# МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

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# MULTIDIMENSIONALITY OF ORGANIZATIONAL AND TECHNOLOGICAL MANAGEMENT OF TRANSPORT FACILITIES CONSTRUCTION ENTERPRISE

**Purpose.** Justify the relationship of organizational and technological solutions of the transport facilities construction in the management of the enterprise as a whole and decisions on individual projects and submit this relationship in the form of a multidimensional organization structure. **Methodology.** Synthesis, analysis, combinatorial and morphological analysis. **Findings.** The model of business processes relationship, multidimensional organizational structure of such enterprises are developed and analyzed. The possibility of developing a computer model of operating activity of the organization in question is substantiated. **Originality.** Specific factors of the enterprise structure management and methods of the construction enterprise management are highlighted for the first time, their interaction is described. **Practical value.** Optimization of organizational and technological solutions, made in the management of the enterprise as a whole and decisions of individual projects.

*Keywords:* erection of transport facilities; business processes; multidimensional organizational structure; organizational and technological solutions; numerical optimization

## Introduction

A large number of infrastructure facilities and structures represent transport industry in Ukraine. Many of them need repair works, reconstruction or at least continuous monitoring. Specific conditions of realization of transport facilities construction projects and the analysis of the traditional organizational structures of management show that the management structures of specialized enterprises require appropriate organizational transformation. This transformation will increase the efficiency of management practices of such enterprises. As a result, the study of organizational management structures of the transport facilities construction enterprises is an urgent task.

## Purpose

Justify the relationship of organizational and technological solutions of the transport facilities construction in the management of the enterprise as a whole and decisions on individual projects and submit this relationship in the form of a multidimensional organization structure.

The objectives of the work:

1. Develop a three-stage scheme of consistent modeling of the operating activities of the transport facilities construction enterprise.
2. Analyze the business processes relationship model of the enterprise under consideration.
3. Develop a multidimensional organizational structure, which simulates the relationship of organizational and technological solutions of the transport facilities construction in the management of the enterprise as a whole and decisions on individual projects.
4. To prove the possibility of numerical optimization of organizational and technological solutions of this enterprise by developing a computer model of its operating activity in the graphical-analytical form.

## Analysis of the literature

Currently, Ukrainian railways operate about 19, 5 thousand man-made structures. Among them, there are about 7500 railway bridges, 11000 tubes and trays, 80 tunnels, overpasses, pedestrian bridges and other engineering structures [5]. These facil-

ities are located throughout the territory of Ukraine and can be different in scale [13]. However, many of them need repair works, reconstruction or at least continuous monitoring [1, 12].

The development of Ukrainian transport infrastructure requires arrangement of specialized transport facilities, which are characterized by different geographical dispersion and production scale of the works necessary for their construction.

Analysis of organizational structures types of enterprises showed that the most common types are linear, linear-staff, project, matrix, multidimensional. The difference of these structures lies in different priorities of vertical and horizontal managerial relationships between their elements. Matrix and at most multidimensional structures have the highest priority of horizontal relations among the considered structures. The development of such relations is effective in the variable environment in which the company sells its activity [14].

It is advisable to use a simulation to improve construction activity. The most effective for the simulation of the operating activity of the enterprises is to build analytical, deterministic, optimizing, imitative, static, correlative-regressive, network models [4, 16].

The following works are dedicated to numerical simulation and optimization of organizational and technological solutions of construction and reconstruction [6, 7, 8, 9, 15, 17]. They proved that the key to the effectiveness of the optimization is the validity of computer models of the object.

The fundamental works on the organization of construction process proved that there is a correlation between the management processes of the organization and construction projects [3, 10]. It is proposed [11], that the operations of construction enterprises may be modeled using multidimensional organizational structures.

In accordance with the common approach [2], a phased sequential development of conceptual, logical and physical models provides consistency and simplicity for modeling of enterprises. At each step, the models are specified, detailed and focused on the most important in the framework of the factors and relationships study.

## Methodology

Fig. 1 shows a block diagram of a three-stage development of operating activity models of the transport facilities construction enterprise.

