Modeling the sustainable development of innovation in transport construction based on the communication approach

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Abstract. The article proposes the models of innovative activity development, which is driven by the formation of "points of innovation-driven growth". The models are based on the analysis of the current state and dynamics of innovative development of construction enterprises in the transport sector and take into account a number of essential organizational and economic changes in management. The authors substantiate implementing such development models as an organizational innovation that has a communication genesis. The use of the communication approach to the formation of "points of innovation-driven growth" allowed the authors to apply the mathematical tools of the graph theory in order to activate the innovative activity of the transport industry in the region. As a result, the authors have proposed models that allow constructing an optimal mechanism for the formation of "points of innovation-driven growth".

1. Introduction
While developing scientifically based approaches to solving the problem of activating innovative activity, there is no escaping from mentioning the clearly observed fractality during the formation of innovative development in the hierarchy presented as "the level of the country - the level of the region - the regional construction complex - the backbone enterprise of the regional construction complex - the construction enterprise" [1]. Innovative development process is influenced by a large number of organizational factors. Converting the system of management of innovative activity in the region and its improvement, first, mean a change of organizational relationships and consequently organizational forms of management [2]. The effectiveness of organizational changes in the activities of the regional management system is correlated with the conditions of the external environment, with fluctuations in the economic cycles of business activity, with implemented and spontaneous organizational and economic changes, and with the communication system of the region, its enterprises and industries [3].

When developing an innovative strategy, especially at the level of the regional construction industry, the authors find important to take into account the regional specifics of the center for innovation spreading in accordance with the "neighborhood effect" of T. Hagerstrand. According to the theory of "diffusion of innovations", firstly it is necessary to create an agglomeration which is a center for the innovation development, and then its diffusion into the territory of the region should occur. Such activities can be considered as organizational innovations.

The conducted researches allow to make a conclusion that the literature often considers technological innovations, but it pays much less attention to managerial or organizational innovations [4]. Communicative nature of organizational processes is reflected in the specifics of this type of innovation, which should be considered when developing models of promoting innovative activity in the region.
The need to consider the communication aspects of organizational innovations and the consideration of the "neighborhood effect" during the development of the region's innovative development strategy confirm the relevance of this study [5].

2. Materials and Methods

Because adaptation to innovations is irregular, there is a need to place enterprises in such a way, that the "neighborhood effect" would be implemented in order to increase the speed of diffusion of innovations. Therefore, while creating a promising innovation policy and developing a strategy of a construction organization that significantly improves its investment and construction activities, it is necessary to provide the stimulation of innovation processes by introducing modern methods of strategic management of regional zoning and creating "points of innovation-driven growth" which consider the institutional, economic, organizational, information-analytical and regional aspects of management.

When developing the mechanism of the formation of "points of innovation-driven growth", not only the territorial aspect of the "neighborhood effect" should be taken into account, which promotes the diffusion of innovations against "center-periphery" model (which is a horizontal projection of diffusion of innovations according to the authors’ opinion), but also the possibility of inter-industry diffusion of innovations (which can be represented as a vertical projection of the diffusion process), that can be promoted by the cluster principle of organizing the productive forces in the region. Practically such a principle can be realized by creating industrial parks with cluster location of enterprises belonging to various industries. Realization of the revealed "neighborhood effect" projections is possible while developing a scientifically based strategy for regional zoning. At the same time, special economic zones of the region can be defined as "points of innovation-driven growth". Concerning the horizontal projection, the creation and agglomeration of innovations within the special economic zone are occasioned by the proper economic mechanisms of impact on the SEZ resident enterprises (a system of benefits which may involve preferences for innovators). Similar conditions can be provided for industrial parks either. Accommodation of residents in the SEZ by a cluster basis helps to activate the diffusion of innovations in the vertical projection. The circuit diagram of the influence of "points of innovation-driven growth" on the diffusion of innovations is presented in Figure 1.

![Circuit diagram of the influence of "points of innovation-driven growth" on the diffusion of innovations](image)

**Figure 1.** Circuit diagram of the influence of "points of innovation-driven growth" on the diffusion of innovations

Further development of formation models of regional "points of innovation-driven growth" is impossible without justification of the corresponding theoretical basis. From the analysis of the concepts of "organization", "innovation", "management" and the retrospective analysis of approaches to
managing the organization, it was found that the creation of "points of innovation-driven growth" is an organizational innovation. So, from the semantic analysis it was determined that organizational innovation is a task-oriented change of innovative communication processes in the organization management system with the purpose of transferring it or any element of its system to a new qualitative state which is often characterized by quantitative criteria. (Fig. 2) Regarding to the process of organizational innovation while creating "points of innovation-driven growth", it may be concluded that innovations can be implemented both in defining participants of communication and of their innovative change, and in the process of information transfer and exchange.

