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DEVELOPMENT OF A METHODOLOGY FOR CREATING ADAPTIVE ENERGY EFFICIENCY CLUSTERS OF THE ARCHITECTURE AND CONSTRUCTION INDUSTRY

Об'єктом дослідження є процес створення адаптивних кластерів енергоефективності архітектурно-будівельної галузі. На сьогоднішній день важливим є вирішення інфраструктурних проблем енергозбереження, тому дослідження направлено на розробку методології створення функціонально стійких адаптивних кластерів в умовах стрімко зростаючого дефіциту енергоресурсної бази.

Одним з найбільш проблемних місць є системні властивості кластерів, які часто стають причиною неадекватності моделей, що розробляються, для перспективного планування та розробки стратегії розвитку кластерних організаційних структур.

В ході дослідження процесів формування і прогнозування можливих сценаріїв розвитку кластерів архітектурно-будівельної галузі особлива увага приділяється аналізу особливостей, що пов'язані з інертністю процесів будівництва та тривалістю життєвого циклу об'єктів будівництва. Зазначені особливості суттєво знижують надійність прогнозування на тривалі проміжки часу за рахунок невідомості і ризиків різного характеру. Методологія, що розробляється, ґрунтується на імітаційному моделюванні різних траєкторій розвитку кластерів та впровадженні швидких адаптивних алгоритмів зі зворотним зв'язком. Це пов'язано з тим, що сценарії розвитку кожної сформованої кластерної структури лишаються багатоваріантними на протязі усього життєвого циклу внаслідок дії різних суперпозицій факторів впливу середовища. При імітаційному моделюванні вибір найкращих умов кластеризації, що здатні забезпечити максимальний синергійний ефект, ґрунтується на прогнозах, які проводяться з урахуванням різних показників зовнішніх впливів. Множина ймовірних змін в зовнішньому середовищі та ступінь впливу системних властивостей на механізм адаптації кластерів, на даному етапі розробки, визначаються і оцінюються експертами.

Вибір найкращого управління пропонується здійснювати на основі системного аналізу результатів обчислювальних експериментів, що забезпечить формування оптимальної за заданими критеріями структури кластерів та їх адаптивність до швидких і непередбачених змін середовища. Описано процес розробки математичного інструментарію для моделювання оптимальної, за показниками енергоефективності, структури кластеру.

Ключові слова: адаптивне управління, архітектурно-будівельна галузь, ефективний об'єкт, кластер енергоефективності, стратегічний розвиток.

1. Introduction

Analysis of the world modern market environment shows that the conditions of a crisis economy, energy shortages and financing encourage individual business entities to search for strategic sustainability by conducting interrelated activities. One of the essential factors of economic development and the evolution of socio-economic systems is the formation of clusters.

Clustering according to the principle of optimizing energy efficiency indicators in the architecture and construction industry makes it possible to identify public and private business entities, the interaction of which will make it possible to achieve economic growth in the industry as a whole and each individual subject. At the same time, after clustering, it is possible to implement effective management systems for cluster structural units in order to improve interconnections and control resource sharing between them.

The main subjects of clustering should be energy generating and construction enterprises, housing and communal services and final consumers, the combination of which into cluster structures should lead to a reduction in energy consumption. The advantages that such actors receive are in the realization of synergistic opportunities and emergent properties of the cluster as a system. At the same time, a significant increase in the stability of clusters as a whole is possible by improving the conditions for promoting innovative energy efficient technologies and reducing the level of uncertainty in the supply, distribution and sale of resources [1, 2].

However, the system properties of clusters often cause inadequate models that are developed for forward planning and development strategies for the development of cluster organizational structures [3]. That is why the work aimed at the development of scientific and methodological foundations of the methodology for creating adaptive clusters remains relevant.

2. The object of research and its technological audit

Most often, a cluster is a network of enterprises for inter-sectoral interdependence, localized by geographic proximity or a combination of interrelated enterprises and organizations that reinforce and complement each other's competitive advantages [4]. There are other definitions of clusters [5, 6]. However, in any case, the common for all clusters is the formation of an organizational structure from subjects of different profile activities, aimed at achieving a common goal [7].

The object of research is the process of creating adaptive clusters of energy efficiency in the architecture and construction industry.

The economic conditions in which the clusters of the architecture and construction industry have recently been created and are operating rapidly change. This imposes certain requirements on strategic management, determines the formation of new goals, mechanisms and tools, not only in current activities, but also in the long term.

