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Assessment of core competences of enterprises research and innovation networks

Evaluación de competencias básicas de redes de investigación y de innovación de empresas

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Content

ABSTRACT:
The topicality and practical relevance of studies in area of research is determined by the need to increase the integration of continuous innovative transformations of resources, processes that implies the use of strategic and operational management methods based on modern intellectual technologies. The objective of this article is to identify the peculiarities of economic relations between enterprises within the framework of the network business model and to substantiate the adequacy of the network model of their business for the economy.
Keywords business model, business processes, enterprise engineering, core competences.

RESUMEN:
The topicality and practical relevance of studies in area of research is determined by the need to increase the integration of continuous innovative transformations of resources, processes that implies the use of strategic and operational management methods based on modern intellectual technologies. The objective of this article is to identify the peculiarities of economic relations between enterprises within the framework of the network business model and to substantiate the adequacy of the network model of their business for the economy.
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1. Introduction

The content of this study is to develop mathematical methods and decision-making tools that should provide an opportunity for more effective production management while manufacturing innovative products. The article is devoted to the issues of enterprise engineering, taking into account the determination of the potential capabilities of enterprises and the formation of scientific and innovation networks.

The analysis of the studies of Russian and foreign scholars on the topic under consideration shows that the available theoretical approaches do not make it possible to create a comprehensive practical tool for assessing the core competences of scientific and innovative networks of enterprises that corresponds to modern business conditions in Russia (AVDOSHIN, SHATILOV, 2007; TEECE, 2010).

The problems hampering the innovative development of the Russian economy necessitate a systemic transformation of the organizational and economic mechanism for enterprise operation, as well as interaction of enterprises with other economic entities. Against this background, it seems relevant to consider the issues of network structure engineering for enterprise s specializing in the creation of innovative products. To raise the Russian economy, innovative projects are needed that combine the efforts, potential and opportunities of many enterprises. This integration should be facilitated by the active and ubiquitous use of intelligent information technologies (IIT) creating the prerequisites for improving the process of engineering the activities of enterprises. The advantages in the introduction and development of the enterprise engineering process that shapes the nature of strategic and innovative development can be achieved through the use of IIT of strategic and operational management.

While carrying out the enterprise network structure engineering, the substantiation was given for choosing intelligent technologies, mathematical methods and heuristic rules, with which it now became possible to assess the ability of enterprises to jointly create innovative products.

The originality and novelty of this research is that a new approach to assessing the competences of scientific and innovation networks is proposed, on the basis of which it is possible to develop a methodology for their evaluation, and also to link the characteristics of different types of intellectual and resource potential of joint ventures, which are usually considered separately in the existing studies on this subject.

The research methodology is based on the existing theoretical developments in the field of competence theory, innovation economics, institutional economics, corporate governance, and fuzzy sets.

The theoretical significance of the obtained research results is that they enable to assess the potentialities of enterprises and identify the degree of sufficiency of the human, organizational, client and resource potential for creating innovative products by enterprises. The practical significance of the research is the possibility of using the developed theoretical and methodological apparatus in assessing core competences of scientific and innovation networks of enterprises.

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2. Relevant scholarship

The origin of engineering concept is associated with practice of engineering, and, therefore, its original meaning covered elusively technical aspects. However, engineering soaked up, in the course of its development, practices of building financial models for assessing engineering project cost. After a period of time, a new meaning of engineering as an approach to simulating economic processes and systems emerged. A study of the enterprise engineering problems goes back to the works of such scholars as (HAMMER, CHAMPY, 1993, DAVENPORT, 2005), where the concept of enterprise engineering was viewed as a process of improvement or perfection of the business processes.

However, engineering has a broader meaning in the 21st century. From the systemic point of view, the most general definition of engineering was given by J. Martin (Martin, 1995), who considered engineering to be an integrated set of disciplines for building an enterprise, its processes, and systems, and maximum aligning of people and technology.

We should pay special attention to the national school of engineering that studied the applied aspect of solving critical practical tasks. Thus, A.V. Sheer (Sheer, 2000) developed a framework for business process simulation, using visual design tools. E.G. Ojhman and E.V. Popov (OJHMAN, POPOV, 1997) justified the use of IITs for business process re-engineering. G.N. Kaljanov (KALJANOV, 2006) suggested method of business process formalization, using the theory of formal languages and grammars. E.Z. Zinder (ZINDER, 2008) suggested an enterprise engineering paradigm and related it to enterprise strategy and architecture optimization. V.B. Tarasov (TARASOV, 2002) suggested a multi-agent implementation of network enterprise cooperation.

Ontological engineering plays an essential role in developing the concept of knowledge management-based engineering, and it ensures uniform representation of the enterprise at various levels of management from the viewpoint of integrating all components of a complex system. An important place is occupied by the studies of well-known experts in the design of ontologies to support the enterprise engineering processes (BORODAKIY et al., 2014; CHURSIN et al., 2016; FENSEL, 2004; GRUBER, 2008). These researchers introduced ontologies of various types to describe all basic elements of an enterprise, starting from the corporate structure to implementation of innovations. Creation of ontologies as object domains and solvable problems to collectively unfold the enterprise structure is of great importance.

Ontologies that are obtained in the course of enterprise engineering highlight certain business model faces. Business models and their development were studied in detail by M. Porter (PORTER, 1991) and A.A. Osterwalder (OSTERWALDER, 2004), who noted the existence of different understandings of business models and was the first to develop an appropriate ontology for this.

