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DEVELOPMENT AND RESEARCH OF A MODEL FOR OPTIMIZING THE COMPOSITION OF A PROJECT-ORIENTED FORWARDING COMPANY' SUPPLIERS

The object of this research is the composition of the suppliers of a project-oriented transport and forwarding company. The work is aimed at determining the composition of the suppliers of a project-oriented transport and forwarding company, the purpose of which is to obtain a synergistic effect, which manifests itself in reducing the costs of performing individual operations of the transport process while meeting local requirements for each project.

This study proposes an optimization model that allows to determine the composition of suppliers of a project-oriented organization in order to obtain the maximum systemic effect – a synergistic effect. The proposed approach is based on the creation of a virtual project management office, the work of which is based on the corresponding information system. The proposed model is a flexible tool that allows to quickly form the composition of suppliers of a project-oriented company. The model is developed for the service sector and, in particular, for the transport industry, where suppliers are not responsible for material objects, resources, but for services, the set of which forms the essence of the project. Thus, the product of the project and its parameters in such a situation are directly formed due to the specifics of suppliers and the parameters of their services. For the transport industry, this approach has not been used before and can serve as a theoretical basis for building a project-oriented management system in the transport sector. The synergistic effect taken as a basis in this model provides the greatest difference between the «declared» delivery costs and the «actual» ones, which are formed taking into account the amount of work for all projects. Since the freight forwarding company is the «holder» of the portfolio of all deliveries/projects, a certain part of the synergy effect can be used to reduce delivery costs for customers in order to increase competitiveness and attractiveness.

Experimental studies have substantiated the reliability of the results of the developed model and confirmed its practical applicability. This model is quite universal and can be supplemented with restrictions that take into account the specifics of a project-oriented organization, its projects and requirements for suppliers.

Keywords: synergistic effect, portfolio of projects, distribution of scope of work, virtual project management office.

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1. Introduction

The project-oriented approach to the management of companies (organizations, enterprises) is the leading modern management concept [1]. The effectiveness of this concept has been proven by the practice of use in various fields of activity, regardless of whether the organization is commercial or not, its activities are related to production or services, etc.

The project approach to the organization of operational activities, which forms the basis of project-oriented man-

agement, in contrast to the classical functional approach, implies focus on the result of the entire project, and not on the result of performing individual functions within the current (operational) activities of companies. At the same time, the responsibility for the final result increases the motivation for the staff within the framework of their involvement in a particular project. The need to assess and monitor the use of resources throughout the project, and not for individual operations of the production process, determines an adequate assessment of the effectiveness

of each project and operating activities as a whole. The specificity of project-oriented companies is that, as a rule, employees are involved in work simultaneously on several projects, and the heads of departments or the company as a whole are the heads of many projects at the same time.

However, each industry certainly has its own distinguishing characteristics of project-based management. For transport enterprises, according to the project approach, each delivery of goods in international traffic (delivery service) is a project, which was appropriately justified in [2]. At the same time, the project approach to delivery has practically nothing to do with projects in the transport sector, therefore, the theoretical developments existing in this area (for example, [3–5]) can't be used to solve the problems of project-oriented management of transport companies.

Many participants in the delivery process (and there are a significant number of them, taking into account the complex of necessary operations, both directly related to the movement of cargo, and additional, which is well enough covered in [6]) are suppliers for a freight forwarding company.

Choosing the «right» supplier is of course important for different categories of projects. But for a project-oriented transport and forwarding company, suppliers form not only the final costs of the project, but also the project product itself in terms of its parameters. The main delivery parameters are delivery time, quality of delivery, etc. The suppliers are sea and car carriers, customs clearance agents, etc.

Thus, taking into account the multitude of operational projects implemented by a transport and forwarding company within a specific period of time, it is logical to determine the set of suppliers not locally for each project, but integrated for the entire set of projects to obtain a synergistic effect.

Supply management is an important component of project management [7], therefore a significant amount of modern research is devoted to this issue. Some of them analyze the influence of suppliers on the project as a whole [8] or its risks [9, 10]. Another significant part of these studies is focused on a multi-criteria solution to the problem of choosing suppliers (for example, [11–13]), and it is the maximum compliance with the project requirements in terms of the supplier's «reputation» and «competitiveness» that forms the basis of the proposed methods. Such results are relevant for projects, especially large-scale ones, but not for the considered problem of selecting suppliers for a project-oriented freight forwarding company. Among the research on supply issues in the project, a large number are related to the construction sector (for example, [14–16]), where the importance of supplies (both in terms of cost and in terms of risks) is very high. Particular attention is paid to the problems of integral relations with suppliers [17].