In the framework of the energy saving program, as a priority to improve the economic security of the country [8], it is planned to introduce energy efficient technologies and economical consumption of energy resources. The implementation of these activities in the construction industry will affect the volume and structure of their operating and investment costs.

However, the implementation of these measures by housing and public utilities, energy generating enterprises and end users, combined into cluster structures, should lead to a reduction in energy consumption and the redistribution of financial flows.

Thus, in the internal environment of the cluster, forms of economic relations arise that are different from cooperation and competition. Modeling such relationships, taking into account the influence of system properties on the mechanism of cluster formation, is one of the biggest problems. Another problem, which remains throughout the entire life cycle of a cluster, is the multivariance of possible scenarios and the ambiguity of the choice of management decisions. This problem is associated with the inertia of the construction processes and the duration of the life cycle of construction objects.

These problems significantly reduce the reliability of forecasting for long periods of time due to uncertainty and risks of a different nature, associated with stochastic changes in the external environment [9]. The main task, which it is necessary to solve in the described conditions, is the search for approaches to modeling various scenarios for the development of cluster associations.

The scientific substantiation of the decisions made in the described conditions requires the development of appropriate tool support for modeling the effects of management and working out the decision-making methodology. This will ensure the formation of the cluster structure that is optimal according to given criteria and their adaptability to rapid and unpredictable changes in the environment.

3. The aim and objectives of research

The aim of research is development of a methodology for creating adaptive energy efficiency clusters of the architecture and construction industry in fuzzy conditions.

Achieving the aim determines the need to solve the following objectives:

1. To propose a scheme for developing instrumental support of the methodology for creating adaptive energy efficiency clusters of the architecture and construction industry in fuzzy conditions.
2. To propose an adaptive feedback control algorithm based on computational experiments with synthetic analog models that imitate the activities of structural units and the cluster as a whole.

4. Research of existing solutions of the problem

The problems associated with clustering processes, which are aimed at improving competitiveness, business efficiency and facilitating the promotion of innovations, are investigated in [4, 5]. However, in these works it is about the association of enterprises that are similar in their activities and are in the same region. Such clustering is carried out according to the criterion of territorial proximity of enterprises of the same industry.

In [1, 10], various theoretical approaches to the classification of clusters based on various criteria are considered. However, the problem lies in the lack of approbation of the classification system.

The authors of [11, 12] highlight the problems:

- organization and management of clusters;
- competitive advantages and competitiveness management;
- implementation of innovations and attraction of investments by the enterprises of the cluster;
- determination of the effectiveness of cluster activities and their impact on the ecology and the environment.

The stages and methods of conscious cluster formation, the experience of many countries in organizing clusters are indicated in [13]. However, this paper does not disclose the methodology for creating adaptive clusters.

Among the main directions of solving the problem of developing a methodology for creating adaptive clusters found in the resources of world scientific periodicals may be noted [14, 15], but they do not consider the possibility of including enterprises and organizations of other industries in the cluster structure.

A review of scientific sources [16, 17] allows to state the existence of the scientific problem of forming the theoretical and methodological foundations for creating effective clusters under the conditions of a rapidly growing shortage of the energy resource base. Optimization in terms of energy efficiency in clustering allows to identify those market subjects, which interaction will allow achieving economic growth of the cluster as a whole, taking into account the needs of each structural unit [17].

In [18], a system of relations between the structural units of the cluster is explored, which opens access to joint resources and stimulates the search for optimal and innovative solutions to common problems.

As a toolkit for determining the best for clustering elements, such methods as stochastic limiting analysis and nonparametric method are used [19]. However, these methods do not allow analyzing clusters and their structural units by many parameters simultaneously. In addition, foreign models of clusters require appropriate adaptation to the infrastructural economic, political and technologi-

cal conditions of Ukraine. To solve this problem, in [8], a conceptual model for designing energy-efficient clusters of the architecture and construction industry is proposed, according to which a cluster is synthesized as a result of criterion selection from a variety of implementation subjects, capable of ensuring the coordinated performance of certain functions. Designing a cluster model involves the transition from setting the «goal» to the task of «functions» and the definition of «structure», which contains a finite set of functional elements and the relations between them. At the same time, clustering involves the implementation of effective management systems for the structural elements of clusters in order to improve interconnections and control resource allocation.

