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DEVELOPMENT OF METHODOLOGY FOR EFFICIENCY EVALUATION OF CLUSTER INTERACTION OF INDUSTRIAL ENTERPRISE

Запропонована методика оцінки ефективності кластерної взаємодії. Методика враховує кількісні та якісні параметри базових напрямків кластерної взаємодії і ґрунтується на використанні теорії нечітких множин. Запропонована методика дозволяє оцінити ефективність кластерної взаємодії як комплексно, так і за окремим напрямком на рівні окремого промислового підприємства.

Ключові слова: *кластерна взаємодія, промислове підприємство, оцінка ефективності кластерної взаємодії, теорія нечітких множин.*

1. Introduction

It is generally recognized that the era of isolated, closed industrial enterprises has disappeared. In modern world and domestic practice, a new trend is emerging more clearly, associated with the integration of various business entities, leading to an increase in their competitiveness and reducing the risks of economic activity. In their activities, enterprises use various development strategies, the most effective of which are strategies aimed at strengthening economic relations through the creation of various kinds of alliances and associations, unions and associations of industrialists and entrepreneurs. Particular attention is also paid to clusters – as a modern form of production cooperation.

World experience convinces that one of the effective ways to activate the development of an industrial enterprise is cluster interaction, which is based on the partnership of enterprises in the cluster, which significantly reduces the costs and efforts for competitive rivalry and allows to combine the advantages of enterprises. The main motives for cluster interaction are improving the quality of products and services, access to information related to research and new developments, reducing risks, increasing competitiveness, combining the advantages of enterprises in various areas of activity. It allows the enterprise to reduce transaction costs, stimulate the processes of innovation and diversification of activities, expand sales markets and develop international cooperation [1]. Therefore, for effective economic activity of an industrial enterprise within a cluster, it is necessary to develop and apply modern methods for assessing the efficiency of cluster interaction at the level of an industrial enterprise.

At present, the methodological and practical foundations of cluster interaction of industrial enterprises require detailed study, and the absence of a scientifically based methodology for a comprehensive efficiency assessment of cluster interaction of an industrial enterprise, taking into account the quantitative and qualitative factors of influence, does not allow industrial enterprises to determine the most promising areas of their interaction with cluster participants.

2. The object of research and its technological audit

The object of the study is to evaluate the efficiency of cluster interaction.

It should be noted that efficiency evaluation of cluster interaction is a complex issue, because: first, the objectives of cluster interaction and the characteristics of its areas can vary significantly at each individual enterprise; second, the cluster interaction of the enterprise is affected by a significant number of different factors in various combinations, which are difficult to take into account, but necessary; third, some factors can't be quantified quantitatively, and the qualitative evaluation is approximate; fourth, efficiency evaluation of cluster interaction with the help of an integral indicator may be inaccurate, despite significant errors in its formation; fifth, taking into account the fact that cluster interaction can be carried out in various spheres of the enterprise's economic activities, the evaluation methodology should provide for the establishment of a link between quantitative and qualitative indicators. According to the authors, such connection can ensure the use of fuzzy set theory, which was laid in 1965 by Professor Lotfi Zadeh [2]. Advantages of applying fuzzy set theory is that fuzzy models contain different types of parameters, formalize dependencies of varying complexity and have a high adaptation of expert data.

3. The aim and objectives of research

The aim of the research is the theoretical development of a methodology for efficiency evaluation of cluster interaction of an industrial enterprise based on fuzzy set theory, which makes it possible to decide on the most effective directions of such interaction, taking into account quantitative and qualitative factors of influence.

To achieve this aim, the following tasks are defined:

1. To analyze existing methodological approaches to efficiency evaluation of clusters.

2. To form the basic directions of cluster interaction.

3. To develop a methodology for evaluation of cluster interaction at the level of a single industrial enterprise,

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taking into account quantitative and qualitative factors of influence.

4. Research of existing solutions of the problem

The development of theoretical aspects of the clustering of the economy at the macro level is performed by well-known foreign scientists [3–11]. Thus, one of the first studies in this area is the work [3], in which, although no special terms are indicated, it is obvious that a cluster with a sufficiently deep specialization of enterprises is investigated. In order to identify and study the interrelationships of large Swedish corporations, an innovative dynamics of their development are investigated in [4] due to interaction within clusters. In [5] the formation of clusters is explained by the need to create technological links between sectors and spheres of the economy. In works [7, 8] special attention is paid to the development of interrelations of industries in the cluster, is directly related to the competitiveness of regions and the country as a whole. It is also noted that the main competitive advantages of the company depend on its suppliers, partners, subsidiaries, etc.