Despite extensive material collected, research of national and foreign authors does not contain any economic and mathematic models and techniques to make rather accurate assessments of potential competences of enterprise networks structures according to development and production of any innovation product.

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3. Methods

This research is based on the application of modeling and formalization methods. The proposed economic-mathematical model is based on the decomposition of the integral indicator in the form of a goal tree. Theoretical multiple and algebraic notations are used for the formalization of the object of research.

The term ‘core competence’ was introduced by C. Prahalad and G. Hamel (PRAHALAD, HAMEL, 1990). When assessing the potentialities of enterprises, it is expedient to use the so-called ‘capability approach’ developed by M. Nussbaum and A. Sen (NUSSBAUM, SEN, 1993) in the 1990s; this approach was originally employed for the evaluation of human potential. In the initial interpretation, the capability approach was applied in relation to the labor characteristics of residents of different countries. In this article, we have used the ideology of this approach in relation to enterprises. Thus, the analogy between man and enterprise was used, and in both cases acting as economic agents.

A resource approach is another approach to enterprise activity that we used in this research and that was suggested by E. Chamberlin and J. Robinson. The resource approach pays great attention to enterprise-specific resources and competences within their competent environment.

Enterprise engineering is used as a flow-through method of this research. It relies on application of structural models that are accurate drawings of enterprise's activity (BAG, 2014). These models are organizational, and new business processes and structures are designed around new strategic ideas. At the same time, all model levels and components are closely interrelated; therefore, they represent essential relations of the organization itself (VORONINA, RATNER, 2012).

The above definition of enterprise engineering is rather conventional; however, certain concepts that require special interpretation for the purpose of competence and resource-oriented approach must be clarified to make presentation of any further results more clear.

The concept of business model is a uniting concept of productive activity and resource provision of enterprises. Almost all researchers attempt to provide their own definition for a business model, when they discuss enterprise engineering. At the same time, some researchers, for example A. Osterwalder (OSTERWALDER, 2004), analyzed the available definitions, and many of them were able to formulate their own definitions based on the analysis, and such definitions were more accurate and consistent. To avoid repeating their experience, we will provide the most common definition there is. Thus, a business model is a schematic description of enterprise's business that reflects its essential elements, which are interrelated in a certain way, and allows for clear representation of the revenue generation process by the enterprise (TARABRIN, 2014).

We will use the unified meaning as per international standard (Oslo Manual, 2005), and we will call introduction of a product or service that are new or essentially improved in terms of their properties or applications a product innovation.

Competence is an enterprise's capability of creating new product innovations based on cooperation of potentials and resources of various types (SCOTT, 2014). According to this definition, enterprise's competences are related closely to creating product innovations. We believe that the given definition of competence suits the subject of our research better than the other definition that was also given by J. Scott in the mentioned research and reads as a 'correlated cooperation pattern of potentials and resources of various types.' The expression of competence is used in human sciences, therefore, one should point out in advance that this word is used as an economic term.

The meaning of competence must be reduced to a core one, i.e. the most essential, primary and key competence; however, the conceptual chain is not limited by this one. Thus, for example, a core competence of the personnel is a system of interrelated skills, capabilities of the personnel of an organization aimed at fulfilling unique production and managerial technologies, and ensuring excellence in consumer properties over any competing product (SUMINA, 2011).

Speaking of all core competences of the enterprise as a whole, one should use a term to cover the whole set. Therefore, one should define competence maps patterns that describe actual business activity, e.g. services that are rendered to clients, and internal functions that are fulfilled by the employees.

Ontologies are among the most sophisticated tools of representing a business model and architecture of enterprises and are used in information science and other sciences, besides economy. Therefore, we will use the universal definition of ontology as a comprehensive and detailed computer-assisted formalization of a certain field of knowledge in the form of a conceptual framework (GRUBER, 2008), which includes terms of the object domain and logic expressions that describe their relations.

We will refer to the meaning of ontology and determine in brief the ontological engineering as a process of developing ontologies.

Finally, a networking structure of enterprises is a set of partner enterprises that are united by the same goal and focus in their activity on supporting early stages of the innovative product lifestyle (GORDENKO, 2016). If any enterprises within the network are engaged in research or very production of an innovative product, such enterprises form an innovative research network; however, it is not every networking structure of enterprises that absolutely refers to networks of such type.

We will use a set of special mathematical methods in the form of a combination of fuzzy sets and fuzzy logics, and the universal method of expert analysis for assessing poorly formalized quality characteristics of the core competences (intellectual potential) of innovative research networks.

4. Results

4.1. Ontological engineering of enterprise network structures

A. Osterwalder provides an approach to building a business models, using ontological engineering (OSTERWALDER, 2004). Such business model demonstrates a practical tool that can be used, when making decisions on a certain type of activity to be pursued by an organization for implementing certain suggested product innovation values. Along with the detailed definition of the canvas business model itself, it also contains detailed recommendations on how to develop such model, description of typical styles of modern business models, original techniques of solving core challenges that practitioners face, and a correlation of a business model and business plan, and other enterprise management tools (BOBRYSHEV et al., 2014). Thus, A. Osterwalder developed the business model that relies on correlation of core competences and development strategy for an individual enterprise. We have a challenge here to expand the business model according to A. Osterwalder, while making a transition from an individual enterprise to a network structure that contains a set of enterprises engaged with developing the same innovation product.