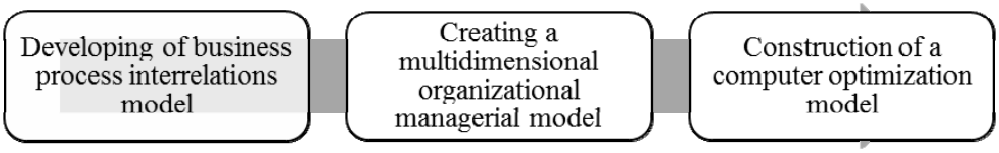


Fig. 1. Block diagram of a phased development of models of the operating activities of the enterprise for the construction of transport facilities

When analyzing the information sources it was identified the feasibility of a phased modeling of the enterprise operating activity. Each successive stage of the modeling is a continuation of the previous one, complements it and refines it. The minor details can be removed. Let us open the main stages of the developed diagram (Fig. 1.)

– Developing of business process interrelations model – is a stage of conceptual modeling, which identifies the main factors of the enterprise operating activity and the relationships between them. At this stage, it is necessary to structure the totality of the studied factors and identify specific impacts of transport facilities construction process.
– Creating a multidimensional organizational managerial structure – is a stage of logic simulation, which describes the operational activity of the reporting enterprise. It is a core of business process, through which the company creates product. At this stage, it is justified in the present work the relationship of organizational and technological solutions of the transport facilities construction in the management of the enterprise as a whole and decisions on individual projects. The model also describes the major modifiable factors and the studied parameters of construction product.
– Construction of a computer optimization model – is a physical modeling phase, which formalizes the operating activity of the enterprise in

question and substantiates the possibility to optimize such activity using a computer model.

## Findings

Model of business processes interrelations for the transport facilities construction enterprise is shown in Fig. 2.

Abbreviations used are presented in Tab. 1.

The factors in the model are grouped in three areas: external factors ($F_{ext}$), factors of the immediate environment ($F_{i,env}$) and internal factors of the enterprise ($F_{int}$). In the present structure (Fig. 2), the internal factors can be divided into two categories: factors of the management structure and management methods factors. The first category includes "departments of a construction company" and "resources for building production"; second – "management of construction enterprise" and "management of construction projects". Allocation of factors into two categories was done due to the following.

