiscernibility, preference, and veto) are defined. In agreement with the experts, I introduced the appropriate values of these parameters into the SOK-P1 indexing system. This system was developed under the EQUAL project no. F0086 of which the leader was the University of Management and Administration in Zamość. The effect of the procedure realization presented in this publication is the report concerning determination of the appropriate class (potential-risk) for a specific enterprise. An interface displaying indexation results are described in the next publication.

Publication 4

Andreasik, J. 2008. "Ocena strategii kompetencyjności firmy sektora MŚP w systemie SOK-P1." *Barometr Regionalny. Analizy i prognozy* 4 (14): 33–45; reprinted in: Andreasik, J. 2013. *Synteza informacji o przedsiębiorstwie. Podejście ontologiczne.* 111–123. Zamość: Wyższa Szkoła Zarządzania i Administracji; Centrum Informacji Europejskiej "Europe Direct."

In the publication, I presented the interfaces of the SOK-P1 system to input and output knowledge from experts estimating potential and risk assessments and to output knowledge about the enterprise position in potential-risk space. In the introduction, I give the definitions of an enterprise competence according to Bartnicki, Harzallah, Berio and Vernadat, who designed the CRAI model, Pepiot, who, together with the team, designed the Unified Enterprise Competence Modelling Language (UECML) language. This language was extended by Cheikhrouhou, Tawil and Choudhary (2013) to organizational competences as well as virtual organization competences. The UEMCL language, in the extended version, defines the enterprise competence system which consists of: virtual organization competences, organization competences, collective competences, individual competences, unit competences. An organization competence C(A) is defined as the organization ability to link, in an effective way, intangible resources (knowledge, know-how, attitudes) as well as material resources (equipment, machines, computer systems, etc.) in order to respond to the

needs of a specific activity (process). The ontology of organization competences was defined by Khilwani, Harding and Tiwari (2011). They determined enterprise competences as capacities and abilities to carry out certain types of tasks based on knowledge and experience in applying one's own methods and resources. Wieczorek-Szymańska (2011) defines an organization competence system through the competence model at the organizational level and through the competence profiles of the workstations. Nogalski and Niewiadomski (2016) gave the following definition of competence potential: "The competence potential is the bundle of human resources, processes and capabilities that underlie organizational flexibility, provide access to important markets, new implementations, make a significant contribution to customers' perception of cost-cutting values, and create and manage a strategic architecture." Siwak (2015) defines key organization competences as an element of intangible resources, which create the strategic potential of an enterprise, defining the scope of permissible strategic plans. The key organization competences include: owner management competencies, employee competencies, organizational knowledge and memory, competences to use the resources of other companies, competencies in products and technologies, competencies in building customer relationships, social competences and ethics, codified specialist knowledge owned by a company, competencies to simultaneously compete and cooperate with partners. Coulet (2019) presents an enterprise management model based on competences: resources (internal and external), competences (abilities, management processes, strategy logic), results (competitive advantage).

In the publication, I present my own procedure for assessment enterprise competences in a given potential range. This procedure includes the following system of criteria for competence assessment:

- criterion 1: available resources (own resources available, own resources partly available, external resources available, external resources not easily available)
- criterion 2: staff resource qualifications (basic qualifications, certified specialized qualifications, unique qualifications)
- criterion 3: skills (attitude, teamwork, cooperation skills, creativity, responsibility, decision making, engagement, search for solutions, communication skills)
- criterion 4: experience (presence of successes, seniority, recommendations, rewards and distinctions)
- criterion 5: technology (procedures, methods and processes, procedures for operating machinery and equipment, computer support systems, unique recipes)

