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CONFICURATION OF ENTERPRISE NETWORKS*

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Abstract. In the study, we consider the methods for optimizing the configuration of the network structure of enterprises based on the theory of fuzzy sets. These methods allow customizing the value chain in such a way as to maximize the likelihood of the success of a joint project to create innovative products. A strategic decision to change the configuration of the network structure is made based on an analysis of deviations of the generalized capabilities from the generalized requirements for the enterprise and its closest neighbors along the value chain. This optimization principle allows changing the configuration, taking into account the interests of participants in the network structure as a whole. We have formulated the task of developing tools for enterprise engineering based on intelligent decision support technologies and multi-agent systems. The approach to justifying decisions in the conditions of lack and incompleteness of the initial data on the basis of soft models is an alternative to existing traditional methods. The proposed network structure optimization model will allow effective strategic planning, supporting flexible management mechanisms at the strategic and operational levels. The research results show that it is possible to improve the efficiency of interaction between enterprises united by common goals by using services that allow enterprises to find information about their potential partners.

Keywords: business model; network structure; value chain; key competencies; clusters; technology transfer

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JEL Classification: C10, C18, C51

1. Introduction

For successful implementation of system transformations, modern methods and approaches of enterprise engineering are applied, including the construction of flexible organizational structures of enterprises and management of business processes on the basis of multi-agent technologies. However, on the way to the implementation of the formulated paradigm there are a number of not completely solved problems, which include the necessity to maintain the integrity of the network structure from the position of optimizing the components of the business models of enterprises, such as resources, business processes, key competencies, etc.

In the field of enterprise architecture development, the formation of more freely communicating communities of enterprises, which cooperate to achieve changing but clearly formulated goals, is acquiring a great importance. The purpose of the present study is to develop methods and tools for intellectual decision support in the field of enterprise engineering in order to optimize the configuration of network structures. In this study, the problem is to develop the methods and tools for enterprise engineering based on intelligent decision support technologies and multi-agent systems. The formation of enterprise network structures should be based on the use of multi-agent technologies and the formalization of the roles of the main agents of the value chain for the network business model. In addition, it is necessary to develop rational criteria for decision-making by the agents of the network structure of enterprises.

The novelty of the proposed model for optimizing the network structure of enterprises is the use of multi-agent technology that allows quick adaptation to changes in the conditions and requirements of the market and the adjustment of the corresponding components of the business model towards alterable innovation strategies. The creation of network architecture allows optimizing the activity and business processes of enterprises by linking the configuration of the network structure with the functional activities and technologies used in accordance with the chosen business model. In this case, the configuration of the enterprise network structure is tied to the architecture of the information system used as a platform for the agent search.

The development of methods and tools for intellectual decision-making support for enterprise engineering and multi-agent network structures will enable implementing effective strategic planning, supporting flexible management mechanisms at the strategic and operational levels. The proposed method of enterprise engineering allows raising the level of systemic transformation of enterprises to the level of modern requirements of innovative development of the economy.

Generalizing the presented concept of engineering of enterprise network structures, which fully applies to the enterprises of the basic technological industries and ensures their effective innovative development, we can identify the most important direction for us, which is engineering of business models and optimization of interactions between enterprises.

The hypothesis of our research can be formulated as follows: agreements between enterprises will bring the greatest benefit to individual participants and give positive results if they are based on the principle that it is necessary not to take into account the interests of each participant separately, but act on the basis of the interests of the entire project.

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2. Literature review

Ensign (2001) proposed the definition of value as a unique combination of goods and services that are important to the buyer. Different types of the cost of the commodity, such as the individual and market costs, with some degree of approximation are identical with its utility, and also with the value of this product.

Ansoff (1989) believes that the competence of the enterprise, on one hand, is determined by the abilities of managers, and, on the other hand, by general experience as a whole. Competence includes a problem-solving method, a problem-solving procedure, a management process, an organizational structure, remuneration and economic incentives, job description, technical means and the organizational potential of the enterprise.

The term "core competencies" was introduced by the Indian economist C. Prahalad. Prahalad, & Hamel (1990) stated that core competencies are a collective subject of research in organizations, especially in order to coordinate a variety of production skills and combine the technologies used. Unlike physical assets that really deteriorate over time, competencies only increase, as they are used and shared. Experts recommend that the enterprise that produces innovative products should have several competencies and many times more capabilities (Song, & Lee, 2014).

While the "capability", in particular, "the capability of the enterprise", is understood as skills, faculties, knowledge, etc. necessary for a certain type of activity (in our case, for the creation of innovative products), we will treat "enterprise capabilities" more broadly as "general" *capabilities of the enterprise*. The general capabilities of the enterprise include its key competencies, as well as its innovative potential.

Similarly, treating requirements in a broader sense as "*general requirements"*, we will include there the requirements for resources, standards and risks. The requirement for risks means working according to the principle of eliminating risky options, actions, measures and alternatives in the enterprises. In this case, collective risks in the network structure as a whole are considered as a component, that is, a common component for all enterprises used in the calculation of individual risks (Batkovsky *et al.*, 2015).