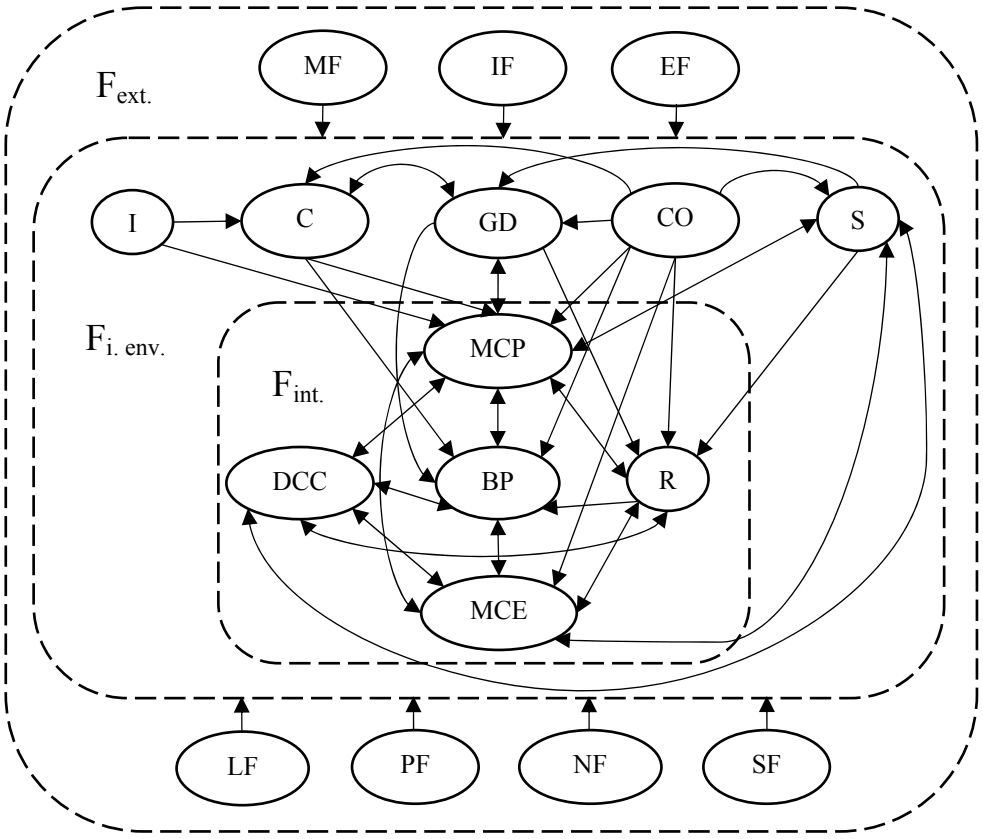


Fig. 2. Model of business processes interrelations for the transport facilities construction enterprise

Widespread department structure of construction companies hardly varies depending on the type of construction organization (building the industrial or civil objects) and on the specific strategic decisions at the enterprise management. The structure of the resources used in the manufacture of building production (labor, material, technical, intellectual, financial resources, and technologies), is not related to the organizational and technological solutions applied on individual sites. At the same, though management structure factors may affect the management methods factors, but this influence is much smaller than the impact of management methods factors on management structure factors. This allows us to consider the management structure factors like the subsystem of management methods factors. Thus, both categories have their own specificity, though related.

The novelty of the proposed model is as follows:

– at first such factors of the internal environment of the construction enterprise as "management of construction company" and "management of construction projects" were highlighted, and the relationship between them were described;

– at first time the factors of management structure and management methods (factors "management of construction organization" and "departments of construction company", "management of construction project" and "resources for the building production") were highlighted on the example of the transport facilities construction enterprise;
– at first the specific factors of internal and external environment of the business processes of transport facilities construction enterprise were highlighted.

Table 1

**List of abbreviations**

| Abbr. | Definition | Abbr. | Definition |
|---|---|---|---|
| BP | building product | WBS | work breakdown structure |
| DCC | departments of construction company | MCE | management of construction enterprise |
| R | resources for the building production | MCP | management of construction project |
| I | investor | C | customer |
| GD | general designer | CO | controlling organizations |
| S | suppliers | LF | legal factors |
| MF | market factors | PF | political factors |
| IF | information factors | NF | natural factors |
| EF | economic factors | SF | social factors |
| $X_1$ | average labor input of the totality of projects | $X_3$ | membership of resources used |
| $X_2$ | average distance relocation | $X_4$ | industriality of applied solutions |
| $\{Y_{\text{tech.}}\}$ | indicators of technical efficiency | $\{Y_{\text{ecol.}}\}$ | indicators of ecological efficiency |
| $\{Y_{\text{econ.}}\}$ | indicators of economic efficiency | $\{Y_{\text{soc.}}\}$ | indicators of social efficiency |
| $Y_1$ | change in total production costs | $Y_{3\text{-}i}$ | cost of building production unit |
| $Y_2$ | ratio of direct and general production costs | э | operator of the affiliation to the superset |
| $\{Y\}$ | plurality of elements $Y$ | ∧ | operator of conjunction ("and") |
| ⋂ | "intersection" operator | ⊃ | "includes" operator |
| ⋃ | "association" operator | ⊇ | "strictly includes" operator |

The relationship between the management of the construction organizations in general and individual construction project management was examined in the analysis information sources. In some of the reviewed works, this relationship was established as a one-sided influence of organizational and technological reliability of the ongoing construction project on the management intensity peaks within the enterprise. In the other – as the impact of market environment of construction projects realization on the formation of the optimal portfolio of construction organization. It is obvious that the change of organizational and technological solutions in the management of the enterprise influences these decisions on individual construction sites, and vice versa. For example, the company focus on the implementation of a specific totality of projects leads to the need to create the appropriate material and technical base. This in turn limits the possible technological solutions. Also, the choice of certain organizational and technological schemes necessitates the adaptation of means and

methods of enterprise management, and may also require changes to the company structure. This causes necessity to allocate specific factors while making the organizational and technological solutions at the enterprise level or individual objects and find the relationships between them and the characteristics of building production.