These criteria are used to estimate potential assessments according to the AHP method. It compares resources, skills, experience and technology in two states: the current state and the target state determined in the enterprise strategy. I also presented in the publication the interfaces for introducing assessments based on the potential taxonomy and the risk taxonomy, which are defined in next publications as part of the enterprise ontology. The enterprise competences defined in this way, in specific ranges of potential and risk) are the enterprise competence system. The experts assess the following enterprise competences: competences to build capital potential, competences to build innovation and investment potential, competence to build stakeholder potential, competence to build relational potential (neighborhood), competence to build relational potential (environment), competence to consider capital risk impacts, competence to consider innovation and investment risk impacts, competence to consider stakeholders risk impacts, competence to consider neighborhood relation impacts, competence to consider environment relation impacts. I also presented the results concerning the parameters of the sorting system classes according to the procedures described in the previous publication. The class parameters were determined as a result of training the system on the basis of the introduced potential and risk assessments for 220 enterprises from the SME sector in the Lubelskie and Podkarpackie voivodships. The SOK-P1 system with the interfaces discussed in the publication was used in consultancy for the SME sector in the period 2005–2012. The whole system in the e-barometr tool was subject of the criterion introduced (with a weighting of 20 points) for the assessment of applications in the Human Capital Operational Programme announced by the Self-Government of the Mazowieckie Voivodship. Strategic criterion: "The e-barometr model was tested within the framework of the EQUAL CIP Theme F and proved to be effective in providing advisory support to SMEs."

Publication 5

Andreasik, J. 2007. "A Case-Based Reasoning System for Predicting the Economic Situation of Enterprises — Tacit Knowledge Capture Process (Externalization)." In *Computer Recognition Systems 2*, edited by M. Kurzyński, 718–730. Berlin – New York: Springer.

In the publication, I present the conception of using the CBR cycle in the formalization of the knowledge externalization process of the SECI model. I presented an analysis of several CBR models, in which the stages of knowledge extraction, knowledge systematization, and knowledge storage were introduced. I presented the process of knowledge extraction (from tacit to explicit) in the form of enterprise potential and risk assessments in the UML diagrams (Rhem 2006). This process involves experts who carry out evaluations, experts who estimate the weights of particular types, kinds and ranges of both potential and risk. The experts use financial and accounting documents in the form of financial statements (balance sheets, profit and loss accounts), strategic documents (developed strategies, letters of intent, agreements on contracts, investment projects, agreements with partners and customers), expert reports (forecast reports of the foresight type). The experts conduct interviews with the enterprise owners and managers in order to obtain information on the projects being prepared and on the agreements with the enterprise stakeholders. The experts estimate the weights of the different types and kinds of potential and risk, respectively. I used the AHP method and EXPERT CHOICE software to estimate the weights. The evaluation process takes place in teams. In the realized project within the EQUAL initiative, I was the manager of the whole project and supervised the work of two teams of experts. One team assessed SME enterprises from the Lubelskie Voivodship and the other one assessed enterprises from the Podkarpackie Voivodship. The analysis covered 220 enterprises. A separate group of experts is made up of experts estimating the parameters for the ELECTRE TRI sorting subsystem. These are the thresholds of discernibility, preference and veto. I led this group of experts directly and I was involved in determining the value of these thresholds. In the publication, I presented use case diagrams, sequence diagrams and class diagrams. The diagrams show the roles of the assessment experts, estimating the weights, defining the parameters of the sorting subsystem and the experts of the early warning system. The presented knowledge externalization process system was commented in the paper of Rao and Nayak (Rao and Nayak 2017a). The authors of this paper use the Dietz's enterprise ontology to model the conversion of knowledge from tacit to explicit. In other citations, my approach to the knowledge conversion process is discussed in the context of building collective intelligence (swarm intelligence) models for collective construction systems in Computer Aided Design systems (CAD) (Zhang and Zhou 2015; Zhang and Zhou 2017). The CBR methodology is also used to introduce expert knowledge on the design of similarity measures between cases. A model of this type was presented by Michalczyk and Krupa (2010).

