Formal description model management of cluster structures in construction

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Abstract. Modern organizational forms organization of construction production are cluster structures. Currently, work is underway to develop, formalize and describe the processes of interaction and management within these structures. This article provides a theoretical description of the cluster structure management model based on the system technical management model through logistic interpretation. This work defines and describes a number of limitations for the developed model.

1 Introduction

Construction, as a branch of material production, is characterized at present by the complexity of the tasks being solved. To start implementation process of activities aimed at achieving this goal should be the use of new organizational forms and methods, the most potential of which are cluster structures.

Construction cluster as a model of representation of the organizational structure has specific features due to the fact that it has a wider functional and target decomposition. Cluster integrates to all components of production process to the investment cycle: from suppliers of material and technical resources to consumers of final construction products, including the service sector and specialized infrastructure.

However, the construction cluster, as a combination of technologically and organizationally interrelated independent economic entities, has a more complex management model than the traditional general contract scheme. Further in the article disclose the theoretical description of the system technical model of cluster structure management in the sphere of construction production is revealed.

2 Description of the system engineering management model in the logistic interpretation

As is known, the vector of state is important for determining the dynamic behavior of the technical-economic system, which is investment and construction activity, and its formalized description. Also, one of the distinctive features of the technical and economic system is that its state often characterized by a multidimensional vector.

As in any technical and economic system, in investment and construction activities it is

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possible to distinguish two sides of its behavior – internal and external behavior, between which there is unity.

In this regard, the state vector z_t of the management model contains information about volume of construction production, labor productivity, efficiency and profitability of construction, etc. u_t label the management vector, which reflects the fundamental decisions in relation to investment and construction activities.

According to the above, the mathematical description of the system technical control model has the following General form:

$$z_{t+1} = G_t(z_t, u_t, x_t), \quad (1)$$

where: x_t -input vector, which contains information about the need for material, technical, labor, information, financial and other resources.

Based on the logistic interpretation of the model, the area of acceptable management measures U for sustainable growth is established and is a product of sets U_i :

$$U = U_1 \times U_2 \times \dots \times U_k. \quad (2)$$

U_1 designation of the area of permissible values of the I -th component of the control vector.

Turning to the direct description of the management of cluster structures, we considered the option of clusters (territorial, sectoral and corporate), operating on the basis of integrated structures, for example, in the framework of public-private partnerships.

The General form cluster management model in comparison to the above-described management model of the technical system in the logistic interpretation, is supplemented by a number of re-strictions, for example the method of using resources due to both territoriality and specific conditions on construction sites.

The system of restrictions of mathematical control model has the following form:

$$\sum_{t=0}^T H_t(z_t, u_t, x_t) = \lambda. \quad (3)$$

Through T , the boundaries of the corresponding forecast period are indicated, and λ is a vector that is given on the basis of the program of development of the integrated structure.

Depending on the area of acceptable management measures, the organizational structure of management, dynamics and constraints, based on traditional methods of forecasting and logistics, the observed and achievable areas of growth, as well as management areas.

Given the fact that the challenge is to improve the efficiency of the investment and construction sector, the management system within the achievable area limits the zone P_t , which means overall progress. In defining this zone, the governing body of this level of hierarchy takes into account the need to increase the return on investment in construction, while the current interests should be in harmony with the future.

Control of the system development in the so-called progress zone is carried out using the vector of output values. The components of this vector y_t relate to the size and structure of the construction cluster, as well as indicators of investment and construction activities, the level of productivity, etc.

The development of the construction cluster as a technical and economic system in the established progress zone P_t is described by the expression

$$y_t = \varphi_t(z_t, u_t, x_t) \in P_t. \quad (4)$$

Thus, the mathematical model of management of investment and construction activity within the cluster (territorial, branch, corporate) consists of the following equations:

1. $z_{t+1} = G_t(z_t, u_t, x_t);$
 2. $\sum_{t=0}^T H_t(z_t, u_t, x_t) = \lambda;$
 3. $y_t = \varphi_t(z_t, u_t, x_t) \in P_t.$
- (5)

From a large number of trajectories determined by this management model during the

iterative optimization process, we select those that provide optimal balanced and proportional growth of the cluster in the space of investment and construction activities.

In order to optimize the model, different target functions are given and different growth trajectories are simulated. In this regard, such a growth path is chosen, which most fully corresponds to the selected target. Related to systems engineering model of management of investment-construction activities within the cluster of the target function must enforce that the trajectory of growth that contribute to the increase of investment profitability in construction. These functions have the following general form:

$$\max I(z, u) = \max \sum_{t=0}^T \beta_t(z_t, u_t, x_t). \quad (6)$$

Thus, the system technical control model is transformed into a dynamic optimization model.

Due to the use of logistics algorithms, the system technical model of investment and construction activities within the cluster supports the optimal management model

$$\tilde{u}_t = \zeta(z_t, z_{t-1}, \dots, z_{t-k}, x_t, x_{t-1}, \dots, x_{t-k}). \quad (7)$$

The trajectory of optimal, balanced and proportional growth is characterized by dependencies:

$$z_{t+1} = G_t(\tilde{z}, \zeta_t(\tilde{z}, x), x_t), \quad (8)$$

$$u_{t+1} = \varphi_t(\tilde{z}, \zeta_t(z, x), x_t). \quad (9)$$

The distribution of resources, forces and funds on the fronts of the work provides a more complete involvement of participants in the investment and construction activities and, ultimately, the growth of its efficiency.