In general terms, Fig. 2 can be described by the following expressions (1-2):

$$\begin{cases} F_{ext.} \ni \{MF, IF, EF, LF, PF, NF, SF\} \\ F_{i,env.} \ni \{I, C, GD, CO, S\} \\ F_{\text{int.}} \ni \{MCE, MCP, DCC, R, BP\} \end{cases}, \quad (1)$$

$$\begin{cases} (F_{i,envp.} \bigcup F_{\text{int.}}) = f(F_{ext.}) \\ (F_{i,env.} = f(F_{\text{int.}})) \wedge (F_{\text{int.}} = f(F_{i,env.})) \end{cases}. \quad (2)$$

It is possible to allocate the following when analyzing the external factors of the transport facilities construction enterprise (3-6)

$$MF \bigcap NF = F_{ter.}, \quad (3)$$

$$MF \ni F_{sc.}, \quad (4)$$

$$IF \ni F_{tech.}, \quad (5)$$

$$SF \ni F_{cont.}. \quad (6)$$

The impact of factors of the immediate environment on internal factors of the transport facilities construction enterprise in general does not differ from the effect on the internal factors of traditional construction organizations. However, the effect of specific external factors interacts these changes to some extent (Formula 7):

$$S = \begin{cases} f(F_{ter.}) \\ f(F_{sc.}) \\ f(F_{cont.}) \end{cases}. \quad (7)$$

Other factors of immediate environment can be omitted from consideration. Thus, the model of studied business processes interrelations for the transport facilities construction enterprise takes the following form (Fig. 3).

Impact of the studied external factors on the internal factors of enterprise in question can be described by the following system of equations (8)

$$\begin{cases} (MCP = f(F_{sc.})) \bigcap (MCE = f(F_{sc.})) = X_1 \\ (MCP = f(F_{ter.})) \bigcap (MCE = f(F_{ter.})) = X_2 \\ (MCP = f(F_{cont.})) \bigcap (MCE = f(F_{cont.})) \bigcap (R = f(F_{cont.})) = X_3 \\ (MCP = f(F_{tech.})) \bigcap (MCE = f(F_{tech.})) \bigcap (R = f(F_{ttch.})) = X_4 \end{cases} \quad (8)$$

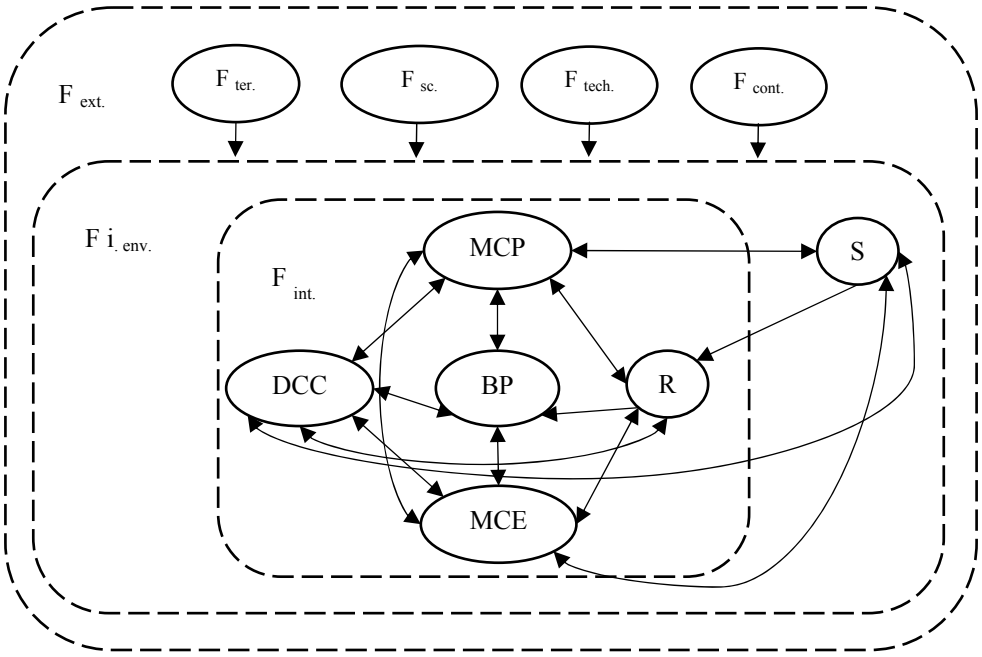


Fig. 3. Model of studied business processes interrelations of the transport facilities construction enterprise