Boynton, & Zmud (1984) claim that planning in the enterprise is carried out at three levels: political, strategic and executive (or operational). By analogy, it is possible to distinguish the strategic and operational levels in the management of the enterprise. Decisions at the highest level imply management of the enterprise as a large economic system as a whole. Lower-level solutions are related to the management of production, technological and other business processes. In addition, Ansoff (1989) notes that the choice of a strategy at any level should always be based on the capabilities of the enterprise.

Reinforcing their own considerations, Boynton and Zmud argue that the benefits of applying critical or key success factors (CSFs) at all levels of enterprise planning are connected with effective support of the planning process, development of information service ideas, which can affect the competitiveness of the firm. The weaknesses in the CSFs are manifested in that it is more difficult for managers who are remote from management positions to identify significant CSFs. Besides, it is difficult for certain managers to specify their information needs using only CSFs (Boynton, & Zmud, 1984).

Grunert, & Ellegaard (1992) define a critical success factor as a skill or resource that the business can invest in the market and that impacts the market, while making up the bulk of the perceived differences in present value or relative costs.

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In turn, Scheer, & Nüttgens (2000) associate strategic goals with the activities to achieve goals (in the form of an ordered list) and the tree of goals (a graph composed of nodes with the key performance and effectiveness indicators). Adhering to the newest ideology of strategic management, Haughey (2013) writes that the goal should be measurable, that is, should be expressed through target values of indicators or maxima (minima) of objective functions, in some cases, very sophisticated ones. Thus, the strategic goals, expressed through KPI (key performance indicators), turn out to be related to CSFs.

The formulation of our above hypothesis in the terms considered in this review is as follows: contracts between enterprises belonging to different parties of the configuration of the network structure will bring the maximum benefit to individual participants and the entire network of enterprises if they are based on the principle, according to which it is necessary to minimize not the sum, but the product of the generalized capabilities of enterprises with respect to the general requirements to them.

3. Materials and Methods

The calculation of most of the indicators mentioned in this study was based on the method of expert assessments, because it is the most convenient tool for assessing the quality characteristics belonging to certain objects with a complex structure. To date, this method is still being developed including in the applied research in the economic sciences. General issues of expert assessments in the context of decision making, intellectual technologies and risk assessment are considered in (Orlov, 2013). The expert method of assessing the qualitative characteristics of objects, which we are most interested in, is used in various versions such as semantic differentials (Stepnova, 1992) or the Thurstone scale (Bozhuk *et al*., 2011).

Expert methods can be effectively combined with so-called “soft models” (Zadeh, 1994), especially with fuzzy sets and fuzzy logic. There is a variety of different types of fuzzy sets, which in the articles (Chen, & Xu, 2014; Torra, 2010) are successfully reduced to a universal type of hesitant fuzzy sets. The fuzzy sets, involved in this study, with a continuous membership function analytically defined on intervals, are not an exception to this generalization.

In the present study, the models of subject fields that are commonly referred to as ontologies (Mizoguchi, 2003; Gruber, 1993; Liu, & Özsu, 2009) are interpreted differently from the philosophical interpretation of this term. Since our research has a theoretical rather than an applied orientation, thus we are interested first of all in the development of ontologies, which in the future can be used in the business models engineering and the network structures of enterprises. The ontological approach to enterprise representation, described in the study (Telnov, 2014), makes the aspects of enterprise activity more “transparent”, and the profile of the enterprise itself more open.

The formal presentation of the hypothesis, formulated in two versions, requires the application of the mathematical tools mentioned in this section. But before proceeding to the description of mathematical methods, it is necessary to consider more closely the value chain, because this chain naturally limits the scope of presenting the research results.

4. Results and Discussion

4.1. Analysis of elements of the network chain of creating the innovation product value

The value added chain diagram (VAD) describes a certain landscape, for which we consider the possibility of flexible optimization of the network structure of enterprises. Osterwalder (2004) and Pigneur (Osterwalder, &

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Pigneur, 2012) distinguish three types: (1) the "value chain" model for the value creation contains various actions that an enterprise performs to supply inexpensive or differentiated products. According to Porter, the main activity of the structure of the value chain includes input logistics of initial resources, operations, output logistics of the results of processes, marketing and sales, service; (2) the "value shop" model of the value creation is an extension of the basis of the conventional value chain, in its usual sense according to Porter (1985); (3) the "value creation network" model, where the value chains are created by connecting customers who are or want to be interdependent. The enterprise itself is not a network, but it provides network services. The network value is considered as a direct product of mediation.

For the network value model, standards are of great importance. In many areas of activity there are common for all standard rules and requirements. This is the minimum requirement for all enterprises to enter the network structure. All enterprises within the network business model must comply with mandatory standards, but the standardization of business can be made even before the company in question officially joins the network structure.

Another element of the value chain is a business layer. A *business layer* is usually used in combination with a strategy for modeling the enterprise architecture, defined as a description of the structure and interaction between strategy, functional organization, business processes, and information needs (Josey *et al*., 2016). As applied to our research, the business layer is the area of interaction between enterprises cooperating within a network structure.

If we consider the business layer in more detail, a conceptual scheme of the chain of creating value of a product innovation in a network business model can be obtained:
− at the first level, there is a chain of value creation; it is a chain, because the graph is not suitable for our "simplified model";
− at the second level, there are horizontal links between the "neighbors" along the chain, that is, "paired" links;
− further at the third level, there are the "attributes"of these links, that is, "capabilities" and "requirements".