Publication 6

Andreasik, J. 2009. "Enterprise Ontology According to Roman Ingarden Formal Ontology." In *Man-Machine Interactions*, edited by K.A. Cyran, S. Kozielski, J.F. Peters, U. Stańczyk and A. Wakulicz-Deja, 85–94. Berlin, Heidelberg: Springer Berlin Heidelberg.

The publication includes the definition of the original enterprise ontology designed according to the postulates, presented earlier, in the BNF (Backus-Naur-Form) notation. I designed a concept scheme defining an individual object according to the Ingarden's formal ontology. I present particular definitions of the Ingarden's formal ontology, in Polish, in the chapter "Ontologia wiadomości o przedsiębiorstwie" (Andreasik 2013, 11–27). Analogously to the definition of an individual object, I presented a concept scheme defining an enterprise from the- point of view of activity potential and risk (terminal concepts of the formal grammar) taking concepts used in combination processes (module II of the model) and internalization processes (module III of the semantic knowledge management model) into consideration. I made mapping of concepts of the Ingarden's formal ontology into concepts of the enterprise ontology:

```
<object> := <enterprise>, <subject>:= <competence system>, <positive state of thing> :=
   <potential assessment>, <negative state of thing> := <risk influence assessment>,
   <property> := <expert assessment>, <constitutive nature> := <enterprise result
   pattern>, <way of being> := <enterprise legal form>
```

According to the hierarchical system assumed, there were distinguished the following potential taxonomies and risk taxonomies (they are presented in details in the next publication):

```
<enterprise potential> := <capital potential> | <stakeholder potential> | <innovation
   and investment potential> | <relational potential - neighborhood> | <relational
   potential - environment>
<enterprise potential> := <potential type> | <potential kind> | <potential range>
<activity risk> := <financial risk> | <innovation and investment risk> | <stakeholder
   impact risk> | <relation risk - neighborhood > | <relation risk - environment>
<activity risk> := <risk type> | <risk kind> | <risk range>
```

The system presented above results from the analysis of the enterprise environment models according to Krzyżanowski and the environment segmentation according to Obłój (1998).

Competence assessment for building potential consists of a weight of a given type and a potential kind in the potential structure and an assessment value according to the AHP method:

```
<potential assessment> := <weight> | <comparative assessment>
<comparative assessment> := <comparable competences> | <small comparability> | <me-
   dium comparability> | <large difference> | <very large difference>
<competence for building potential> := <resource assessment> | <qualification assess-
   ment> | <ability assessment> | <experience assessment> | <technology and system
   assessment>
```

Competence assessment for taking into consideration a risk impact on operational activity consists of a weight and impact assessment, which is estimated by the expert on the basis of calculated risk values in respect of estimated profit values resulting from enterprise potential.

```
<risk assessment> := <weight> | <risk impact assessment>
```

In order to explain the enterprise situation in terms of forecasting, the characteristics of the enterprise results are covered (revenues from sales over a period of several years) in the form of result patterns determined by Argenti:

```
<result pattern> := <Argenti's pattern>
<Argenti's pattern> := <stable growth> | <stepwise drop "boiled frog"> | <intense
   drop from the stable level "bullfrog"> | <intense drop from strong growth "drowned
   frog"> | <slow drop from slow growth "tadpole">
```

The categories concerning the sorting model are presented in the next publication.

Publication 7

Andreasik, J. 2009. "Enterprsise Ontology for Knowledge-Based System." In *Human-Computer Systems Interaction*, edited by Z.S. Hippe and J.L. Kulikowski, 443–458. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg.