The quantitative accounting of the synergy effect that forms as a result of integration was considered within the framework of project portfolios and development programs in [18]. Nevertheless, these works are based on the synergy effect due to saving resources or costs without being tied to specific suppliers, which makes it possible to develop these results precisely within the framework of the task of selecting a set of suppliers.

To summarize: *the object of this research* is the composition of the suppliers of a project-oriented freight forwarding company. And the main aim of determining the composition of the suppliers of a project-oriented transport and forwarding company is associated with obtaining a synergistic effect, which is manifested in reducing the costs of performing individual operations of the transport process

while meeting local requirements for each delivery project. Thus, *the aim of this research* is to improve the efficiency of project-oriented management of transport and forwarding companies based on the practical use of the developed model for the formation of the optimal composition of suppliers.

2. Methods of research

To develop a mathematical model for optimizing the composition of suppliers, the conceptual model [19] of project portfolio management of a project-oriented freight forwarding company was taken as a basis.

Let the project portfolio include operational activities of n projects. Each project is presented as a set of works, technologically linked into a certain structure of the network model (graphics). Each project is characterized by a set of:

$$\{A^i, G^i, q^i\},$$

where $A^i = \{A_j^i\}$, $j = \overline{1, m_i}$ – set of work on the project; m_i – their total number; G^i – directed graph that describes the technological sequence of work (network schedule of projects); q^i – the number of product units (for a freight forwarding company – the amount of cargo/the number of containers with cargo).

Within the considered set of projects, subsets of the same type of work can be distinguished. For example, sea transportation or customs clearance, etc., that is, those works (operations) that are inherent in almost all operational projects of a freight forwarding company. Such works can be defined as «typical» [19]. Thus, all activities in the project portfolio $\bigcup_{i=1}^n A^i$ can be regrouped as follows:

$$\bigcup_{i=1}^n A^i = \bigcup_{k=1}^K A_k \cup B, \quad (1)$$

where $A_k = \{A_k^i\}$, $i = \overline{1, n}$ – set of works of the k -th type; A_k^i – work of the i -th project, corresponding to the k -th type of work («typical»); $\bigcup_{k=1}^K A_k$ – set of works of all projects that are «typical»; K – total number of «typical» works; B – set of works that do not belong to typical ones and are peculiar to individual projects.

Some of the typical works are associated with suppliers, but limiting the generality, let's assume that these are works $k = \overline{1, K'}$. Moreover, each of the specified works corresponds to a certain set of suppliers. Thus, for each typical work $k = \overline{1, K'}$ let's put in correspondence a set $B_k = \{B_k^l\}$, $l = \overline{1, L_k}$, $k = \overline{1, K'}$, elements of which B_k^l , $l = \overline{1, L_k}$ correspond to the characteristics of the given work at the given supplier. In [19], it is proposed to use the following as a minimum set B_k^l :

$$B_k^l = \langle T_k^l, R_k^l(Q_k) \rangle, \quad (2)$$

where $T_k^l, R_k^l(Q_k)$ – respectively, the time and cost of this work by the l -th supplier; Q_k – volume of work, which is formed from the volume of this typical work for all projects within the considered period of time, that is:

$$Q_k = \sum_{i=1}^n q_k^i, \quad k = \overline{1, K'}, \quad (3)$$

where $q_k^i = q^i$, $k = \overline{1, K'}$, that is, the volume of work corresponds to the amount of products – the amount of cargo in this case.

Let's note that the context of a «typical» work can be considered in two ways:

- 1) in a broad sense, for example, «sea transportation»;
- 2) in the narrow sense «sea transportation from China to Ukraine».

Both approaches are realizable in practice.

To take into account the synergistic effect, it is proposed to use a reduction in costs as a whole for the totality of projects related to economies of scale for each supplier:

$$\sum_{i=1}^n \sum_{k=1}^{K'} \sum_{l=1}^{L_k} R_k^l(Q_k) = \sum_{i=1}^n \sum_{k=1}^{K'} \sum_{l=1}^{L_k} R_k^l \left(\sum_{i=1}^n q_k^i \right) < \sum_{i=1}^n \sum_{k=1}^{K'} R_k^*(q_k^i), \quad (4)$$

where

$$R_k^*(q_k^i) = \min_{l=1, L_k} \{ R_k^l(q_k^i) \}, k = \overline{1, K'}. \quad (5)$$

Thus, as a rule, even the minimum individual costs of work on a project for the corresponding volumes do not provide the level of costs that is possible with an integral consideration of all work on all projects. The synergistic effect S of the portfolio of operating projects of freight forwarding company is:

$$S = \sum_{i=1}^n \sum_{k=1}^{K'} R_k^*(q_k^i) - \sum_{i=1}^n \sum_{k=1}^{K'} \sum_{l=1}^{L_k} R_k^l(Q_k). \quad (6)$$

Accounting for this effect is the basis for maximizing the profit of a freight forwarding company.