The relationship between internal factors of the transport facilities construction enterprise can be described by the following equations (9)

$$\begin{cases} (MCE \ni \{X_1, X_2\}) \bigcup (MCP \ni \{X_3, X_4\}) \\ WBS = f(MCP \subset R) \\ MCE \subset DCC \end{cases} . \quad (9)$$

Building product can be described as a set of indicators imposed on it. Thus, the performance of this product must demonstrate the effectiveness of operating activity at the level of individual projects and their combination. It can be written (10)

$$BP \supseteq \{\{Y_{tech.}\}, \{Y_{econ.}\}, \{Y_{ecol.}\}, \{Y_{soc.}\}\} . \quad (10)$$

The cost of the project, totality of projects or the cost of expenditure items reflect the efficiency of project management and enterprise management as a whole in the most complete way when making organizational and technological solutions. The specifics of the considered transport facilities construction project is that general production expenses, payroll costs and operation of machinery and equipment dominate the cost structure. Furthermore, the area of construction industry under consideration is characterized by the creation of various kinds of building production. In this regard, it is suggested to use the following indicators:

– Changing of the full production costs ($Y_1$) – percentage change in the total production cost, depending on the influence of organizational and technological factors. Full production costs are the sum of direct and general production costs.

– Ratio of direct and general production costs ($Y_2$) – the percentage of the amount of general production costs to the sum of the direct costs of the totality of projects.

– Cost per unit of building production ($Y_{3-i}$) – the direct costs necessary for the unit of building production. The cost price can be calculated for the main types of production: load-bearing metal structures (1 t.); installation of technological equipment (1 u.) and so on.

Thus, it can be written for the present study (11)

$$BP \supseteq \{Y_1, Y_2, Y_{3-i}\} . \quad (11)$$

Tab. 2 analyzes the main factors that change the operating activity structure of the transport facilities construction company. The factors $X_1$ and $X_2$ are business management practices of the enterprise in general, $X_3$ and $X_4$ – management techniques for individual construction projects.

Varying factors and indicators, which were considered, as well as the internal factors may be presented in the form of multidimensional organizational managerial model of the transport facilities construction enterprise (Fig. 4).

Table 2

**Variable factors**

| Factor name | The essence, definition of the factor | Variation feature |
|---|---|---|
| $X_1$ – average labor input of the totality of projects | Simulates the course of the company: focus on the implementation of large, medium or small projects | The arithmetic average of labor input of construction and installation works of the totality of projects, min. UAH |
| $X_2$ – average distance relocation | Simulates the company focus on the implementation of projects considerably or slightly distant from each other | The arithmetic average of resources relocation distances between any of two projects of the totality, km |
| $X_3$ – membership of resources used | Simulates the company focus on the use of its own resources or contractors. Used for manpower and machinery | The percentage of own resources use of total resources |
| $X_4$ – industriality of applied solutions | Changes the labor input of work using industrial methods of construction: the use of prefabricated materials, the methods of mass production, the degree of mechanization | The percentage of use of industrial methods in the total volume of work |