The concepts related to the network business model are integrated into the semantic network displayed in Figure 1. The connections between enterprises within the network structures have the form of flows. It is possible to distinguish "workflows", "cashflows", "information flows", etc. Some of the flows can be very closely intertwined, for example, as in the blockchain technology (Pilkington, 2016). Thus, the material exchange between enterprises as a part of network structures is carried out in the form of flows with different contents corresponding to one or another kind of resources.

There are tasks that an enterprise must solve with the highest priority, as well as tasks that an enterprise has the opportunity to outsource. Such "secondary" competencies will be called *peripheral*. The level of key competencies of various enterprises should not be below a threshold value; otherwise such an enterprise should in advance be recognized as not completely competitive. The resources within the network structure should be distributed in such a way as to maximize the key competencies of each of the enterprises, since it is difficult to maximize all key competencies at once for all enterprises. Maximizing the key and delegating the peripheral competencies of individual enterprises is proposed to be implemented through a mechanism of optimizing the configuration of the network structure.

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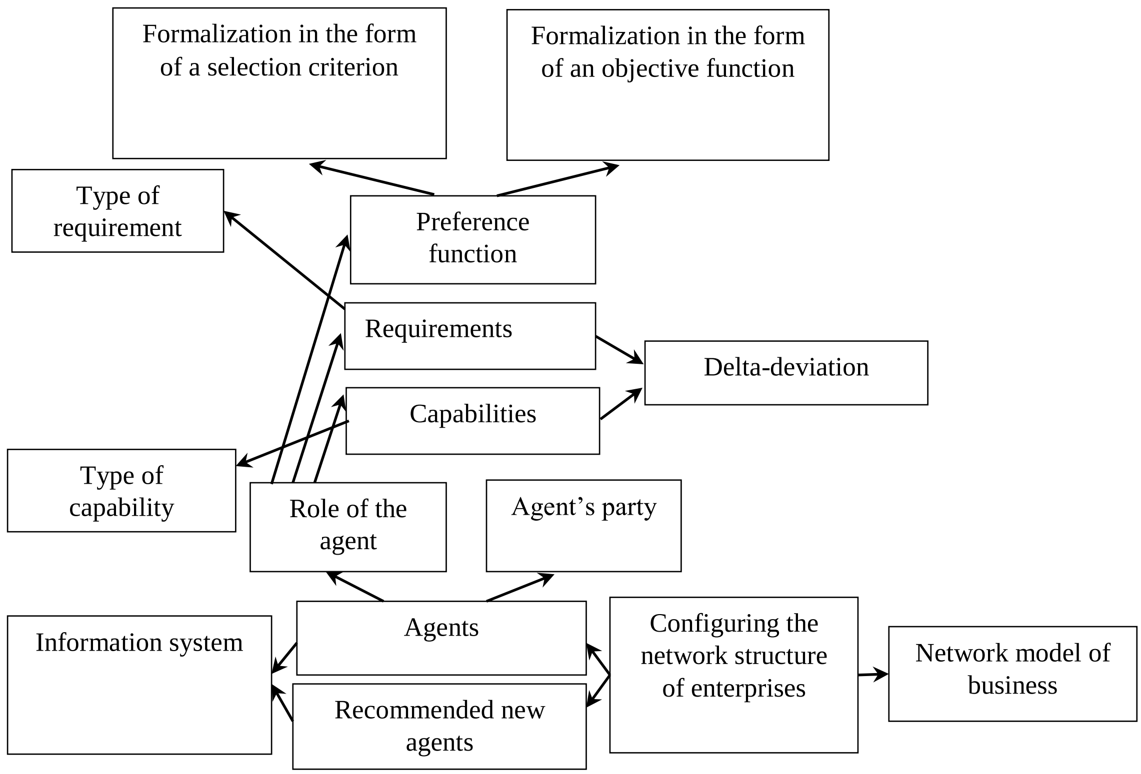

Fig.1. Semantic network of the network model of business [compiled by the authors]

4.2. Methodology for assessing the fuzzy deviation of the capabilities of network agents from the requirements

We are faced with the task of constructing a model that will optimize the configuration of the network structure of enterprises when their own capabilities for creating an innovative product are insufficient; and therefore they are forced to attract additional agents from the outside into the network structure. In the present study, we focus primarily on projects to create product innovations.

Before proceeding directly to economic-mathematical models, it is necessary to settle the issues of terminology in order to avoid confusion in the presentation of further research material: the agent (actor) is a subject that is capable of carrying out active behavior. The role implies responsibility for a particular type of behavior for which an actor can be assigned in a particular action or event (Josey *et al.*, 2016); the role is a certain type of agent, generalized according to function. Among the plenty of roles, the following roles should be distinguished: developer, manufacturer, creator, investor, seller, consumer, user, buyer, client, supplier, and contractor.

In the network model of business, two main business groups act, which we will simply call the parties: the "Customer" Φ and the "Executor" Ψ. Each of the two sides can own an arbitrary number of enterprises (agents); in a sense, the roles of agents on both sides can be mixed with each other due to the extreme flexibility of network configurations. Let us assume that the "Customer" is a financial structure that is not a producer.