In the publication, I presented a prototypical system of the enterprise potential taxonomy and the enterprise risk taxonomy:

```
<capital potential> := <own capital> | <outside capital> | <circulating capital> |
   <organizational capital>
```

Capital potential assessment concerns the answer to the question whether an enterprise has a sufficient capital level to achieve its strategic objectives. The experts assess the enterprise ability to acquire both own and outside capital. The possibility of increasing own capital is subject to assessment. In joint-stock companies, the process of acquiring share capital through new share issues is assessed. The level of retained earnings available to an enterprise is also assessed. The assessment covers the method of determining retained earnings in relation to formation of revenues,

costs, amortization write-offs, draining taxes and interests on credits. In the range of competence assessment in terms of acquiring outside capital, the leverage effect is assessed. The fulfilment of the "golden balance sheet principle" is analyzed. The assessment covers the competence to maintain financial fluency according to the financial fluency strategy (Wędzki 2003). Organizational capital is part of intellectual capital of an enterprise. Taking into account assessment of competence to create such capital is justified by the fact that the enterprise intangible assets are reflected. In the chapter "Identyfikacja kapitału intelektualnego przedsiębiorstwa" (Andreasik 2014, 19–37), I presented classifications of intellectual capital. Organizational capital is created as a result of the implementation of the following accounting and communication systems in an enterprise: ERP, CRM, CAD/CAM, BPM, WMS, etc.

<financial activity risk> := <own capital acquiring risk> | <outside capital acquiring risk> | <circulating capital management risk> | <organizational capital management risk>

Assessment of financial activity risk consists of assessment of acquiring own and outside capital. The expert assesses the possibility of the occurrence of additional expenses such as dividends or a higher cost of capital. The effects of the enterprise debt in relation to the operating profit generated are assessed. The impact of risk in management of circulating capital is assessed in terms of the effect of uncollectability of receivables, excessive inventories and excessive short-term liabilities. The risk assessment of organizational capital management concerns estimation of unplanned costs related to introduction of additional functionalities (e.g., resulting from legal regulations — personal data protection regulations RODE), costs of maintaining additional specialists, increase of license fees, purchase of additional software and IT hardware, costs of audits and controls.

<innovation potential> := <project teams> | <project management> | <implementation of new products or services> | <modernization of new products or services> | <investment projects>

According to Poznańska (1998), innovation potential is the ability of an enterprise to effectively introduce innovations — i.e., new products, new technologies, organizational methods and marketing innovations of the environment. Assessment of innovation potential includes assessment of project teams, their functioning, methodology used (certificates of an organization managing according to PM — Project Management). Assessment covers the process of implementing new solutions (patents) and profitability of new or modernized products. There is also assessed the enterprise involvement in investment projects related to production infrastructure, technical production preparation infrastructure and IT systems.

<innovation or investment risk> := <project team management risk > | <project management risk> | <new products and services implementation risk> | <investment project risk>

Investment and innovation projects are characterized by a high degree of risk. Therefore, risk of incurring additional costs related to the maintenance and management of project teams as well as risk of exceeding the planned costs of investment and innovation projects. There is also risk that the market will not accept new products and services, which results in additional costs associated with the withdrawal of unfortunate products or services and liquidation of production lines. Risk of additional insurance is also taken into account.

<stakeholder potential> := <owners potential> | <board potential> | <employee potential> | <regulation institution potential> | <supplier potential>

The institutions, enterprises and natural persons with whom an enterprise has signed agreements are treated as the enterprise stakeholders. The ability of an enterprise to achieve synergy effects resulting from the relationship with stakeholders is assessed. According to Adamska-Chudzińska (2014), "Relational potential is a set of beliefs concerning a specific reality, which most often take the form of cognitive-interpretational schemes. These are specific 'schemes-ideas' by which people and enterprises create identities, perceive and interpret environments, formulate their evaluations and program activities to achieve their goals. During the interaction, in an enterprise, relational potentials possessed by stakeholders are activated and confronted."

<stakeholder risk> := <hostile takeover risk> | <bad management risk> | <weak staff risk> | <risk of policy changes by regulatory institutions> | <risk of changes in contracts by suppliers> | <risk of changes in contracts by distributors of products/services>

The identification of risk related to the relations between and enterprise and individual stakeholders is one of the key assessments which significantly influences the forecast of the continuation of the enterprise activity. Assessment of particular types of stakeholder risks is connected with the estimation of additional costs resulting from changes in contracts that bind the enterprise to particular stakeholder groups.