The system technical model of development of investment and construction activities in the selected aspect (territorial, sectoral, corporate) operates on an iterative principle. The dynamic nature of the model is expressed in the equation:

$$G_{t+1}^i = (1 - \mu_t^i) G_t^i + \sum_{\tau=0}^{\Theta_i} \lambda_{t-\tau}^i u_{t-\tau}^i, \quad (10)$$

In this equation: μ_t^i - coefficient taking into account the manufacture of construction products at the expense of own funds; G_t^i - the volume of construction production of the i -th enterprise cluster at the beginning of year t ; $\lambda_{t-\tau}^i$ is the share of investments realized in year $(t - \tau)$ i -th enterprise cluster and transforming in year t in the construction products; Θ_i - the period of exploration investment by the i -th enterprise of the cluster; u_t^i - basic adjustable amount of investments implemented by the i -th enterprise cluster in year t .

The following are restrictions for this model:

1. Restrictions on the use of human resources.

One of the goals of the system technical model is to identify the possibility of development of investment and construction activities within the cluster and at the same time ensure full employment of labor resources (both male and female). Since enterprises have a specialization or orientation towards certain types of work, they differ in the level of male and female labour force use, a restriction is adopted for each group of labour force

$$\sum_i \eta_t^{i,s} A_t^s = \hat{A}_t^s, \quad (11)$$

In this equation: $\hat{A}_t^s$ - the amount of labor resources to be employed in year t (for the male group of labor resources $s = 1$, for the female group $s = 2$); $\eta_t^{i,s}$ - the share of male or female labor force in the enterprise I cluster, and

$$\eta_t^{i,1} + \eta_t^{i,2} = 1 \quad (12)$$

2. Limitations of material and technical resources.

Investment and construction activities require material and technical resources, but their cluster structure should be developed in such a way as to prevent overspending, i.e. to avoid overspending.

$$\sum_i \delta_t^{i,j} Q_t^j \leq R_t^j. \quad (13)$$

In this relation, Q_t^i is the amount of work on the objects of the I -th enterprise of the

cluster in year t ; $\delta_t^{i,j}$ means the specific consumption of the j -th resource in the I -th enterprise of the cluster in year t , and R_t^j - the available amount of resource type j in year t . It is assumed that the standards $\delta_t^{i,j}$ are reduced, for example, due to measures aimed at reducing the consumption of materials, scientific and technological progress, etc.

3. General restriction.

In systems engineering model development of the cluster the device investment and construction activities (territorial, sectoral or corporate aspect) should be set lower limits related to performance, profitability, construction, salaries, etc., however, aim to exceed these lower limits.

3 Discussion

The content of the iterations of the model is to determine the necessary level of labor productivity and the average level of wages of workers (for this region, this industry or company) based on the goals and related General indicators of construction production.

Subsequent iterations take into account the limitations of the upper and middle limits within which the volume of construction production can be located, as well as the volume of distributed resources, including centrally, for example, in the framework of public-private partnership. These restrictions take the following form:

$$\hat{A}_{t,k} \geq \sum_i a_{t,k}^i \cdot Q_t^i, \quad (14)$$

$$\hat{B}_{t,k} > \sum_i b_{z,k}^i \cdot Q_t^i. \quad (15)$$

Unknown to the model are the values of z_t^i , the investments required by the objects of the I -th enterprise of the cluster in year t . Unknown z_t^i can be determined under the additional condition that the value of $\sum_t \sum_i z_t^i = \min$, the goals are carried out with minimal investment. In the case when all relations of the model are linear, a linear dynamic optimization model is obtained.

Results of the model contains:

$Z_t = \sum_i z_t^i$ – total annual investment required;

$Z_t^{\text{external}} = \sum_i \omega_t^i z_t^i$ – annual volume of necessary investments provided by external sources.

Through ω_t^i the share of necessary investments attracted from external sources in the total volume of investments in the objects of the I -th enterprise of the cluster is indicated.

The other resulting values of the model:

$A_{t,k} = \sum_i a_{t,k}^i \cdot Q_t^i$ – required amount of centrally allocated resources from own sources;

$B_{t,k} > \sum_i b_{z,k}^i \cdot Q_t^i$ – required number of resources.

The results obtained with the help of this model should be supplemented by other studies aimed at ensuring the sustainable development of investment and construction activities, taking into account the cluster representation of its organizational structure (in territorial, sectoral, corporate aspect). Also this model, integrated into the sphere of knowledge about the probabilistic spatial growth of the investment and construction sector, can be a useful tool for practical forecasting and planning of construction, as well as for the management of systems at this hierarchical level. The model can participate in the description of processes and in the space of the national economy, and help to determine the ways of its development. As promising areas for further research, we specify:

1. Methodological basis for identifying opportunities to work with constraints.
2. Improving the scientific and methodological basis of the management decision-making procedure.

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