The "Buyer" party creates a market demand for innovative products in relation to the "Customer" and dictates the requirements for the characteristics of innovative products in relation to the "Executor". In return, innovative

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products can be supplied to the "Buyer" both from the "Customer" (when the "Executor" is responsible only for R&D) and from the "Executor" (when the "Customer" is an investor, and the "Executor" combines scientific innovation and production activity).

At first glance, when calculating the deviation Δ_p of the capabilities Ξ of enterprises from the requirements Θ from a list of n characteristics, it would be better to use the so-called "Euclidean distance" between the numeric indicators Θ_i and Ξ_i for the i-th characteristics:

$$\Delta_p = \sqrt{\sum_{i=1}^{n} \left(\Theta_i - \Xi_i\right)^2} \tag{1}$$

However, in connection with the fact that, in practice, the list of such characteristics is quite flexible, greatly varying when moving from one possible network structure of enterprises to another network structure, instead of n-dimensional vectors $\vec{\Xi}$ and $\vec{\Theta}$, consisting of indicators, it seems more optimal to use the indicators that we call "delta deviations", calculated using the method of expert assessments.

Delta deviations are indicators whose optimization through objective functions, in our opinion, will be equivalent to following the interests of the network structure as a whole. It should be noted that for enterprises with different roles, delta deviations will be calculated using different methodologies. Meanwhile, these methodologies are united by the fact that, at the output of the delta deviation calculation, fuzzy numbers should be obtained. In addition, delta deviations are always calculated as the difference between generalized capabilities and generalized requirements.

The methods by which the generalized capabilities and requirements will be calculated depend on the type of the particular enterprise-agent (more precisely, on its role in the network structure of enterprises). It should be noted that in spite of the fact that delta deviations are defined for the pairs of enterprises (or agents), they do not commute (and therefore are not permutable) if the order of the elements in the pair is changed. However, this does not mean that all relations between agents should be correctly written only in the form of ordered pairs, in other words, that all connections between agents must be of the form "one-to-one". From the point of view of designing relational databases, it would be much more convenient to use the "one-to-many" kind of relation. For example, one supplier can have relations with several clients at once, which cannot be represented in the given particular case in the form of "one-to-one", for example, if specific, individual contract terms are used for each of the clients.

Thus, it is possible to write down the formula for estimating the delta deviation $\tilde{\Delta}_p$ of the "generalized capabilities" Ξ from the "generalized requirements" Θ as follows:

$$\tilde{\Delta}_p = \varphi\left(\Theta - \Xi\right), \tag{2}$$

where φ is the fuzzification function, that is, the function of reducing the numerical value of the delta deviation Δ_p to a fuzzy form.

The delta deviation $\tilde{\Delta}_p^{dev}$ for the "Executor" party, which may include a number of the role types of the network structure agents, is calculated in the following manner:

$$\tilde{\Delta}_p^{dev} = \varphi\left(\Theta_{req} - \Xi_{cap}\right), \tag{3}$$

where Ξ_{cap} are the key competences of the "Executors", corresponding to the capabilities Ξ from (2); Θ_{req} are the requirements of the "Customer", corresponding to the requirements Θ from (2); φ is the fuzzification function.

The delta deviation $\tilde{\Delta}_p^{inv}$ for the "Customer" party is calculated similarly:

$$\tilde{\Delta}_p^{inv} = \varphi\left(\Theta_{risc} - \Xi_{res}\right), \quad (4)$$

where Ξ_{res} is the resource potential of the "Customer", corresponding to the capabilities Ξ from (2); Θ_{risc} are the existing project risks, corresponding to the requirements Θ from (2); φ is the fuzzification function.

For the indicators of capabilities Ξ and requirements Θ, we can specify some interval scales of quantitative values that normalize the estimates of the indicators in the interval $[0,1]$.

The capabilities of the "Executor" Ξ_{cap}, the seriousness degree Θ_{req} of the requirements placed on the Executor should be evaluated by the expert method. The risks Θ_{risc} that arise before the "Customer" should also be estimated using the method of expert assessments:

$$Z_i = \frac{\sum_{j=1}^{N} Ex_{ij}^{*} \cdot W_j}{\sum_{j=1}^{N} W_j}, \quad (5)$$

where in the place of indicator Z_i there can be Ξ_{cap}, Θ_{req} or Θ_{risc}; Ex_{ij}^{*} is the expert assessment of indicator Z_i by the j-th expert; W_j is the weight coefficient of the competency of the j-th expert; $\sum_{j=1}^{N} W_j = 1$; N is the number of experts in the expert commission.

A two-sided scale of risk assessment Θ_{risc} allows taking into account not only the danger and the degree of risk with a bias toward the probability of occurrence, but also the deviations in the opposite direction, reflecting the positive probability of achieving a successful outcome by the object of assessment. Read more on scaling uncertainty and risk in the study Kuzmin (2015). The advantage of a two-sided risk assessment scale is that it combines in the same indicator the likelihood of risk and the likelihood of success, which, in the usual interpretation, are opposite random variables.

The translation of risk assessments from a two-sided qualitative scale to a numerical form is carried out in accordance with Table 1.