From the point of view of process management, it is about the formation of a mechanism for optimizing joint business processes of cluster enterprises. In this formulation, the task of forming a cluster management mechanism can be solved on the basis of monitoring and analyzing the deviations of the expected values of key performance indicators from the results of computational experiments of a modeled cluster organizational structure. But there remain the issues of creating a dynamic reference model of cluster functioning and the development of efficient algorithms for comparing real cluster structures with a standard.

In simulation, the selection of the best clustering conditions that can provide the maximum synergistic effect should be based on forecasts that are made taking into account various indicators of external influences. At the same time, the multicomponent cluster structure is considered as a system capable of adapting to external influences represented by economic, resource, environmental and social factors.

The management of a system operating on the basis of such models consists in setting up the internal parameters of the economic and mathematical equations that model its cluster activity [20, 21]. But it is necessary to take into account that the expected value of the integral indicator of the functioning of the system can be provided by various sets of parameters.

The development of computer technology has expanded the set of modeling tools in the face of uncertainty through the introduction of models and methods of fuzzy mathematics, evolutionary modeling and artificial neural networks. In [22, 23], the models, methods and tools developed for comparing effective objects are investigated, but they are not adapted to the conditions of this task, requiring the acquisition of special software and personnel training.

Thus, the results of the analysis allow to conclude that:

- generalized and descriptive recommendations on the creation and functioning of territorial clusters and conceptual models of clusters of renewable energy are not able to provide a solution to the infrastructure problems of energy saving in the architecture and construction industry;
- experience of creating cluster schemes is described on the example of countries that have long been working in a market economy [13];
- introduction of the latest information technology modeling cluster structures requires additional material and intellectual costs.

In addition, there are other questions on this issue, which still remain unresolved or have a debatable character.

5. Methods of research

When performing the work, various research methods were used, including:

- system analysis – to simulate the synergistic properties of the cluster;
- abstractions and analogies – for the construction of key indicators and the rationale for many explanatory factors;
- simulation based on dynamic quasilinear equations – for estimating energy efficiency indicators;
- combinatorial analysis – to create a set of superpositions of environmental influences;
- expert method – to assess the system's response to possible changes in the environment.

6. Research results

The realization of the advantages of energy efficiency clusters over traditional associations is possible only with the introduction of an effective mechanism for their formation and the implementation of adaptive management based on adequate models for predicting the activities of clusters [9, 24].

If the conditions of the functioning of the cluster structural units are substantially changed, then forecasts based on the modeling of the performance of the subjects of implementation based on past statistical data provide the opportunity to:

- determine the future level of the objective function;
- identify and evaluate significant development potentials;
- identify management problems;
- identify sources and assess the internal reserves of the cluster structural units.

Cluster adaptation to insignificant changes in the environment is carried out by setting the parameters of the management model.

Configuring the parameters of the adaptive feedback control model consists of:

- in the assignment of unmanaged variables of the economic-mathematical model of numerical values that these variables can acquire as a result of the effects of various superpositions of financial, energy, environmental, material, social and man-made factors to current conditions;
- by varying the values of the coefficients of the controlled variables in order to achieve the expected value of the objective function.

Such variation reflects the adaptation of the system to a changing environment.

The parameter setting algorithm is described in detail in [24]. A schematic representation of the settings of the model parameters, according to which control is exercised, is shown in Fig. 1.

The main source of inadequacy of models for forecasting is the lack of reliable information about the future state of the external environment. Rapid stochastic changes in various interrelated external factors of a modern unstable economic environment are accompanied by risks that most likely lead to internal changes in the system. The situation is complicated by the fact that it is not always clear at the beginning of changes in the environment that managing the development of such a complex system as a cluster requires changing the strategy, since for some time the problem is «solved» by setting the parameters of the existing model.

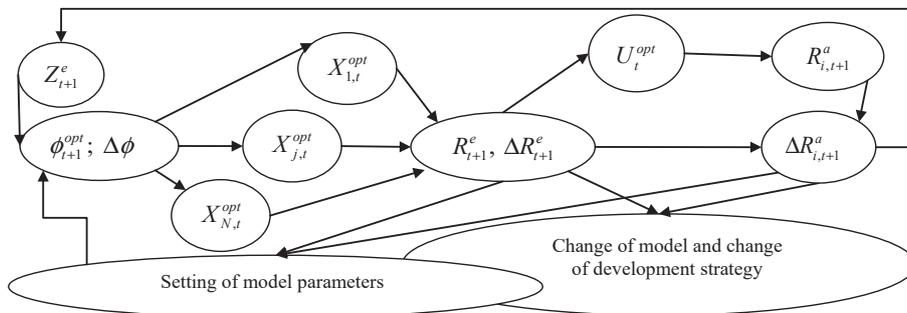


Fig. 1. Schematic representation of the process of setting the parameters of the model [24]:

Z_{t+1}^e – a function that reflects the expected influence of the external environment; ϕ_{t+1}^{opt} – the expected value of the objective function; $\Delta\phi$ – the limit of tolerance from the expected value; $X_{1,t}^{opt}$, $X_{j,t}^{opt}$, $X_{N,t}^{opt}$ – the best values of the controlled variables; R_{t+1}^e – the expected value of a key indicator of cluster activity; ΔR_{t+1}^e – the expected value of a key indicator of cluster activity; R_{t+1}^a – the actual value of the key activity indicator; $\Delta R_{t+1}^a = R_{t+1}^a - R_{t+1}^e$; U_t^{opt} – control function; t – time period

The scientific substantiation of the decisions made in the described conditions, first of all, requires the development of appropriate mathematical tools for modeling the effects of management and working out the decision-making methodology that will ensure the formation of the cluster structure that is optimal according to specified criteria.

Mathematical tools are called «model-method» pairs for predicting the performance of enterprises.

The instrumental support of the methodology for creating adaptive energy efficiency clusters of the architecture and construction industry is developed on the basis of simulation modeling and is intended to simulate changes in the internal environment of clusters that can occur during structure transformation.

The development of the methodology (Fig. 2) is carried out according to the scheme; it is a generalization of the developments [9, 24].

Tool builder – a specially formed and trained group of specialists whose duties include:

- analysis of information about the state of the environment;
- development of economic and mathematical models of performance;
- justification of the strategic development of subjects of implementation and implementation of feedback.

In addition, in Fig. 2 and in the context of the work:

- *expert* – highly qualified specialist, who determines

the knowledge characterizing the problem, and ensures the completeness and correctness of the knowledge entered into the system;

- *subject of implementation* – a business unit that plans to integrate into a cluster organizational structure in order to achieve high levels of energy efficiency;
- *standard* – a similar company, the development model of which is selected for the simulation modeling of the development of the implementation subject.