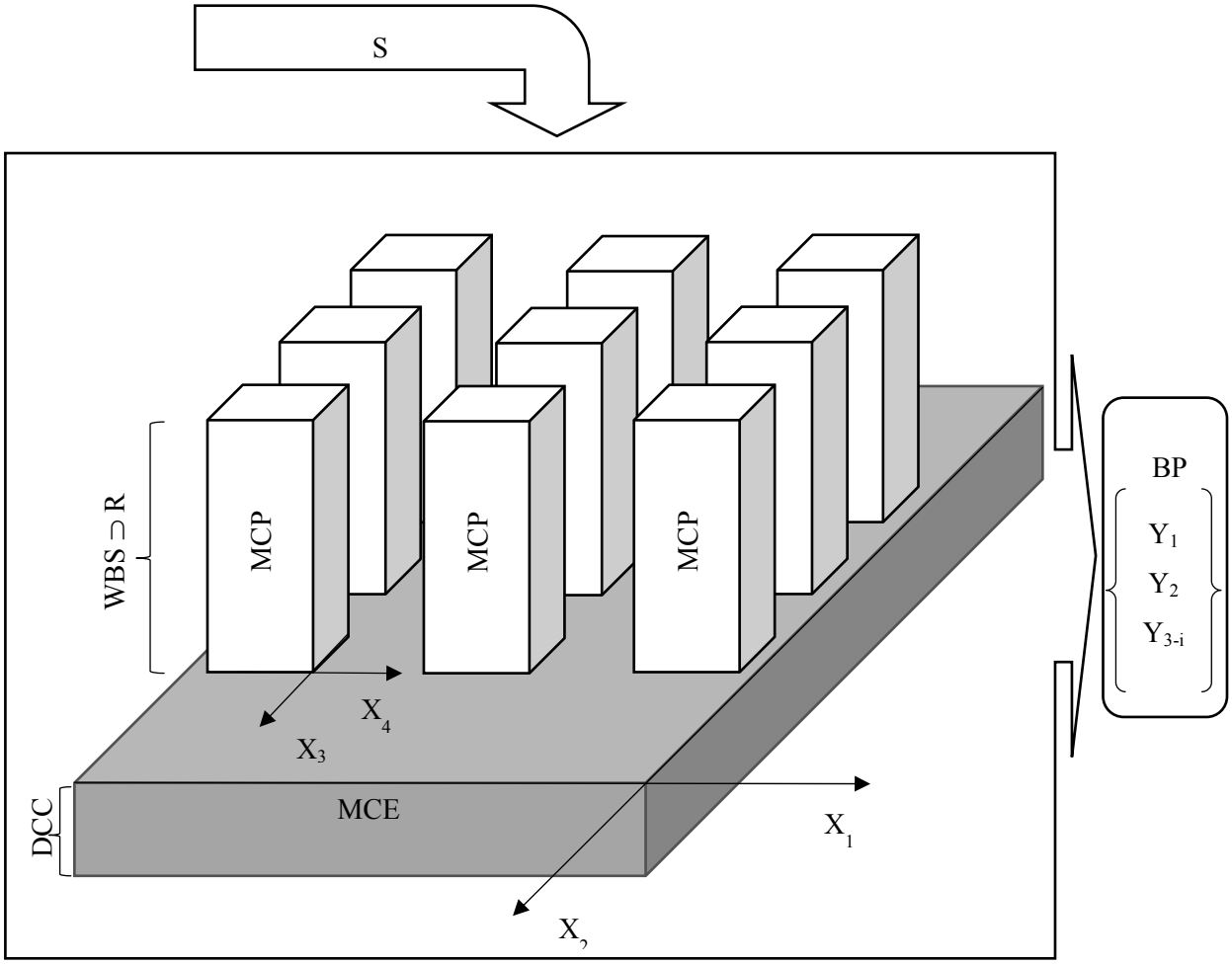


Fig. 4. Multidimensional organizational managerial model of the transport facilities construction company

Multidimensional structure shown in Fig. 4, allows to group projects performed by the organization, according to their scale ($X_1$) and territorial dispersion ($X_2$). This makes it possible to analyze the organizational and technological links between similar projects. There are different organizational and technological solutions at the specific projects: various membership of resources used ($X_3$), different industriality of applied solutions ($X_4$). The model shows that there is a connection between the structure of the organization (DCC) and its management methods (MCE), as well as between the structure (WBS) and management practices (MCP) of individual projects.