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Table 1. Translation of assessments of the Customer's risks from a two-sided qualitative scale to a numerical form [compiled by the authors]

Level of risk value by qualitative scale	Quantitative risk assessment
Has a sharp negative impact	-0.50
Generates appreciable hindrances	-0.25
Has no significance whatsoever	0.00
Contributes to success to some extent	0.25
Creates noticeable positive conditions	0.50

Expert assessments should be carried out according to qualitative scales specified as follows:

$$\{"Very\,low"; "Low"; "Normal"; "Much"; "Very\,much"\} \rightarrow \{-0.5; -0.25; 0; 0.25; 0.5\} \tag{6}$$

As one can see, initially the expert assessments are proposed to be implemented in both directions, that is:

$$-0.5 \leq Ex_{ij} \leq 0.5, \tag{7}$$

where Ex_{ij} is non-reduced expert assessment of the i-th indicator by the j-th expert.

Accordingly, the reduced estimate Ex_{ij}^{*} is obtained as follows:

$$Ex_{ij}^{*} = 0.5 + Ex_{ij}. \tag{8}$$

Due to the fact that the distribution of expert assessments is subject to a normal law (Voshchinin , 2004), the fuzzification function φ can be exponential or normal (Gaussian) (Ryzhov, 1998).

The so-called s-function is defined as follows:

$$s(x,\alpha,\beta,\gamma) = \begin{cases} 0 \text{ for } x \leq \alpha \\ 2^{\left(\frac{x-\alpha}{\gamma-\alpha}\right)^2} \text{ for } \alpha \leq x \leq \beta \\ 1 - 2^{\left(\frac{x-\gamma}{\gamma-\alpha}\right)^2} \text{ for } \beta \leq x \leq \gamma \\ 1 \text{ for } x \geq \gamma \end{cases}, \tag{9}$$

where α, β, γ are numerical parameters.

The graph of the exponential s-function has the form:

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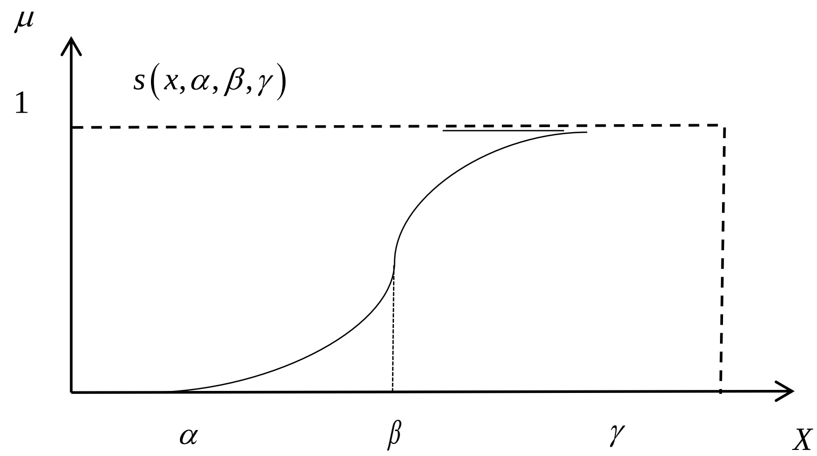

Fig. 2. Graph of the fuzzy set membership s-function in the form of an exponential curve

Source: (Ryzhov, 1998)

The so-called π-function is defined as follows:

$$\pi(x,\beta,\gamma)=\begin{cases} S\left(x;\gamma-\beta,\gamma-\frac{\beta}{2};\gamma\right) & \text{for } x\le\gamma \\ S\left(x;\gamma,\gamma+\frac{\beta}{2},\gamma+\beta\right) & \text{for } x\ge\gamma \end{cases}, \quad (10)$$

where β, γ are numerical parameters.

The graph of the normal π-function has the form:

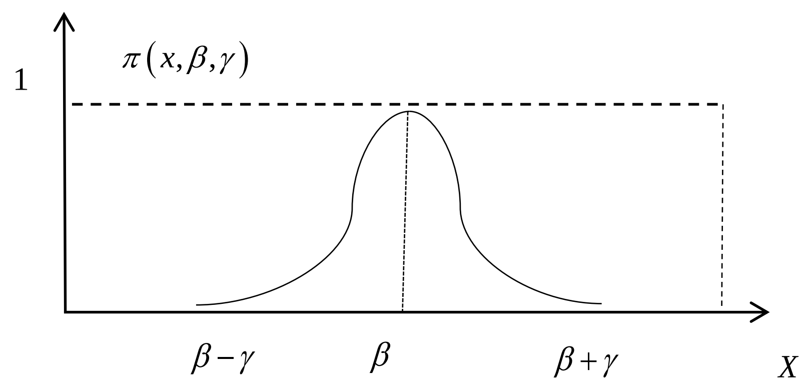

Fig. 3. Graph of the fuzzy set membership π-function in the form of a normal distribution

Source: (Ryzhov, 1998)

In this case, the function φ is also defined for negative values due to displacement along the abscissa coordinate axis; therefore, in Figures 2 and 3, the parameter β should be considered equal to zero.