In the term of cybernetic approach, while implementing innovation, the communication system represents the information network (communications space), which is reasonable to be presented in the form of a graph, the optimal critical path of which will meet the objective of this communications space (the goal of innovation).

The parts of the communications space and the links between them, representing information flows, can change regarding to several innovations in the internal communications of the region or industry (between elements of the internal environment), due to which innovations in the management structure (the change of centers of the communications space both in vertical and horizontal control) occur, and in management methods (the change of links between the elements of the communications space and their characteristics). Furthermore, organizational innovations can be implemented in a way of changes in communication between an organization (industry) and the external environment (innovations in creating external connections, implemented as changes in the centers of the communications space or in the links between them).

The example of a communication graph for creating "points of innovation-driven growth" in an aggregated form is shown in Figure 3.
Modeling the activation of innovative activity in the region following the communication graph includes the selection of the optimal structure of the communication graph with account of the following aspects: the innovation process duration, costs and effects, determination of the options for implementing organizational innovation for a given duration, a model for aggregating the communication graph.

The possible options for the formation of "points of innovation-driven growth" can be represented as a network. The network ingress is for the beginning of the process, which can include the options for creating a special economic zone or an industrial park, negotiations on the creating of a technological cluster, signing a contract, and other things depending on the operation, which the organizational innovation planning begins with. The network egress corresponds to the end of the process (the implementation of innovation and regional budget earning income, the change in the innovation activity of enterprises). Each peak corresponds to a certain subject or some of its actions aimed at the implementation of innovation. The authors assigned two numbers for each peak of the network: first is for expenses for conducting the proper transaction (including transaction expenses which are inevitable during implementing the communications), second is for the duration of the transaction. These numbers are in the arbitrary form of correlation. The task is to determine the $\mu$ cycle and the duration of all its transactions so that the amount of costs and lost profits is minimal.

Unlike the problem of optimizing the production cycle, in this case one should choose the path $\mu$ in the network (a certain innovation cycle), and then optimize it according to the criterion

$$\Phi = \sum_{i \in \mu} s_i(\tau_i) + F\left(\sum_{i \in \mu} \tau_i\right)$$

(1)

Where $\mu$ is the path in the network describing the innovation cycle; $s_i$ is expenses for the relevant transaction (transaction value); $\tau_i$ is the duration of the transaction; $s_i(\tau)$ is the ratio of costs to duration of the transaction; $F(T)$ is the expected revenue from the implementation of the innovation at time point $T$, which is assessed using the indicator of of profit loss.

In fact, we are dealing with binary optimization consisting in choosing the optimal path and choosing the optimal duration of this path.

Many situations require consideration of the function of forfeits for rejecting the duration of the innovation project from a given value of $T_0$ as a loss function, however, communication graph allows using the criterion of effectiveness or reliability of information instead of the time criterion.

$$F(T) = \begin{cases} \alpha(T-T_0), & \text{when } T \leq T_0 \\ \beta(T-T_0), & \text{when } T \geq T_0 \end{cases}$$

(2)

Since the authors determined that communications mostly reduce to organizational communications during implementing the organizational innovations (representing targeted focus changes), the innovation goal achievement will become the main criterion. Then minimizing transaction expenses and maximizing the efficiency of enterprise communications can be interpreted as limitations of the optimization problem. However, according to the authors a specific method for solving the problem of
multi-criteria optimization of the effect of organizational innovation should be chosen depending on the conditions and the purpose of its implementation.

3. Results
The authors obtained the model for determining variants of the commercial cycle of the project, which is distinguished by the fact that at the first stage the problem should be solved for different values of the directive duration, resulting in the obtainment of the dependence of the minimum costs on the duration, and at the second stage, we solve the the problem of minimizing the function of one variable is being solved, which allows determining the critical path in the technological graph, which minimizes the amount of costs and losses (lost profits).

A modification of the method of dynamic programming is proposed in order to solve the problem of minimizing costs, while limiting the period of implementation of organizational innovation. The modification involves the sequential examination of network peaks (the network is supposed to have no contours and have the correct numbering of any peak, which has its certain place \((i<j)\) for any arc \((i;j)\)). The following problem is solved for each peak: to determine the path with the minimum cost of \(S_i\) \((T)\), among all the paths connecting the ingress with the peak \(i\), taking into account that its duration does not exceed the value of \(T\). Firstone should determine the minimum path length from the ingress to the peak \(i\). Define it as \(A_i\).