Development of methodological approaches to efficiency evaluation of clusters is given more attention in the works of domestic scientists [12–16] and scientific works of scientists from the near abroad [17, 18].

Thus, in [12], it is proposed to use indicators selected in three groups (analysis of indicators of economic activity, evaluation of cluster management results, and economic feasibility of management activities in a cluster) for analyzing and evaluating the management activity of an entrepreneurial cluster. It also suggests the use of certain indicators to evaluate the economic effects of public-private partnerships within the framework of cluster activities, which, in the opinion of the author, allow the most comprehensive evaluation of the effects of cluster initiative in the form of an entrepreneurial cluster at the regional level.

Methodological approach that allows to evaluate the synergetic effect from the creation and functioning of a cluster based on economic, social, innovative and tax effects is proposed in [13].

In [14], the author believes that it is not necessary to reduce the overall evaluation of cluster functioning to a single indicator, since the effect of clustering can manifest itself in various spheres and suggests a methodology for multifactorial evaluation of cluster performance in terms of the timeliness of implementing joint projects of cluster participants and achieving its goals, including indicators: timeliness of implementation of projects and activities in the process of cluster creation; obtaining planned project results; achieving the objectives of the cluster.

Determination of the economic efficiency of the cluster project implementation, as the excess of the results obtained from the cluster activity in value terms over the value expression of the aggregate expenditures of the cluster for the entire period of its operation is proposed in [15].

Efficiency evaluation of the machine-building cluster on the basis of forecasting scenarios («inertial», «organizational», «modernization», «target») development of cluster enterprises and quantitative economic and social indicators of their activities at the micro- and meso-level is proposed in [16]. Profitable indicator of the realization of development scenarios is profit. The presence of such generalized indicator allows to investigate the general dynamics of cluster development and also to compare the efficiency of different clusters with each other.

There is a methodology for efficiency evaluation of cluster structures, which is based on the final integrated assessment of the qualitative indicators of cluster performance, including micro- and macro-level [17].

In [18], the existing methods for efficiency evaluation of cluster functioning in the industry at the level of the system of design, management and state regulation of cluster activities are considered. Among the existing methods are: cluster size evaluation, social efficiency evaluation, target efficiency evaluation, rating evaluation methodology, economic efficiency evaluation based on the integral indicator, which is proposed to be supplemented with evaluation of the financial expenditures of the state budget to support the cluster and the relative coefficient of the price premium.

The analysis of methodological approaches allows to draw a conclusion about the existence of different approaches to efficiency evaluation of cluster activities, both on the scale of the cluster itself and at the regional level, which allow to evaluate the different types of effects from the creation of clusters in the region and the participation of individual enterprises in these clusters.

At the same time, for all the variety of methodological approaches to efficiency evaluation of the clusters, there is a problem of the methodology for efficiency evaluation of cluster interaction at the level of a single industrial enterprise, taking into account the quantitative and qualitative factors of influence that would make it possible to take decisions on the most promising areas of cluster interaction directly for the enterprise-participant of the cluster.

Traditional methods of multifactor analysis of complex economic systems do not allow describing the cause-effect relationship between the parameters of impact and the predicted value using factors that take into account qualitative indicators. Therefore, to evaluate the cluster interaction, the authors propose to use fuzzy set theory, which allows to make optimal decisions taking into account quantitative and qualitative parameters [19].

5. Methods of research

To solve the tasks, the following methods are used: critical analysis and generalization of theoretical studies, abstract-logical, algorithmic, graph-analytical methods and fuzzy logic method.

6. Research results

Development of an industrial enterprise largely depends on the nature and degree of its interaction with various market actors. Cluster interaction is based on the necessity to use the competitive advantages of partner enterprises and formation and expansion of contractual relations. Development of cluster interaction positively influences the increase in the efficiency of the industrial enterprise, contributing to the achievement of a qualitatively new level of technological development, organization of production and management in all other spheres of economic activity.

The main sign of the existence of cluster interaction is cooperation between cluster participants (suppliers, competitors, educational, research and scientific organizations, buyers, consultants, etc.).