A. Osterwalder suggests any business to be decomposed in the form of ontologies of four basic blocks, those being infrastructure, offers for clients, clients and finance. Eight core elements are distinguished within these four blocks, i.e. core competences, a partner network, infrastructure, offered value for the client, client relations, distribution channels, target clients, expense structure and income flow (TITOV et al., 2015).

Currently, according to M. Porter (PORTER, 1991), business models of value added chain building are replaced by network models of interaction and cooperation of enterprises, where chains for raw material and semi-finished product supply, knowledge sharing and technology transfer between the enterprises are established dynamically and depend on specifics of a certain innovation idea. Network cooperation forms modify the sequential order of any product innovation life cycle. A feedback iteration design model should be used at the product innovation development stage and intensive knowledge sharing between the enterprises and all interested parties should be done. At the stage of product innovation implementation, the role of interface organization in the interaction of business processes between external and internal participants in an enterprise network structure is increasing (DANILIN, KLOCHKOV, 2016).

Distribution of knowledge about the scheduled business projects, including new products or services offered to consumers, is required in the information space for implementing the value-oriented network business model. The business model itself must reflect knowledge about capabilities of implementation of network projects, potential presentation in the form of know-how, reflection of quality and efficiency of the resources used and insufficient resources required (FULLER, MORGAN, 2010).

The central aspect of the business model is associated with a value-oriented offer, which implies a set of actual or potential products produced or services rendered. The value-oriented offer may be considered an enterprise's competence of effectively functioning for the benefit of consumers. All other blocks of the business model are associated with offers one way or another. Then, a consumer or supplier selects a certain value-oriented offer and gets the whole picture of knowledge about such offer.

Business competences describe unique collective capabilities, which may be used for achieving a certain goal. This functional model describes a full set of capabilities of an organization that is required for fulfilling their business models or their own mission. At the moment, competences are not assessed in any other way than subjectively, which makes creation of a more objective assessment technique necessary (SCOTT, 2014).

Core competences must be assessed prior to implementing a project in product innovation development, as long as these contain estimates that rely not on actual figures, but strategic assessment of potential capabilities of the enterprise and operative assessment of the immediate situation. Network structures are the result of the evolution of production relations and refer to a rather perfect form of cooperation between economic agents, playing the role of certain ‘cells’ in the modern economy when cooperating among specialized enterprises. Then, we will imply that each link of product innovation value adding chain is associated with the same set of core competences of a number of enterprises that specialize in this stage. One should assess core competences in a way to make possible horizontal folding according to different links of the innovation value adding chain and vertical folding according to individual enterprises within the network structure. If insufficiency of core competences is observed on any section of the innovation value adding chain, this section must be reinforced by attracting new partners to the network structure from the outside. If total core competence of any network that includes several enterprises is extremely low, such innovation idea must be rejected or certain measures must be taken to rectify the adverse investment situation.

The value added chain connects all elements of any business model through the analysis of value adding stages and resources, expenses, competences and partners engaged at each stage (PASHKOV, 2015). Value transfer indexes and risks make possible efficiency assessment of the existing business model and deciding on the necessity of modernization of such business model. Competence areas of an enterprise will be determined by the selection of specialized lines of activity within the chain. While the enterprises expand their core competences in the certain area of activity, they are forced to purchase lacking resources from partners and cooperate even more closely within the value adding chain, thus outlining the common business model (value added network, VAN). While the enterprises delegate certain types of activity to each other and adopt joint development strategies, they attempt to reduce business risks under the global economic instability. Thus VANs are shaped around the VAC (YULDASHEVA, OREHOV, 2014).

The value added chain consists of partners, who generally have equal rights and serve specific markets or client orders. Such network focuses its efforts on tuning up processes and processing information. This form of network relations targets increased performance, and its members aim in their activity at improving indices, such as reduction of terms, expenses, improvement of services and consideration of consumer's requests. The value adding network is a form of vertical integration. It is always a strategic network, as long as relations in this network imply significant investment and any benefit is not obtained until later.

Strategic partnership of network members may lead to development of new break-through technologies, which can only be done by very large enterprises, or elimination of blocking positions of technological market leaders, thus limiting market power of the latter. Creation of innovation networks of value adding type at such market allows for expanding resource capabilities of network agents, increasing research and development efficiency, saving expenses due to removed duplication of such research and developments, and initiating activity that would not be carried out otherwise (VORONINA, RATNER, 2012).

Competent advantages (competitive advantages) of an enterprise that are accounted for in the SWOT-analysis (Team FME, 2013) may be interpreted as powered by critical success factors, CSF of innovation projects. We may combine critical success factors and prospects of success of any innovation project, the latter being the reciprocal of random variable of the integral risk, and provide our own definition: a core competence of an enterprise is a set of critical success factors that determine possible establishment of a value of product innovations, according to the potential (capacity) and capabilities that are available at the enterprise.