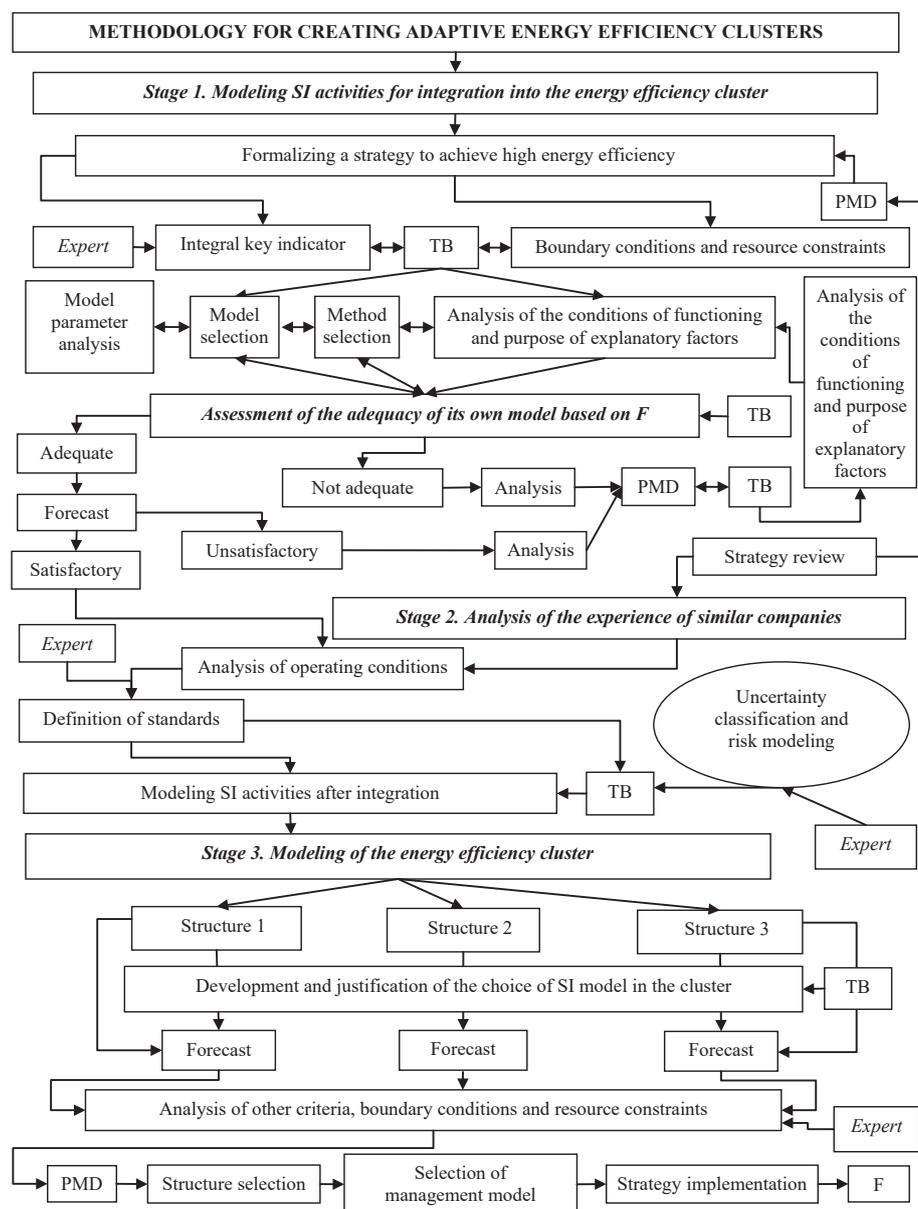


Fig. 2. Scheme for the development of instrumental support of the methodology for creating adaptive energy efficiency clusters of the architecture and construction industry: PMD – person authorized to make decisions; TB – tool builder; SI – subject of implementation; F – feedback

The integral key indicator – the objective function – the main criterion of optimization – the indicator best describes the degree of achievement of a strategic goal or the assessment of the consequences of management as a whole [1, 8].

According to the structure of the cluster are divided into the following [11, 13]:

- in which large companies form a core, around which small firms are grouped (structure 1);
- consisting of small and medium-sized enterprises (structure 2);
- having a fragmented dynamic structure (structure 3).

The formation of a system of key indicators for planning and managing the internal combined resources of cluster organizational structures, from the standpoint of optimizing the structure of the system in the face of uncertainty, remains unique in each case. It is proposed to analyze not only the experience of those companies that are planning to integrate, but also the experience of other companies that functioned or function under similar conditions.

7. SWOT analysis of research results

Strengths. The strengths of the proposed methodology include the disclosure of the significant potential of enterprises by identifying production capacity and labor potential, are not used.

Multivariate modeling also allows to:

- optimize the cluster structure based on scientifically based forecasts of the activities of the implementation subjects;
- quickly detect the loss of model adequacy due to controlling based on feedback;
- time to adapt the cluster's activities to environmental changes based on adequate models.

The simulation process takes into account:

- features of the geographical location of the country as a whole and certain of its regions, the geopolitical component;
- ability of business entities to optimize the distribution of their own resources.

Weaknesses. The weaknesses of the research include:

- imperfection of clustering development programs and state support;
- lack of perfect legislation on the clustering of the economy;
- a small interest in introducing innovations into the economy;
- there are no partnership skills with foreign colleagues;
- low awareness of cluster type integration;
- there is no motivation in the community of cluster members.

Opportunities. The opportunities for research include:

- increasing opportunities for specialization and innovation; due to the introduction of new technologies, the competitiveness of cluster members is increasing;
- rational and effective use of available resources and attracted investments;
- creation of single financial centers, financial support for cluster members;
- coordination of the actions of the cluster members through effective marketing and implementation of organizational and economic measures.

Threats. Research threats include:

- economic, political and legislative risks;
- restriction of customs and tax laws;
- strengthening state regulation.

8. Conclusions

1. A scheme for the development of instrumental support of the methodology for creating adaptive energy efficiency clusters of the architecture and construction industry is proposed. The methodology is based on simulation modeling of various trajectories for the development of clusters of various structures and the implementation of fast adaptive algorithms with feedback.

2. An algorithm for adaptive feedback control is proposed based on computational experiments with synthetic analog models, which makes it possible to maintain the functional stability of clusters under conditions of rapid stochastic changes in the environment. Cluster adaptation to risks of a different nature is ensured by a set of possible development strategies that are tested at the stage of structure selection.

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