Let us note that the resources (R: labor, material, technical, intellectual, financial resources and technologies), used to create building product, can be ordered via the project work breakdown structure (WBS). As it can be seen from the figure, the multidimensional managerial model presents a conversion tool of external resources provided by suppliers into construction products.

The novelty of this model is as follows:

– at first the contrast between the following factors as part of a multidimensional structure was described: the management structure and management methods of construction enterprises;

– at first multidimensional organizational managerial model of construction enterprise was created, showing:

– the process of building product creating;

– bilateral causal relationships between the management of the construction enterprise and management of individual construction projects, consisting of the organizational, technological and managerial impact of the organization at the construction project, and vice versa.

The basis of all the information about the operating activity of construction organization are the resources that are necessary to implement this activity. The structure of the resources used in the

creation of product of transport facilities construction enterprise, as well as information about the values of their costs in physical and monetary terms allow to create accurate computer model of operating activity (Fig. 5). Such model can be most easily created using the software for project management. Variation of the most significant factors and study of selected indicators change will allow numerically optimizing the operating activity of the transport facilities construction enterprise.

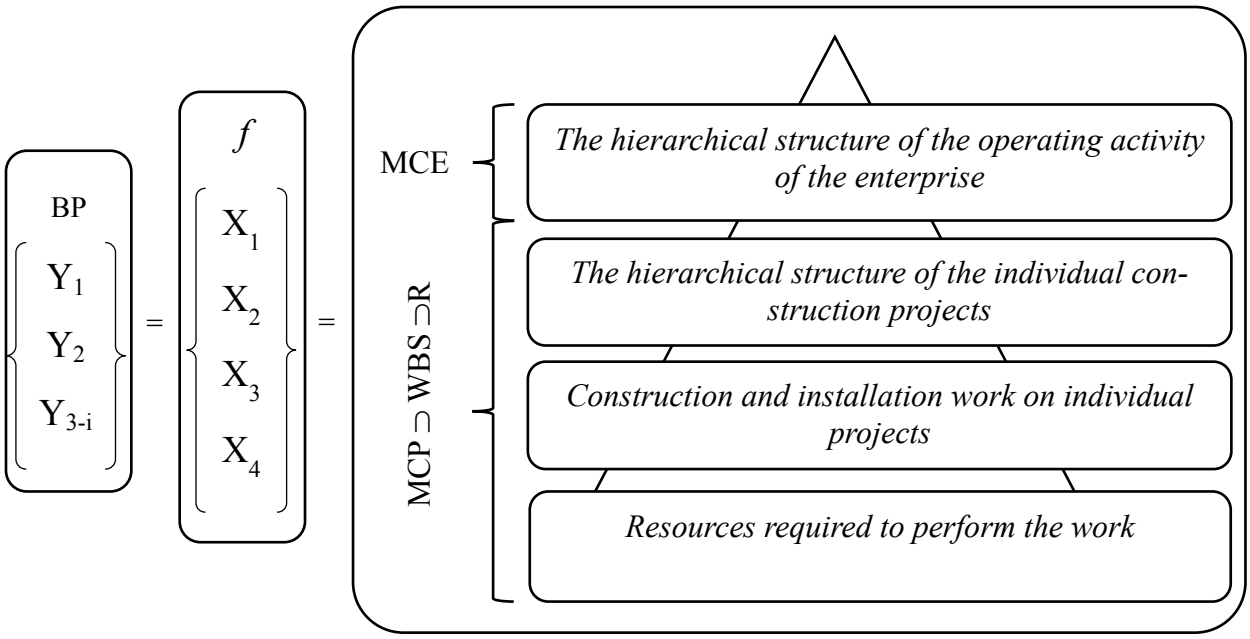


Fig. 5. Graphical analytical form of a computer model to optimize the operating activity of the transport facilities construction enterprise

**Originality**

Specific factors of the enterprise structure management and methods of the construction enterprise management are highlighted for the first time, their interaction is described.

**Practical value**

Optimization of organizational and technological solutions, made in the management of the enterprise as a whole and decisions of individual projects.