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The resource potential Ξ_{res} of the "Customer" is estimated by the indicator method using the formula (Kalachikhin, 2014):

$$\Xi_{res} = \sqrt[n]{\prod_{i=1}^{n} \frac{R_i}{C_i}}, \qquad (11)$$

where R_i is the quantity of the available resource of the i-th type available for the "Customer", C_i is the quantity of the resource of the i-th type required for the Customer. In this case, n types of resources are taken into account, whereas the number of available and necessary resources is counted by grouping with respect to expenditure items and cost estimates.

The resource potential Ξ_{res} of the "Customer" in relation to the project for the creation of innovative products within the framework of the network structure makes it possible to determine how the allocated resources cover the expected costs.

The block diagram of the algorithm for optimizing the network structure of enterprises on the basis of estimates of fuzzy deviations of the generalized capabilities of enterprises from generalized requirements is shown in Figure 4.

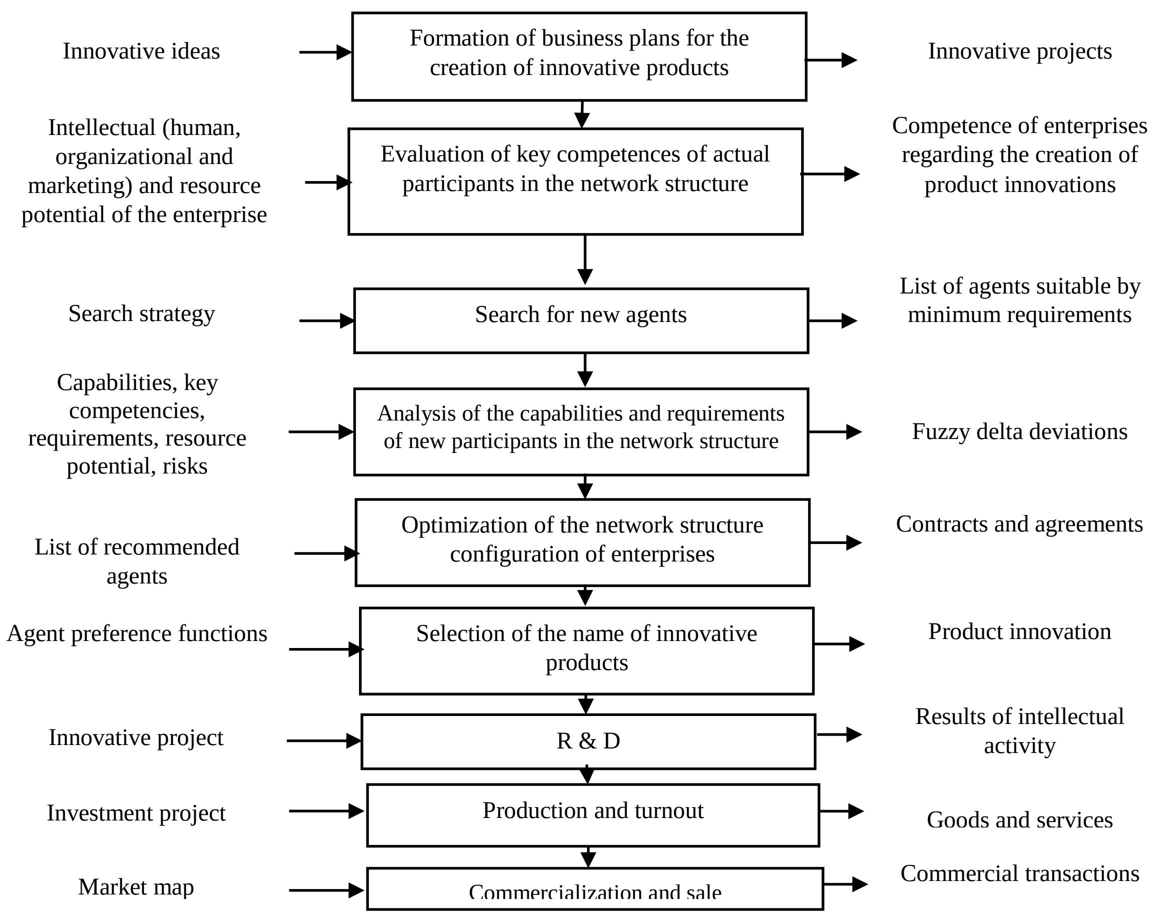

Fig. 4. Optimization algorithm for network structure configuration [compiled by the authors]

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The parties (participants in the value chain, alias, enterprises-nodes of the network structure) will make efforts to maximize their own benefit. In this case, further relations between the parties will have the form of a chain of transactions, that is, from a proposal to agreement and further to the conclusion of an agreement.

The need for turning to ABC (activity-based costing) is due to several factors. They include new evidence of financial gain, the emergence of new-generation information technology to provide operational information to decision makers. ABC can be used to predict at the operational level whether the amount of allocated resources is sufficient to provide the necessary actions (activities and projects), but the ABC method is not able to reliably measure the short-term impact of management decisions at the operational level (Turney, 2010).