<relational potential - neighborhood> := <advisory institution potential> | <self-government administration risk> | <business partner risk> | <local market customer risk>

Relational potential – neighborhood is related to achievement of synergy effect as a result of successful transactions between entities and institutions of the nearest environment. The ability of an enterprise to implement effective agreements with advisory institutions, research centers, financial institutions, etc., is assessed. Contracts for the implementation of projects commissioned by the self-government administration are an important element. The planned capital transactions concerning mergers, acquisitions of shares, etc. are also subject to assessment. An extensive system of environmental potential factors is defined by Lachiewicz and Matejun (2016). Zakrzewska-Bielawska (2016) adopted the following elements of relational potential in the research: relations with scientific and research units, science and technology parks, relations with suppliers, relations with customers, relations with competitors, with local authorities, relations with local communities.

<relation risk - neighborhood> := <risk of advisory programmes> | <risk of cooperation with partners> | <risk of projects with self-government administration> | <customer relationship risk>

Assessment of relation risk in neighborhood is connected with estimating additional costs that may be generated by complex environmental relations. Risk of unsuccessful projects commissioned by the self-government administration resulting from problems with payments and failure to meet the adopted indicators is also estimated.

<relational potential – environment> := <state policy potential> | <EU policy potential> | <financial exchange potential> | <commodity exchange potential> | <international cooperation potential>

Koźmiński and Piotrowski (2001) characterize the environment by the following elements: authority (state institutions, owners), nature (market trends, nature, demographic processes, cultural changes), gaming (customers, suppliers, banks, service and advisory companies, stock exchanges, insurance companies, intermediaries, shareholders), fight (competitors, opponents). Królik (2017) lists macroeconomic segments: economic environment, technological environment, social environment, demographic environment, political and legal environment, international environment. An enterprise can obtain great benefits from the use of state policies and international institutions. An enterprise can benefit from various tax concessions and support programmes. It may also raise capital from stock exchanges. An enterprise can benefit from various effects of the international pro-innovation policy.

<relation risk with environment> := <unfavorable state policy> | <unfavorable EU policy risk> | <risk of unfavorable phenomena on financial exchanges> | <risk of unfavorable phenomena on commodity exchanges > | <risk of entering international competition>

The experts assess risk related to the functioning of an enterprise in the macroeconomic environment. Here, an enterprise may be affected by restrictive fiscal policy of the state and regulations of international institutions. Unfavorable phenomena on the financial and commodity exchanges may increase the prices of materials, components, media, etc. It is important to estimate risk of price reductions for manufactured goods or services as a result of competitive entry or substitution occurrence.

Publications 8

Andreasik, J. 2008. "Enterprise Ontology — Diagnostic Approach." In *2008 Conference on Human System Interactions, Vols 1 and 2*, 503–509. New York: IEEE.

In the publication, I presented the enterprise ontology A-E-AE (Agent – Expert – Act of Explanation), which is my original contribution to management sciences. It is based on the enterprise competence system model, which was earlier defined. The ontology is classified in the group of enterprise ontologies defined from the diagnostic point of view. I designed my own classification of ontologies according to the criterion of a function of ontology in knowledge management systems. I distinguished: lexical functionality, system functionality, process functionality, transaction functionality, identification functionality, and diagnostic functionality. I gave the examples of ontologies representing each of the functionality. Ontologies are used in process knowledge management models to organize processes: knowledge capturing, knowledge gathering, knowledge distribution. The EO ontology developed by Uschold, King, Moralee and Zorgis (1998) is an example of the lexical ontology. In this ontology, there are defined concepts concerning enterprise structural organization as well as concepts concerning strategic planning and marketing management. The TOVE ontology designed by Fox, Barbuceanu and Gruninger (1996) is an example of the system ontology. The REA ontology designed by Geerts and McCarthy,[4] defining process accounting, is an example of the process ontology. The REA ontology is a basic model in the OeBTO (Open-edi Business Transaction Ontology) ontology covered by the ISO 15944–4:2007 standard: Information Technology — Business Operational View. Part 4: Business transaction scenarios — Accounting and economic ontology. The ontology developed by Dietz (2006) is an example of the transaction ontology. This ontology covers the concept apparatus of business transactions. The enterprise competence ontology BusCO designed by Jussupova-Mariethoz and Probst (2007) is an example of the identification ontology. Ontologies of the diagnostic nature are oriented to concepts concerning audits, controls and assessments. Therefore, the A-E-AE ontology designed by me, is placed in this group.