**Algorithm description.**

**Step 1.** Consider the peak 2. Set \(S_2(T)=S_{12}, \tau_{12}\leq T\), i.e, \(A_2=\tau_{12}\).

**Step k.** Suppose that the dependences \(S_i(T)\) are defined for all \(i\leq k\). Consider the vertex \((K + 1)\). We define the set of peaks \(i\) by \(Q_{k+1}(T)\). The peaks are such that \(A_i+\tau_{i,k+1}\leq T\) and there exists an arc \((i,k + 1)\)

Define

\[
S_{k+1}(T)=\min \left\{ S_i(T-\tau_{i,k+1})+S_{i,k+1} \right\}, \quad T\geq A_{k+1}
\]

Expression (9) defines the Bellman’s optimality principle for the described modification of the dynamic programming method.

The value of \(S(T)\) is equal to the minimum costs under the condition \(T(\mu)\leq T\). The proof follows directly from the optimality principle (3).

Proceeding from the above, the flowchart of the algorithm for assessing the effectiveness of organizational innovations in the term of the communication approach will have the form (Fig. 4).

Implementing the proposed algorithm results in obtaining the possibility to assess the level of achievement of the innovation aim, taking into account the dynamics of transaction expenses occurred due to organizational innovation (which will also allow to take into account the influence of informal and non-informational communications) and the effectiveness of business communications of a commercial enterprise. The authors believe that the proposed methodology reflects the essence and specificity of organizational innovations, and also enables formalizing the results of the calculation for the purposes of planning and forecasting innovations.
Defining the objectives of organizational innovations

| Strategic objectives | Tactical objectives | Operational objectives |
|----------------------|--------------------|-----------------------|
|                      |                    |                       |

The goal is a strategic direction

Defining the objectives of organizational innovations

Selecting the criteria for achieving the goal of building a model for multicriteria optimization

\[ F = \{ T(K), E(K), C(K) \} \]

Evaluation of transaction costs

\[ T(K) = \sum_{i=1}^{k} t_i \cdot r_i + \sum_{i=k+1}^{n} \]

Integral assessment of the objective achievement level

\[
\begin{align*}
E(K) &= f(D_{PM}, \Theta_D) \rightarrow \text{max} \\
C_{d}(K) &= f(k_{qi}, k_{ui}) \rightarrow \text{min} \\
T(K) &= f(y_1, ... y_n) \rightarrow \text{min}
\end{align*}
\]

Figure 4. Flowchart of the algorithm for assessing the effectiveness of organizational innovation in terms of the communication approach

where \( I_i \) is the cost of one transaction of the \( i \)-th type. \( t_i \) is the time required to complete the \( i \)-th transaction type; \( r_{i}\) is the cost of the time unit of the \( i \)-th transaction type.

4. Discussion

Determination of the conditions for the effective management of innovative activity of the construction organization basing on the formation of regional "points of innovation-driven growth" in the construction sector is the most important stage in the development of the methodology of the a promising innovation policy formation. Making "points of innovation-driven growth" in the region is an organizational innovation, according to the sense and essential features of the concept.

Communicative nature of organizational innovations allows formalizing the communications space of regional innovative development as a graph of innovation process that takes into account the socio-economic character of organizational innovation through determining transaction costs of communications. It is worth noting that the content-related statements of problems for managing organizational innovations on a communication basis, including the problems of optimizing the innovation cycle, can be reduced to the following formal statements. Shall assume that a there is a defined network consisting of an arbitrary number of peaks, the arcs of which correspond to operations representing either communications concerning the creation of the SEZ, or works included into the program of opening an industrial park, etc. Therefore, it is reasonable to optimize the network by the following criteria: costs, duration, efficiency, reliability of information (taking into account the communication nature), etc. The corresponding models are exposed in the article.

As the result of drawing the communication graph, creating "points of innovation-driven growth" and optimization of the graph, it was proved that the mechanism for managing the region and its innovative
development should be formed in accordance with the regional policy of zoning and the functioning of innovation development institutions. However, in the particular calculation case [6,7] the construction should trigger the innovative development, uniting enterprises of various industries in the operation of technological clusters and special economic zones, in the development of infrastructure of a city and a region.

5. Conclusions
The statement about the communicative genesis of organizational innovations, which was accepted as the basic premise of the study, allowed to educe and clarify the factor conditions demanded and sufficient for activating innovative activity in the region [8].

The analysis of the existing models of project management has shown that the main issues regarding to the modeling of organizational innovations can be reduced to formal statements of the graph theory.

Through the introduction of a complex criterion describing the costs and duration of innovation implementing, the authors developed a model for solving the problem of determining the best option for creating "points of innovation-driven growth" in a region. Using this model the authors obtained the optimal solutions of the problem of choosing the most rational ways to implement an innovative organizational change with minor costs and losses representing forfeits for the deviation of the implementation duration from the given value.

A modification of the dynamic programming method is constructed, based on solving a series of problem determination for each peak of the path with minimal costs. Such optimization of the mechanism of regional zoning policy promotes the acceleration of innovation diffusion both in the territory of the country and in the sectoral context, which will provide a synergetic effect of innovative activity.

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