**Conclusions**

1. Development of three-stage scheme of operating activity modeling of the transport facilities construction enterprise has allowed to perform systematic review of this activity, to highlight the most important factors to establish the relationship between them and to optimize enterprises management techniques.
2. Analysis of the model of business processes interrelations of the company in question has allowed to identify factors of operating activity, to structure them and to distinguish the most significant among them: average labor input of the totality of projects ($X_1$), average distance relocation ($X_2$), membership of resources used ($X_3$), industriality of applied solutions ($X_4$).
3. At first, it has been described on the example of the transport facilities construction company that the difference between management structure and management methods is in the variability of the first ones under the influence of constantly changing external factors.
4. Construction of a multidimensional organizational model of transport facilities construction enterprise has made it possible to substantiate the relationship of organizational and technological solutions, taken in the management of individual construction projects and the organization as a whole.
5. Development of a multidimensional organizational model has allowed firstly in its framework: to identify and to formalize the factors of management structure and management methods of construction enterprises; reflect the process of building production.

6. The use of advanced software in the field of project management, the adopted structuring of the resources used for the building production, the proven multidimensionality of organizational and technological solutions has allowed developing a computer model of the operating activity of the transport facilities construction enterprise in the graphical-analytical form. This model can be the basis of numerical optimization of this activity.

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МОСТИ ТА ТУНЕЛІ: ТЕОРІЯ, ДОСЛІДЖЕННЯ, ПРАКТИКА

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# БАГАТОМІРНІСТЬ ОРГАНІЗАЦІЙНО-ТЕХНОЛОГІЧНИХ РІШЕНЬ ПРИ УПРАВЛІННІ ПІДПРИЄМСТВАМИ ІЗ БУДІВНИЦТВА ТРАНСПОРТНИХ СПОРУД

**Мета.** Обґрунтувати взаємозв'язок організаційно-технологічних рішень будівництва транспортних споруд при управлінні будівельним підприємством в цілому і окремими об'єктами будівництва і представити цю взаємозв'язок у вигляді багатовимірної організаційної структури. **Методика.** Синтез, аналіз, комбінаторно-морфологічний аналіз. **Результати.** Розроблено та проаналізовано модель бізнес-процесів і багатовимірна організаційна модель розглянутих підприємств. Обґрунтовано можливість розробки комп'ютерної моделі операційної діяльності даної організації. **Наукова новизна.** Вперше розглянуто специфічні фактори структури і методів управління будівельною організацією, проаналізовано їх взаємозв'язок. **Практична значимість.** Запропоновано методи оптимізації організаційно-технологічних рішень, що приймаються при управлінні будівельним підприємством в цілому і окремими об'єктами будівництва.

*Ключові слова:* зведення транспортних споруд; бізнес-процеси підприємства; багатовимірна організаційна структура; організаційно-технологічні рішення; чисельна оптимізація

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# МНОГОМЕРНОСТЬ ОРГАНИЗАЦИОННО-ТЕХНОЛОГИЧЕСКИХ РЕШЕНИЙ ПРИ УПРАВЛЕНИИ ПРЕДПРИЯТИЯМИ ПО ВОЗВЕДЕНИЮ ТРАНСПОРТНЫХ СООРУЖЕНИЙ

**Цель.** Обосновать взаимосвязь организационно-технологических решений строительства транспортных сооружений при управлении строительным предприятием в целом и отдельными объектами строительства и представить эту взаимосвязь в виде многомерной организационной структуры. **Методика.** Синтез, анализ, комбинаторно-морфологический анализ. **Результаты.** Разработаны и проанализированы модель бизнес-процессов и многомерная организационная модель рассматриваемых предприятий. Обоснована возможность разработки компьютерной модели операционной деятельности рассматриваемой организации. **Научная новизна.** Впервые рассмотрены специфические факторы структуры и методов управления строительной организацией, проанализирована их взаимосвязь. **Практическая значимость.** Предложены методы оптимизации организационно-технологических решений, принимаемых при управлении строительным предприятием в целом и отдельными объектами строительства.

*Ключевые слова:* возведение транспортных сооружений; бизнес-процессы предприятия; многомерная организационная структура; организационно-технологические решения; численная оптимизация

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