In the publication, I presented the classes of the A-E-AE ontology, which covers names of computational procedures, which were earlier discussed:

<Procedure of determining parameters of sorting system>, <Procedure of determining the position in the potential-risk space>, <Procedure of aggregation of potential assessment>, <Procedure of aggregation of risk assessment>, <Procedure for determining potential assessment in the fixed range>, <Procedure for determining risk assessment in the fixed range>, <Procedure of determining the potential kind weight>, <Procedure of determining the risk kind weight>, <Procedure of determining the potential type weight>, <Procedure of determining the risk type weight>, <Expert assessment according to potential taxonomy>, <Expert assessment according to risk taxonomy>, <Procedure of determining result patterns>.

I presented the procedure system using the Protege editor of the OWL language.[5] In the publication, I presented the class diagram. The presented scope of the ontology was used in construction of the SOK-P1 system. The interfaces of the system was earlier presented.

Contribution to science

The presented monothematic publication cycle entitled "A semantic knowledge management model for assessment of an ability of small enterprises to continue as a going concern," is my contribution to the development of the scientific area: management science. I am solving the problem of operationalization of the SECI model of knowledge creation in a new scope, i.e., in relation to knowledge about managing an SME enterprise in conditions of uncertainty. This knowledge includes the

4. See: The Ontological Foundation of REA Enterprise Information Systems. By Guido L. Geerts and William E. McCarthy, November 1999, March 2000, August 2000, [@:] https://pdfs.semanticscholar.org/514e/e2a4d6dec51d726012bd74b32b1e05f13271.pdf.

5. Protege (open source ontology editor) can be downloaded from the Leland Stanford Junior University website, [@:] https://protege.stanford.edu/.

assessment of the enterprise in the potential – risk space of operational activity. I solve this problem theoretically by developing the original A-E-AE enterprise ontology and practically by constructing the SOK-P1 system, which was used in the advisory practice for SME sector enterprises in the Lubelskie and Podkarpackie voivodships in years 2006–2013. The system was a part of the e-barometr knowledge portal (Łoboda et al. 2008), which was developed under the EQUAL CIP F project: "System przeciwdziałania powstawaniu bezrobocia na obszarach słabo zurbanizowanych" (System of counteracting the occurrence of unemployment in poorly urbanized areas). The ontology developed by me was classified in the „Creating Enterprise Ontologies" class in the literature review concerning new ontologies designed after year 2007. The authors of the literature review Leinweber, Freiberg, Spenke and Lantow (2014) gave the ontology as an representative example of the class. The A-E-AE ontology is characterized by its reference to the Ingarden's formal ontology and the Bocheński's enterprise ontology.

The way, designed by me, of knowledge acquisition from a group of experts in the form of an interface to the system of a CBR class is a new approach to collective knowledge acquisition. This direction is currently being developed owing to functioning and creation of social networks for knowledge management (Mezghani, Exposito, and Drira 2016) in different applications — research, designing products in different industries (Cha et al. 2015). The presented semantic knowledge management model with algorithmization of particular processes of the SECI cycle and the KB DSS system based on the CBR methodology is an original contribution to the area of knowledge management models. Rao and Nayak (2017a, 2017b) citing my publication, points to the use of the CBR cycle in the knowledge externalization process as a new approach.

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