4.2. Assessment technique of competences of innovative research networks

Competence E_p is assessed, for the purpose of developing a product innovation p with efforts of the enterprises that make up the innovative research network Ω, as a ratio of the intellectual potential (IP) IP of the enterprises that contribute to the innovation and resource component $\overline{RP}$ of these enterprises, using the following:

$$E_p = \frac{IP}{\overline{RP}}.$$

Thus, core component assessment E_p is a positive real number, i.e. $E_p \in R^+$.
Accordingly, the intellectual potential of an enterprise IP is comprised of the following components (SVEIBY, 2010):

human potential I_{hum} (covers knowledge, skills and experience of the personnel);

organizational potential I_{org} (reflects all formalized knowledge and know-how);

client potential I_{cl} (it is determined by relations with clients and other partners).
According to V.V. Feshchenko and N.Yu. Shchelikova (FESHCHENKO, SHCHELIKOVA, 2011), the human potential of an enterprise HP is comprised of the following components:

essential component H_{ent} (implies availability (or not) of knowledge about the essence of any innovations that will be implemented at the enterprise);

motivational component H_{mot} (describes motives that drive the employees, when developing innovations);

communicative component H_{com} (reflects relations between the employees, while developing innovations);

practical component H_{pr} (accounts for mastering technologies required for developing and implementing innovations).
Thus, the research by Feshchenko and Shchelikova (FESHCHENKO, SHCHELIKOVA, 2011) gives the following primary indices that are necessary for assessing quality characteristics of the human potential (HP) of an enterprise:

capability of generating new ideas (G_{cr});

level of professional knowledge, skills and experience (G_{comp});

degree and learning capability (G_{ed});

capability of understanding and acknowledging enterprise's value (G_{mis});

pursuance of career (G_{car});

capability of team work and stress resistance (G_{soc});

capability of processing information, sharing knowledge and building data (G_{inf});

capability of contributing to introduction of innovations (G_{int});

readiness for making decisions and taking responsibility for out-comes (G_{res}).
Another research (PAVLOVA, 2014) contains the following components of the organizational potential (OP) I_{org} of an enterprise:

management system (O_{sm});

set of values (O_{sv});

information and communications system (O_{incom}).
In its turn, OP components are formed by the following indices:

managerial maturity (J_{man});

management innovation level (J_{inn});

cultivating organizational culture (J_{orcul});

cultivating production culture (J_{prcul});

scope of corporate knowledge (J_{know}); and

capability of the information and communications system of transferring knowledge (J_{transf}).
A tree with components and primary indices of the integral intellectual potential structure of an enterprise is given in Figure 1.
E.A. Golysheva (GOLYSHEVA,2011) suggests integrating and distinguishing between the following elements making up the client potential I_{cl} of an enterprise:

relations with business counterparties (P_{rel});

trademark, brand, goodwill and image (P_{rep}); and

marketing channels and communications system (P_{mar}).
Primary indices of Figure 1 are quantitative measures of core success factors of an enterprise. Enterprise's CSF contents are formed, depending on its mission and strategy; therefore, the set presented is limited by enterprise's innovative activity. Such diagrams are commonly referred to as 'goal trees', as during the postorder walk they enable move from secondary to aggregated indicators (goals).
Primary indices of components of each subtype of enterprise's intellectual potential are assessed using a 7-point scale, which is provided in Table 1. Table 1 makes it possible to transfer qualitative assessments of characteristics into points, and then to bring these points to a normalized form in a unit range. Quantitative assessments in a standardized form were obtained on the basis of experimental data for a number of Russian enterprises.

Linguistic variable IP of enterprise's HP is obtained by adding linguistic variables I_{hum} of enterprise's HP, I_{org} of enterprise's OP and I_{cl} of enterprise's CP with the help of operator $\oplus$:

$$HP = \hat{I}_{hum} \oplus \hat{I}_{org} \oplus \hat{I}_{cl} \qquad (2)$$

Assessment of enterprise's human potential I_{hum}, which is scaled to linguistic variable $\hat{I}_{hum}$, is done as follows:

$$\hat{I}_{hum} = \hat{H}_{ent} \otimes \hat{H}_{mot} \otimes \hat{H}_{com} \otimes \hat{H}_{pr}, \qquad (3)$$

where $\hat{H}_{ent}$ is the linguistic variable of the essential component of enterprise's HP, accordingly, $\hat{H}_{mot}$ motivational component, $\hat{H}_{com}$ communicative component, $\hat{H}_{pr}$ practical component; $\otimes$ – is multiplication operator of the linguistic variables.

The organizational potential I_{org}, which is scaled to linguistic variable $\hat{I}_{org}$, is assessed as follows:

$$\hat{I}_{org} = O_{man} \otimes O_{val} \otimes O_{incom}, \qquad (4)$$

where O_{man} is the linguistic variable of the management system component, accordingly, O_{val} is the linguistic variable of the set of values component, O_{incom} – is the linguistic variable of the information and communications system component; $\otimes$ – is multiplication operator of the linguistic variables.

Assessment of the client potential I_{cl}, which is scaled to linguistic variable $\hat{I}_{cl}$, is done as follows:

$$\hat{I}_{cl} = \hat{P}_{rel} \otimes \hat{P}_{rep} \otimes \hat{P}_{mar}, \quad (5)$$

where $\hat{P}_{rel}$ is the linguistic variable of the component of business relations with clients and counterparties, accordingly, $\hat{P}_{rep}$ is the linguistic variable of the goodwill component, $\hat{P}_{mar}$ – is the linguistic variable of the marketing channels and communications system component; $\otimes$ – is multiplication operator of the linguistic variables.