The efficiency of cooperation depends on the level and quality of the components of cluster interaction. Based on the analysis of methodological approaches to efficiency evaluation of cluster interaction of an industrial enterprise, the authors form the basic directions of cluster interaction, containing the following components:

1) production interaction – interaction in the formation of material and technical base, strategic business planning; cooperation in the production process;

2) technologically innovative interaction – creation and implementation of technological innovations; transfer of technological innovations; patenting, use of scientific results in related industries, as well as in joint projects;

3) financial and economic interaction – interaction in the sphere of organization of work with credit and financial institutions, investment projects, use of funds for R&D, reconstruction and technical re-equipment and other goals;

4) personnel interaction – interaction in the sphere of selection and provision of personnel, training and professional development;

5) information interaction – interaction in the exchange of information and provision of consulting services on legal, financial, industrial and other issues;

6) marketing interaction – interaction at carrying out of marketing actions and the organization of distributive process and sale of production;

7) management interaction – interaction between the cluster participants, which ensures coordination of actions in the cluster to overcome emerging problems and achieve the goals.

To determine the efficiency of the cluster interaction of an industrial enterprise, taking into account the quantitative and qualitative factors of influence on the basis of fuzzy set theory, the authors develop the evaluation methodology given below [20].

The methodology for cluster interaction evaluation includes five stages.

Stage 1. Construction of derivation tree. Derivation tree reflects the hierarchical relationship between input variables, input variable classes and output variable (integral indicator) represented as a tree (Fig. 1), to which the system of relations (1–8) corresponds.

Linguistic variable Y can be represented as:

$$Y = f_y(X_1, X_2, X_3, X_4, X_5, X_6, X_7), \quad (1)$$

where X_1 – linguistic variable (LV), describing the industrial interaction of enterprises; X_2 – LV, describing the technologically innovative interaction of enterprises; X_3 – LV, describing the financial and economic interaction of enterprises; X_4 – LV, describing the personnel interaction of enterprises; X_5 – LV, describing the information interaction of enterprises; X_6 – LV, describing the marketing interaction of enterprises; X_7 – LV, describing the management interaction of enterprises.

Linguistic variable, describing the production interaction of enterprises, can be represented by the expression:

$$X_1 = fx_1(X_{11}, X_{12}, X_{13}, X_{14}), \quad (2)$$

where X_{11} – LV «volume of sales»; X_{12} – LV «share of product updates»; X_{13} – LV «level of growth in the volume of orders»; X_{14} – LV «level of resource intensity».

Linguistic variable, describing the technologically innovative interaction of enterprises, can be described by relation:

$$X_2 = fx_2(X_{21}, X_{22}, X_{23}), \quad (3)$$

where X_{21} – LV «level of costs for technological innovation in the total amount of the company's expenses»; X_{22} – LV «level of expenditure on R & D in the total amount of the company's expenses»; X_{23} – LV «share of innovative products (new or significantly improved) in the total output»; X_{24} – LV «level of new or improved technological innovations»; X_{25} – LV «level of profit from the introduction of technological innovation».