In the cases when operational-level management includes specific simplification and standardization of production processes, the use of ABM (activity-based management) at the strategic level does not offer a reconsideration of competencies; however, neither ABC nor ABM can function if the business activity is not related to cost objects or expenditure items. Strategic changes are important for the enterprise, but cannot be characterized as financial actions, since this term is already defined in ABC and ABM (Armstrong, 2002); therefore, in this context the term transaction is more appropriate.

4.3. Formation of the network structure

The choice of the main and only product innovation in the conditions of limited resources should be carried out on the basis of agent preferences, but for different enterprises the preference functions are different, so they can be written down only in the most general form. In practice, the use of preference functions is equivalent to applying a complex criterion for choosing the best alternative, which in turn is associated with multi-criteria optimization methods.

In their original meaning, the preference functions are associated with the law of diminishing utility and other categories discovered by S. Jevons, C. Menger, L. Walrs and F. von Wieser. We will use the term "preference functions" as a certain generalized criterion that allows any enterprise or some other agent to make the most profitable decisions for choosing, thereby optimizing the objective function of its own effectiveness. Thus, it becomes possible to conclude favorable *contracts* between the "Customer" and the "Executor".

Let us make the convention that each agent must make either a negative decision y^-, refusing to conclude contracts, or a positive decision y^+ on the same issues. In the first case, the utility function of such a solution equals zero, since the agent does not get any benefit, but on the other hand, does not lose anything. In the second case, the agent receives, with some probability V_i, some income D_i, which, generally speaking, may be also negative, that is, a loss. The expected utility function $U(y)$ of such decision y^+ has the form:

$$U\left(y^+\right) = \sum_{i=1}^{k} V_i \cdot D_i, \qquad (12)$$

where the index i runs through the values for each of the possible k scenarios of the development of the innovation project.

Thus, when an agent chooses one of the two alternatives y^- and y^+, it is necessary to be guided by the value of the expected utility function. However, for (12), the determination of a complete set of k scenarios for the development of an innovative project, as well as an accurate calculation of the probabilities V_i and expected benefit D_i for each scenario, are connected with difficulties, because there is always uncertainty about the future course of events.

It is exactly for this reason that, to choose an agent preference function, instead of substituting the income D to the von Neumann-Morgenstern function $U(y)$ of expected utility (von Neumann, & Morgenstern, 1970), we will use the delta deviations of the agents generalized capabilities from generalized requirements imposed on them by other participants of the network structure. The fuzzy deviation of generalized capabilities from generalized deviations must be calculated for enterprises in order for each of the parties to assess whether it is profitable to participate in an innovative project.

Each of the enterprise-agents belonging to one of the parties (there may be several such pairs in the value chain) has a certain limit of resources that it needs for further activity, and, based on its own interests, puts forward certain requirements for partners. At the same time, it may happen that the enterprise does not have any information about the market at all, or has such information by using an electronic platform as an information broker when looking for agents. In the first case, with closed access to information about potential agents, the situation is described using the non-cooperative game model (Gubko *et al*., n.d.), whereas the second case of open access to information about potential agents can be considered in the framework of a cooperative game with coalition (Smagin, 2008). In both cases, enterprises will seek to conclude only mutually beneficial contracts. If the terms of the agreement turn out to be mutually beneficial, then enterprises within the network structure should begin to negotiate. During the negotiations, the terms of the mutually presented requirements are repeatedly reviewed. At the same time, from the point of view of creation of innovative products within the whole network structure of the enterprises, the configuration of the network structure formed on the basis of contracts, reflecting some equilibrium solution for each pair of agent enterprises, seems to be the most profitable.

Thus, the parties arrive at conclusion of a mutually beneficial contract in the sense of (Langlois, 1992). In the calculation, the delta deviation of the capabilities and requirements of agents turn out to be closely intertwined, but the creation of an innovative product proves to be beneficial to all parties. Indeed, the "Executor" dictates the cost of the forthcoming works, which is included in the resource potential Ξ_{res} of the customer (4). In turn, the "Customer" sets forth the requirements Θ_{req} that the "Executor" must fulfill (3).

The enterprise can only perform actions that are similar to movement along one or another dimension. One of the limitations of capabilities is that enterprises must connect with other enterprises. This often happens through the most ordinary market contracts. The viewpoint on the capabilities of enterprises assumes that the boundaries of the enterprise are determined (at least partially) by the relative strength of internal and external capabilities, that is, the capabilities within the enterprise, accessible through a contract with other enterprises. Any capability of an enterprise is a matter of knowledge.

In the network structures of enterprises there is a need to coordinate innovations through the production stages. Suppose that an enterprise decides to carry out a specific activity within itself instead of relying on the market. This should mean that the enterprise has an advantage in terms of value in comparison with the market.

On the other hand, all enterprises must rely on the capabilities belonging to others, especially to the extent that the capabilities of others are different from those that the enterprise has. The enterprise is able to acquire different capabilities, additional to those that it already possesses.

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The most vivid examples of the types of network structures of enterprises are production clusters and scientific-innovation networks. A production cluster is defined as a group of commercial enterprises and non-profit organizations involved in purchase and sale agreements, joint technologies and distribution channels (Kozhukhivska et al., 2017). Constancy and diversity have a significant impact on the innovative capabilities of the enterprise clusters (Xu, 2018). Science-innovation networks form an environment that is highly suitable for cooperation, and are usually formed to create innovative products or pursue the goal of technology transfer (Câmara et al., 2018).