Assessment of the component K of each of three enterprise's IP sub-types above is done as follows:

$$K = \prod_i J_{hi}, \quad (6)$$

where J_{hi} – is i primary index referring to h component of enterprise's IP; $h \in \left\{ \begin{matrix} \text{ent, mot, com, pr,} \\ \text{man, val, incom, cl} \end{matrix} \right\}$; $i \in \left\{ \begin{matrix} \text{cr, comp, ed, mis, car, soc, inf, int, res, inn,} \\ \text{man, orcul, prcul, know, transf, rel, rep, mar} \end{matrix} \right\}$ out of index tree, which is provided in Figure 1. K refers to intellectual potential subtypes (index of the first group), h refers to intellectual potential subtype components (indices of the second group), I refers to primary indices of intellectual potential subtype components (index of the third group).

Assessment of primary indices J_{hi} that make up intellectual potential components is done as follows:

$$J_{hi} = \sum_{j=1}^{N} \left(Ex_{ij}^{*} \cdot W_j \right), \quad (7)$$

where Ex_{ij}^{*} is the given expert analysis of index i by expert j; W_j is the weight of expert j; N is the number of experts in the expert group.

Expert analyses Ex_{ij} are brought by expert j of primary index i as follows:

$$Ex_{ij}^{*} = \frac{Ex_{ij} - X_{\min i}}{X_{\max i} - X_{\min i}}, \quad (8)$$

where $X_{\max i}$ and $X_{\min i}$ are accordingly, maximum and minimum value of the point scale for assessing primary index i.
The weight of any expert depends on his competences and it is assessed, using a certain rating model, for example (PETRICHENKO, PETRICHENKO, 2015).

Resource component $\overline{RP}$ of core competence E_p of any enterprise within the innovative research network Ω with regard to developing innovative product p (reverse resource potential. RRP) is calculated as follows:

$$\overline{RP} = \frac{1}{RP} = \frac{1}{\sqrt[n]{\prod_{i=1}^{n} \frac{R_i}{C_i}}}, \qquad (9)$$

where R_i is total for all network enterprises Ω amount of the resource of type i at their disposition; C_i required resource expenditures for resource of type I for developing innovation; n is number of types of engaged resources.

The amount of resources available R_i of various types in equation (9) is brought into monetary form and the required resources are at the same time calculated by ABC-method, using market prices.

The fuzzification procedure for components K of each of three enterprise's IP sub-types is carried out, using the following set of fuzzy logic rules:

P. 1. IF $K = 0$, THEN $\hat{K} = \{\text{"Very low"}\ CF\ 100\}$;

P. 2. IF $K > 0$ and $K < k$, THEN $\hat{K} =$
$= \{\text{"Very low"}\ CF\ \mu_1(K), \text{"Low"}\ CF\ \mu_2(K)\}$;

P. 3. IF $K > k$ and $K < l$, THEN $\hat{K} =$
$= \{\text{"Low"}\ CF\ \mu_2(K), \text{"Middle"}\ CF\ \mu_3(K)\}$;

P. 4. IF $K > l$ and $K < m$, THEN $\hat{K} =$
$= \{\text{"Middle"}\ CF\ \mu_3(K), \text{"High"}\ CF\ \mu_4(K)\}$;

P. 5. IF $K > m$ and $K < n$, THEN $\hat{K} =$
$= \{\text{"High"}\ CF\ \mu_4(K), \text{"Very high"}\ CF\ \mu_5(K)\}$;

P. 6. IF $K \geq n$, THEN $\hat{K} = \{\text{"Very high"}\ CF\ 100\}$.

Thus, IP component assessments are fuzzified in accordance with the membership function that is presented in the fuzzification diagram in Figure 2. To do this, it is required to mark the component value on the abscissa and find the ordinates of the corresponding membership functions:

Assessment of enterprise's intellectual potential IP is related to a certain innovation p, using numerical parameters k, l, m, n, with their values varying based on distinguishing features (industry affiliation, degree of acute importance, research intensity of the production technology etc.) of the innovation p.

The following linguistic variables are obtained, as a result of defuzzification:

$$\hat{L} = \left\{ \begin{matrix} \text{"Very low"}\ CF_1;\ \text{"Low"}\ CF_2;\ \text{"}Middle\text{"}\ CF_3 \\ \text{"}High\text{"}\ CF_4;\ \text{"}Very\,high\text{"}\ CF_5 \end{matrix} \right\}. \qquad (10)$$

At the same time, not more than two adjacent non-zero values may serve as linguistic variable $\hat{L}$.

Two linguistic variables $\hat{L}_x$ and $\hat{L}_y$ are added according to the following rule:

$$L_x \oplus L_y = \left\{ \begin{array}{l} "Very\ low"\ CF_{x_1} + CF_{y_1} - \dfrac{CF_{x_1} \cdot CF_{y_1}}{100}; \\ "Low"\ CF_{x_2} + CF_{y_2} - \dfrac{CF_{x_2} \cdot CF_{y_2}}{100}; \\ "Middle"\ CF_{x_3} + CF_{y_3} - \dfrac{CF_{x_3} \cdot CF_{y_3}}{100}; \\ "High"\ CF_{x_4} + CF_{y_4} - \dfrac{CF_{x_4} \cdot CF_{y_4}}{100}; \\ "Very\ high"\ CF_{x_5} + CF_{y_5} - \dfrac{CF_{x_5} \cdot CF_{y_5}}{100} \end{array} \right\}, \quad (11)$$

where CF_{x_i} and CF_{y_i} are confidence factors of value scales i of linguistic variables $\hat{L}_x$ and $\hat{L}_y$; $i \in \{1, 2, 3, 4, 5,\}$.