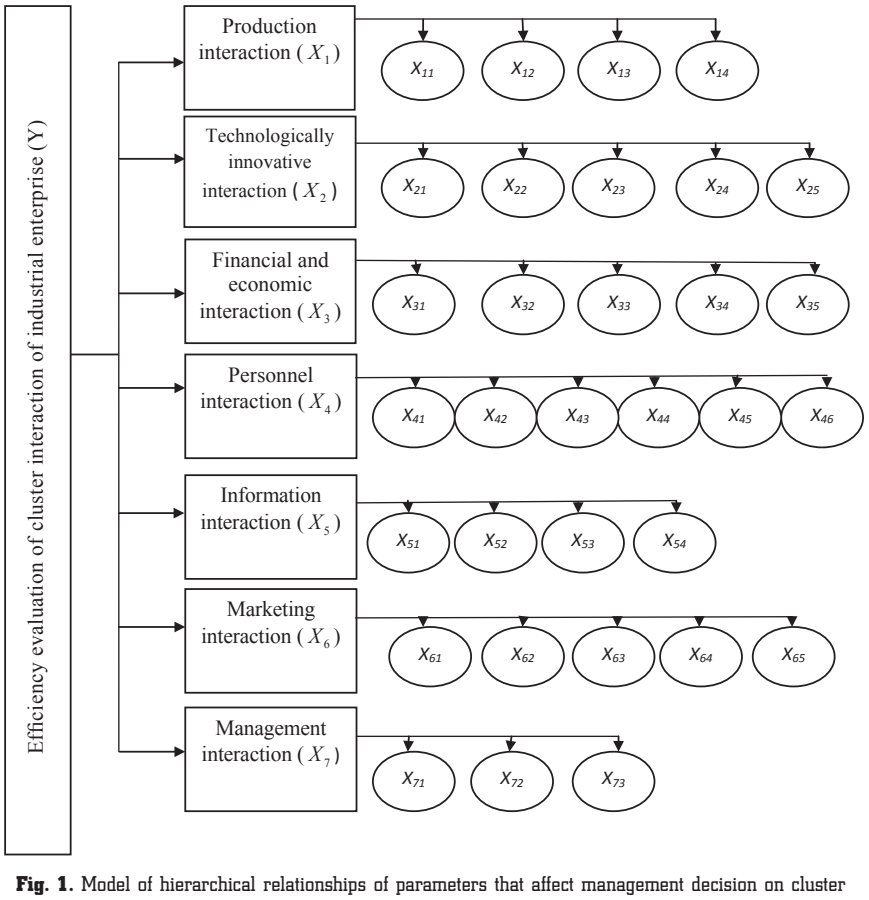

Fig. 1. Model of hierarchical relationships of parameters that affect management decision on cluster interaction efficiency of industrial enterprise

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Linguistic variable, describing the financial and economic interaction of enterprises, can be given by the relation:

$$X_3 = fx_3(X_{31}, X_{32}, X_{33}, X_{34}, X_{35}), \quad (4)$$

where X_{31} – LV «volume of investments in the development of the company»; X_{32} – LV «solvency ratio»; X_{33} – LV «share of costs per unit of value of sold products»; X_{34} – LV «level of reconstruction and technical re-equipment»; X_{35} – LV «volume of access to the financial services market».

Linguistic variable, describing the personnel interaction of enterprises, can be given by the relation:

$$X_4 = fx_4(X_{41}, X_{42}, X_{43}, X_{44}, X_{45}, X_{46}), \quad (5)$$

where X_{41} – LV «share of highly skilled workers in the total number of employees»; X_{42} – LV «educational level of the administrative personnel»; X_{43} – LV «proportion of personnel engaged in R & D»; X_{44} – LV «level of inventive and rationalization activity of employees»; X_{45} – LV «level of labor productivity»; X_{46} – LV «share of costs for training and retraining of personnel».

Linguistic variable, describing the information interaction of enterprises, can be described by the expression:

$$X_5 = fx_5(X_{51}, X_{52}, X_{53}, X_{54}), \quad (6)$$

where X_{51} – LV «number of new cooperation programs»; X_{52} – LV «level of participation in new projects»; X_{53} – LV «volume of the state order»; X_{54} – LV «level of application of modern information technologies».

Linguistic variable, describing the marketing interaction of enterprises, can be given by the relation:

$$X_6 = fx_6(X_{61}, X_{62}, X_{63}, X_{64}, X_{65}), \quad (7)$$

where X_{61} – LV «volume of funds for market research»; X_{62} – LV «level of positions in existing markets and development of new markets»; X_{63} – LV «expenses for the sale of products»; X_{64} – LV «volume of sale of products»; X_{65} – LV «level of assortment expansion».

Linguistic variable, describing the management interaction of enterprises, can be represented in the form:

$$X_7 = fx_7(X_{71}, X_{72}, X_{73}), \quad (8)$$

where X_{71} – LV «efficiency of resource allocation and development of internal and external communications»; X_{72} – LV «level of risk»; X_{73} – LV «level of efficiency of using modern methods of organization and management of scientific, technological and production activities».

Stage 2. Factorization of factors that provide for the selection of fuzzy terms for linguistic evaluation of factors and formalization of these terms using membership functions. An example of the constructed membership function for a linguistic variable describing the share of the updated product (X_{12}) is shown in Fig. 2. The universal set of linguistic variable «share of product updates» is adopted for a 10-point scale and described by terms for the evaluation: low, medium, high.

Stage 3. Construction of fuzzy knowledge matrices. The results of a virtual experiment are referred to as a fuzzy knowledge matrix. The expert answers the question: what will be the linguistic evaluation of the output indicator when a combination of linguistic estimations of the factors.