Thus, the technology transfer is, in fact, a choice that is up to the enterprise. Instead of producing by oneself, one can teach others how to produce and convince them to act just in that fashion. Similarly, an enterprise that decided to provide entry to the market might have acquired the necessary capabilities of internal production (Langlois, 1992).

Contracts and agreements are concluded in such a way as to minimize both delta deviations $\tilde{\Delta}_p^{inv}$ and $\tilde{\Delta}_p^{dev}$ separately:

$$\begin{cases} \phi\left(\tilde{\Delta}_p^{inv}\right) \to min \\ \phi\left(\tilde{\Delta}_p^{dev}\right) \to min \end{cases} \tag{13}$$

where p is the product innovation; ϕ is the defuzzification function.

The principle underlying the hypothesis of our research, stated earlier, is formalized as follows:

$$\phi\left(\tilde{\Delta}_p^{inv} \otimes \tilde{\Delta}_p^{dev}\right) \to min \tag{14}$$

where ϕ is the defuzzification function; $\otimes$ is the operation of fuzzy multiplication, which according to (Blyumin *et al*., 2002), is defined for fuzzy numbers $\tilde{A}$ and $\tilde{B}$ as follows:

$$\mu_{A\otimes B}\left(x\right) = \begin{cases} \sup\limits_{a\in\left(R/(0)\right)} \left\{\min\left\{\mu_A\left(a\right), \mu_B\left(x=a\right)\right\}\right\}, \text{ if } x \neq 0 \\ max\left\{\mu_A\left(0\right),\ \mu_B\left(0\right)\right\},\ \text{ if } x = 0 \end{cases}, \tag{15}$$

where p is the product innovation.

The defuzzification function ϕ in (13) and (14) is defined as the "center of gravity" (Zhdanov, & Karavaev, 2002):

$$\phi\left(\tilde{\Delta}\right) = \frac{\int_{-\infty}^{+\infty} x \cdot \mu\left(x\right) dx}{\int_{-\infty}^{+\infty} \mu\left(x\right) dx}, \tag{16}$$

where $\mu\left(x\right)$ is a continuous membership function of the values of the fuzzy set $\tilde{\Delta}$, where $\mu\left(x\right) = s\left(x\right)$ (9) or $\mu\left(x\right) = \pi\left(x\right)$ (10).

The defuzzification transformation ϕ should be more accurately called a functional (Trenogin, 1980).

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The formula (13) describes the situation of closed access to information about potential agents. The formula (14) describes the situation with open access to information about potential agents. Thus, everything depends on what information the “Customer” and the “Executor” have about each other, so that the parties can find and see each other. When such information is sufficient, it will be easier for enterprises to optimize delta deviations and conclude mutually beneficial contracts. It follows precisely from this that for the effectiveness of the network model of business when searching for agents it is necessary to use the services of information brokers in the form of e-platform services.

To each agent Ψ, we need to put into correspondence the threshold value Δ_{max}^{Ψ} of delta deviation, above which the enterprises are not recommended to go. The configuration of the network structure must be adjusted in such a way that the combinations of delta deviations $\tilde{\Delta}$ of the new agent and its counterparties are optimized when substituting into additive or multiplicative objective functions (13) and (14).

In the course of this study, we touched on the problem of how enterprises should find their counterparties in order to get the opportunity to establish cooperation. We are counting on the idea of creating an intelligent system capable of configuring the network structure of enterprises based on an analysis of their capabilities and requirements with respect to the creation of innovative products with specified properties. In this case, a big plus will be if such a system is able to provide useful and understandable recommendations to users in a convenient form. Such a software tool should be based more on management (as well as on retrieval, detection) of non-formalized knowledge than on intellectual data analysis. All the rest of the work will be undertaken by algorithms created on the basis of production rules and other tools of intelligent systems.

5. Conclusion

The present study is focused on the network structures of enterprises that carry out their activities priarily in the basic high-tech sectors of the economy. In the course of the study, we constructed an economic-mathematical model, based on which it is possible to justify making decisions on attracting additional agents into the network structures of enterprises. We propose to implement such decisions on the basis of analysis of estimates for the deviations of generalized capabilities from generalized requirements for each of the potential new agents.

According to the model of optimizing the configurations of enterprise network structures, at the first step it is necessary to determine whether the joint resource potential of the enterprises included in the network structure is sufficient to create an innovative product with specified characteristics, and if it is not enough, whether it is necessary to attract additional agents, thereby widening the scope of the network structure. Then, at the second step, a decision should be made whether it is worth investing in this innovative product or its development is not profitable. Such a decision should be made on the basis of assessments of key competences of the actual participants in the network structure of enterprises, which in our earlier publications are calculated by the expert method using the production rules of fuzzy logic. A specificity of the economic-mathematical model proposed by the authors is the use of fuzzy sets allowing reducing the degree of uncertainty in the input data for performing calculations.

As a result of critical consideration, we came to the conclusion that a more suitable model is such model, where, instead of a pair of two decisions, only one decision is used, but a more constructive decision concerning which companies need to be invited to successfully create a specific innovative product. For this, it is proposed to use the ontology of the network business model.

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