Two linguistic variables $\hat{L}_x$ and $\hat{L}_y$ are multiplied according to the following rule:

$$L_x \otimes L_y = \left\{ \begin{array}{l} "Very\ low"\ \dfrac{CF_{x_1} \cdot CF_{y_1}}{100}; \\ "Low"\ \dfrac{CF_{x_2} \cdot CF_{y_2}}{100}; \\ "Middle"\ \dfrac{CF_{x_3} \cdot CF_{y_3}}{100}; \\ "High"\ \dfrac{CF_{x_4} \cdot CF_{y_4}}{100}; \\ "Very\ high"\ \dfrac{CF_{x_5} \cdot CF_{y_5}}{100} \end{array} \right\}, \quad (12)$$

where CF_{x_i} and CF_{y_i} are confidence factors of value scales i of linguistic variables $\hat{L}_x$ and $\hat{L}_y; i \in \{1, 2, 3, 4, 5,\}$.

Defuzzification function ϕ operates according to the following rule:

$$\varphi\left(\hat{L}\right) = \frac{1}{2} - \frac{CF_1}{200} - \frac{CF_2}{400} + \frac{CF_4}{200} + \frac{CF_5}{200}, \quad (13)$$

where CF_i – are confidence factors of value scales of linguistic variable $\hat{L};\ i \in \{1, 2, 4, 5,\}$. Interestingly, equation (13) does not use CF_3, as long as this confidence factor values refer to the median confidence factor of linguistic variable $\hat{L}$.

Rating operation $\| \ \|$ is expressed as follows:

$$\left\|\hat{L}\right\| = \left\{ \frac{100 \cdot CF_1}{\Sigma}, \frac{100 \cdot CF_2}{\Sigma}, \frac{100 \cdot CF_3}{\Sigma}, \frac{100 \cdot CF_4}{\Sigma}, \frac{100 \cdot CF_5}{\Sigma} \right\}, \quad (14)$$

where $\Sigma = \sum_{i=1}^{5} CF_i$, while CF_i – are confidence factors of value scales of linguistic variable $\hat{L}$; $i \in \{1,2,3,4,5,\}$.

Integral intellectual potential IP across innovative research network Ω is calculated as follows:

$$IP = \otimes_{u=1}^{U} IP_u, \tag{15}$$

where IP_u is the intellectual potential of the enterprise u; U is the number of enterprises in the network Ω; $\otimes$ – is multiplication operator of the linguistic variables.

Thus:

$$\mathrm{E} = \frac{\varphi(IP)}{\overline{RP}} = \frac{\varphi\left(\left\|\otimes_{u=1}^{U}\begin{pmatrix}\left(H_{u,ent} \otimes H_{u,mot} \otimes H_{u,com} \otimes H_{u,pr}\right)\oplus \\ \oplus\left(O_{u,man} \otimes O_{u,val} \otimes O_{u,incom}\right)\oplus \\ \oplus\left(P_{u,rel} \otimes P_{u,rep} \otimes P_{u,mar}\right)\end{pmatrix}\right\|\right)}{\dfrac{1}{\sqrt[n]{\prod_{i=1}^{n}\dfrac{R_i}{C_i}}}}, \tag{16}$$

where IP is the intellectual potential of the enterprises within the network Ω; $\overline{RP}$ is the resource component of the core competence of the enterprises within the network Ω with regard to developing innovation p; $\hat{H}_{u,ent}$ is the linguistic variable of the essential component of enterprises' HP u; $\hat{H}_{u,mot}$ is the linguistic variable of the motivational component of enterprises' HP u; $\hat{H}_{u,com}$ is the linguistic variable of the communicative component of enterprises' HP u; $\hat{H}_{u,pr}$ – is the linguistic variable of the practical component of enterprises' HP u; $\hat{O}_{u,man}$ – is the linguistic variable of the management system component of enterprise's OP u; $\hat{O}_{u,val}$ – is the linguistic variable of the set of values component of enterprise's OP u; $\hat{O}_{u,incom}$ – is the linguistic variable of the information and communications system component of enterprise's OP u; $\hat{P}_{u,rel}$ – is the linguistic variable of the component of business relations with clients and counterparties of enterprise's CP u; $\hat{P}_{u,rep}$ is the linguistic variable of the goodwill component of enterprise's CP u; $\hat{P}_{u,mar}$ is the linguistic variable of the marketing channels and communications system component of enterprise's CP u; U is the number of enterprises within the network Ω; φ is the defuzzification function of the linguistic variable of enterprise's IP; $\oplus$ is the addition operator of the linguistic variables; $\otimes$ is the multiplication operator of the linguistic variables; R_i are resources of type i at disposition of the network Ω; C_i are the required expenditures of the resources of type i for developing innovation p; n is the number of types of resources used.

5. Discussion

This research proposes a methodology for assessing the core competencies of enterprises within scientific and innovation networks, which should be applied in the decision-making process to create product innovations. Together with intellectual technologies, this methodology enables to increase the coherence of activities carried out in accordance with the innovative strategy of enterprise development, continuing other studies such as (BATKOVSKIY et al., 2016) devoted to similar topics.

The gap between the strategic and operational levels, as indicated in the study, is one of the problem areas in enterprise management. While implementing a flexible network business model, this gap is narrowed, as a result, the period from the appearance of the idea of product innovation to the practical implementation takes a minimum time, provided that the methodology is adequately applied and the necessary support is available for decision making.