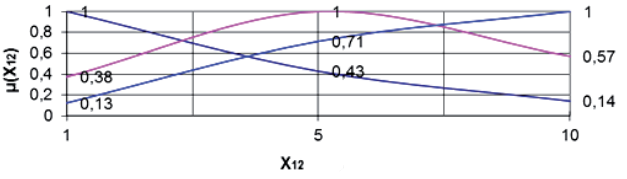

Fig. 2. Membership function for LV «Share of product updates»: X_{12} – point

Stage 4. Fuzzy inference is formed on the basis of the obtained fuzzy knowledge matrices. The fuzzy inference technique applied to the information collected in the previous stages allows to calculate the index that is predicted in the form of a fuzzy set using IF-THEN system of statements linking the fuzzy terms of the input and output variables using AND and OR operation in fuzzy set theory [19, 20]. With the help of these equations, the functions of belonging to different levels of input and output variables are associated with the proposed derivation tree of hierarchical parameter relationships that affect the management decision on the efficiency of cluster interaction of an industrial enterprise.

Stage 5. Defuzzification of the output indicator. To move from the resulting fuzzy set of quantitative assessment, it is necessary to perform a defuzzification procedure, which means turning fuzzy information into a clear form [21]. The model of fuzzy inference together with the defuzzification procedure provides an opportunity to observe changes in the initial indicator, namely, the efficiency of cluster interaction of an industrial enterprise with variation of the impact factors.

7. SWOT analysis of research results

Strengths. Strength of research is the further improvement of the methodological support of the processes of efficient functioning of an industrial enterprise in a cluster. The developed methodology can be used by a specific industrial enterprise to efficiency evaluation of the forms and directions of cluster interaction, taking into account the quantitative and qualitative factors of influence.

The use of fuzzy logic in efficiency evaluation of interaction in an enterprise cluster makes it possible to operate with fuzzy input data, perform a qualitative assessment of both input data and output results, and simulate complex dynamical systems and their comparative analysis with a given degree of accuracy without using complex mathematical models.

Weaknesses. Weakness is that using a qualitative evaluation of the factors influencing the cluster interaction of an industrial enterprise, an expert evaluation is used that is subjective and may be incomplete and contradictory; therefore, in order to make effective management decisions, cluster experts should carefully select experts.

Opportunities. Opportunities for further research consist in the practical application of the proposed methodology in industrial enterprises, which will expand the forms and directions of cluster interaction.

Threats. Threats to further research are that real and reliable information about the activities of clusters of in-

dustrial enterprises in Ukraine is difficult to obtain, since official practice and statistics are not available.

8. Conclusions

1. The analysis of existing methodological approaches to efficiency evaluation of clusters is carried out, which showed that insufficient attention is paid to efficiency evaluation of cluster interaction at the level of the enterprise-participant in the cluster. The proposed traditional methods of multifactorial analysis of complex economic systems do not allow to describe the cause-effect relationships between the parameters of impact and the predicted value using factors that take into account qualitative indicators. Therefore, to evaluate the cluster interaction, the authors propose to use fuzzy set theory, which allows to make optimal management decisions, taking into account the quantitative and qualitative parameters.

2. The basic directions of cluster interaction are formed, containing the following components: production interaction, technologically innovative interaction, financial and economic interaction, personnel interaction, information interaction, marketing interaction, management interaction.

3. A methodology for integrated evaluation of cluster interaction is developed, which takes into account the basic directions of cluster interaction on the basis of quantitative and qualitative indicators of production, technology innovation, financial and economic, personnel, information, marketing and management interaction on the basis of fuzzy set theory, which will allow making optimal management decisions on the efficiency of cluster interaction of an industrial enterprise, both comprehensively and by its individual directions.

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РАЗРАБОТКА МЕТОДИКИ ОЦЕНКИ ЭФФЕКТИВНОСТИ КЛАСТЕРНОГО ВЗАИМОДЕЙСТВИЯ ПРОМЫШЛЕННОГО ПРЕДПРИЯТИЯ

Предложена методика оценки эффективности кластерного взаимодействия. Методика учитывает количественные и качественные параметры базовых направлений кластерного взаимодействия и основывается на использовании теории нечетких множеств. Предложенная методика позволяет оценить эффективность кластерного взаимодействия, как комплексно, так и по отдельным направлениям на уровне отдельного промышленного предприятия.

Ключевые слова: кластерное взаимодействие, промышленное предприятие, оценка эффективности кластерного взаимодействия, теория нечетких множеств.

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