The methodology presented in this article assumes the collection of expert assessments from potential customers and partners using network technologies. Users of such a system could participate in voting, form feedback, formulate comments, and give expert assessments while analyzing business news and business reports. Based on the proposed methodology, it is possible to develop a 'network platform' within the framework of the Web 2.0 concept for economists, managers, experts and entrepreneurs, as a result of which, with the use of intelligent modules, it will become possible to search for counterpart enterprises to be involved in scientific and innovation networks. The mechanisms of such a platform should help select enterprises with core competencies that are most appropriate to a certain stage of the chain for creation of product innovation values at an early stage of the preparation of innovative projects. However, in general, it should be recognized that aspects of software design and development have for the most part remained outside the scope of this study.

The most significant results obtained, in comparison with other studies devoted to the similar area of research, are as follows:

- a new interpretation of the previously known economic task facing innovation-active enterprises has been carried out;

- certain categories and concepts that develop an understanding of this area of knowledge has been refined;

- a new tool for assessing the core competencies of enterprises has been proposed;

- on the basis of the proposed model, methods and methodology, the proposals to improve the management of the innovation-active enterprises' development are formulated and scientifically substantiated.

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6. Conclusion

The problem solved in this study includes the theoretical generalization and development of the research area in the theory of management, enabling to effectively manage the process of increasing the competitiveness of innovative active enterprises based on the creation and application of core competencies.

In the course of the study, the authors succeeded in developing a methodology for assessing the intellectual potential of enterprises, which makes it possible to provide a solution to the problem of assessing their core competencies.

Summarizing the conclusions drawn earlier, it should be noted that the use of the proposed methodology enables to formulate recommendations for optimizing the composition of the network structure of enterprises on the basis of assessing their capability to create innovative products. In addition, due to the fact that competences can provide strategic and operational investment management, they can be embodied in the organizational, process, product and marketing innovations. Hence, the proposed decision-making model has sufficient flexibility and versatility to be effectively used in practice.

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Annexes

Figure 1

A tree of assessment goals for a linguistic variable of enterprise’s intellectual potential

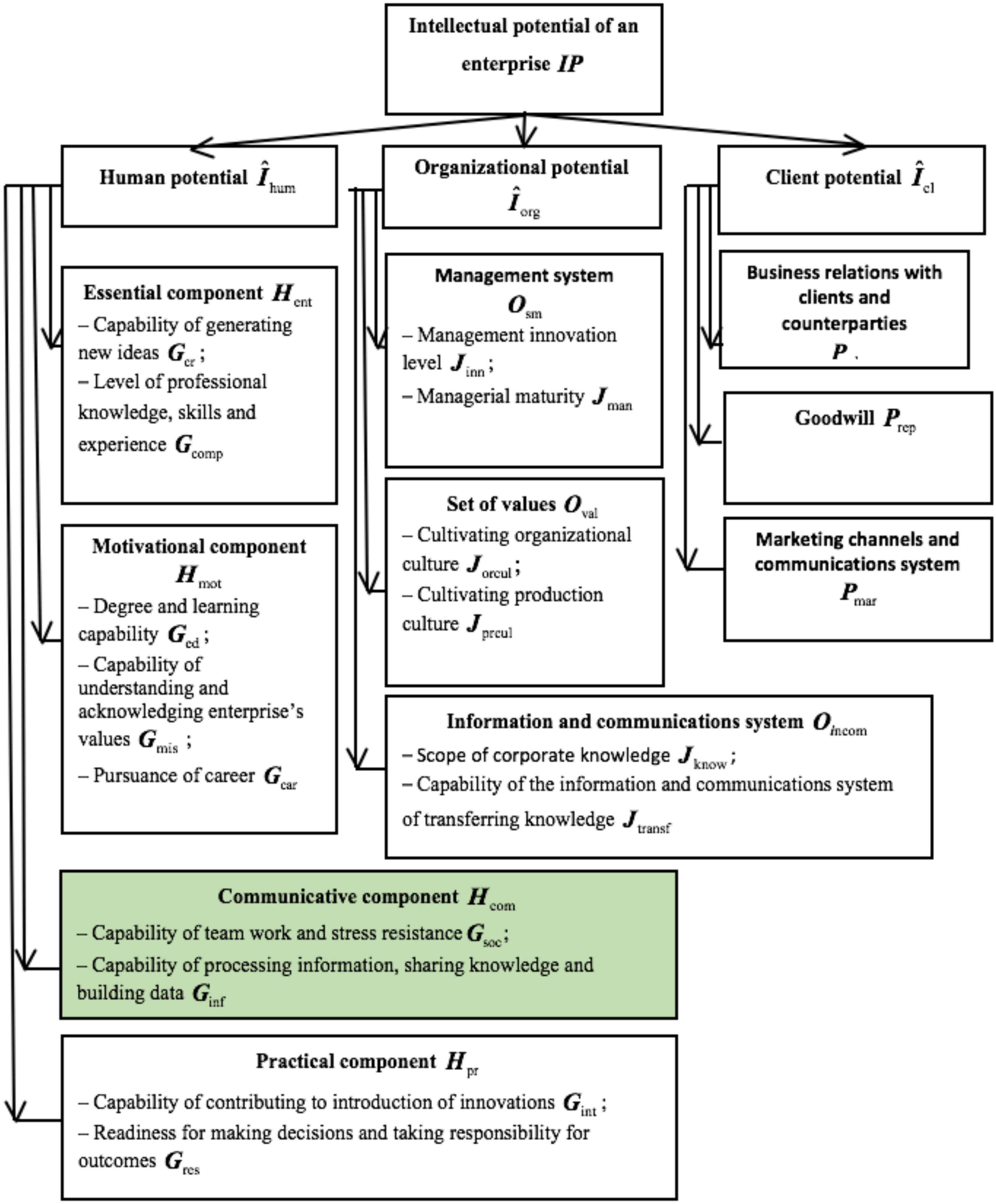

Figure 2
Fuzzification diagram of intellectual potential components of an enterprise

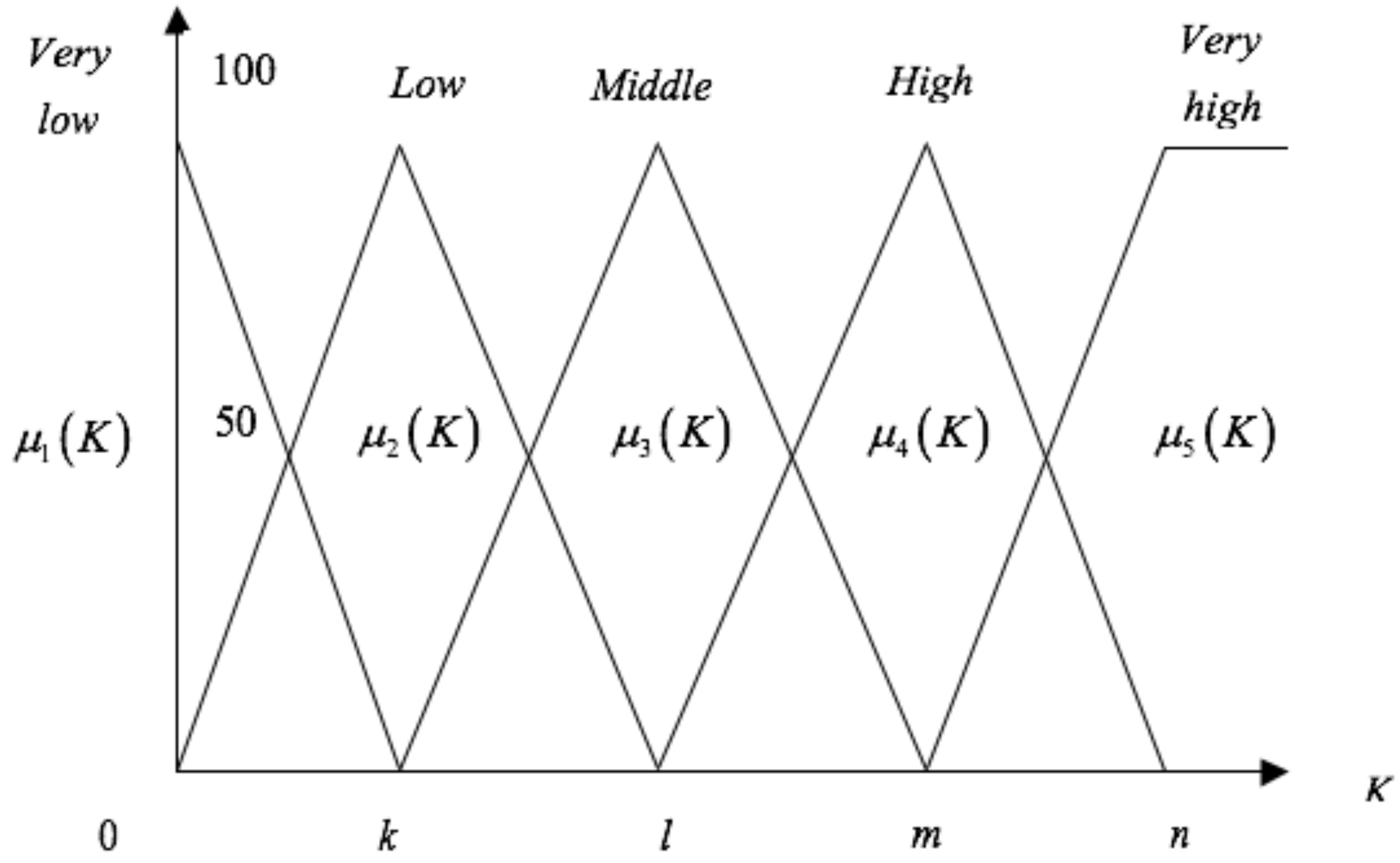

Table 1
Correlation between qualitative and numerical scales for assessing primary indices of components of intellectual potential sub-types of an enterprise

Level	Characteristics	Points	Quantification
Very low	An enterprise does not use the assessed competence at all and does not acknowledge the necessity of applying such competence in its activity	1	0.0
Low	An enterprise uses randomly individual elements of the use the assessed competence; however, it does not acknowledge the importance of such competence for its activity	2	0.170
Almost middle	An enterprise mastered and uses just individual elements of the competence, and it acknowledges the importance of such elements for its activity	3	0.335
Middle	An enterprise mastered each and every element of the competence; however, it uses such elements separately if necessary and does not guarantee any quality.	4	0.500
Almost high	An enterprise mastered all elements of the competence, and it uses them from time to time in standard performance situations	5	0.665

High	An enterprise mastered completely all elements of the competence, and it uses them in all standard performance situations	6	0.830
Very high	An enterprise mastered perfectly all elements of the competence, and it uses them in typical and no—standard situations	7	1.0

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