3. Research results and their discussion

Each project of a portfolio of operating projects of a freight forwarding company is characterized by a set of input parameters:

$$\langle C_i^z \rangle, z = \overline{1, Z},$$

the number of which Z can be determined on the basis of the specifications for the delivery of goods traditionally set in the transport sector [7] (in this case, one of these parameters is the amount of cargo q^i). And also a number of requirements that are transformed into the corresponding limitations of the developed model.

Let's set the following as the main requirements:

$$\langle T_i, \Delta T_i, R_i, \Delta R_i \rangle,$$

where $T_i, \Delta T_i$ – respectively, delivery time and its allowable increase; $R_i, \Delta R_i$ – accordingly, the cost of delivery and its allowable increase. The less $\Delta T_i, \Delta R_i$, the more «stringent» conditions for the project.

Let a set of typical works correspond to each project:

$$A^i = \{ A_k^i \}, k = \overline{1, K'}$$

in this case, let's introduce an exogenous auxiliary parameter:

$$Y_k^i \in \{0; 1\}, i = \overline{1, n}; k = \overline{1, K'}$$

where $Y_k^i = 1$ – if the i -th project requires the performance of the k -th typical work performed by the company's suppliers; $Y_k^i = 0$ otherwise.

Depending on the specification of the project $\langle C_i^z \rangle$, a subset $\Omega_{ik} \subset \Omega_k$ can be selected from the set of suppliers of a specific typical work Ω_k , which corresponds to the essence of this project.

Let's denote by $x_k^{i,l} \in \{0; 1\}, i = \overline{1, n}, k = \overline{1, K'}, l \in \Omega_{ik} \subset \Omega_k$ – a Boolean variable that is responsible for the choice of a supplier for performing work k on project i by supplier l .

Taking into account the previously introduced exogenous parameter, the following should be done:

$$\sum_{l \in \Omega_{ik}} x_k^{i,l} = Y_k^i, i = \overline{1, n}, k = \overline{1, K'}, \quad (7)$$

that is, each typical project work must be assigned a supplier in the event that such work is included in the project (that is $Y_k^i = 1$), or otherwise not assigned ($Y_k^i = 0$).

In turn, the performance of work by each supplier is characterized by the following set:

$$\langle T_k^l, \Delta T_k^l, R_k^l \rangle,$$

where $T_k^l, \Delta T_k^l$ – respectively, the execution time of the k -th typical work and the possible time to increase this duration (the company's experience, expert opinions allow to establish ΔT_k^l); R_k^l – costs associated with the performance of this work by the supplier l . Let's assume that the costs are set and, unlike time, are not subject to increase (this approach corresponds to the practice of the transport business). To apply the model in another area, the performance characteristics of a particular supplier can be complemented by a further possible increase in the cost of performing the work.

As a rule (and this was indicated above), the cost of performing a specific work (the cost for a specific supplier) is a non-increasing function of the quantitative characteristics of the work, in this case, the amount of cargo, that is $R_k^l(Q_k^l)$.

Taking into account the introduced designations and the approach used:

$$Q_k^l = \sum_{i=1}^n q^i \cdot x_k^{i,l}, k = \overline{1, K'}, l \in \Omega_{ik}, \quad (8)$$

where Q_k^l – total amount of work performed by a specific supplier for the typical work under consideration.

Let's note that, as a rule, in today's realities, suppliers can be considered as having no restrictions on production capabilities. Nevertheless, following the path of universality of the developed model, let's take into account the indicated restrictions in the form:

$$\sum_{i=1}^n q^i \cdot x_k^{i,l} \leq P_k^l, k = \overline{1, K'}, l \in \Omega_{ik}, \quad (9)$$

where P_k^l – production capability of performing work k by supplier l .

Let's note that in the presence of restrictions on the capabilities of suppliers (conditions (9)), condition (7) becomes incorrect for calculations – in this case, not one supplier, but several must be selected. In such a situation (7) will change as follows:

$$\sum_{l \in \Omega_{ik}} x_k^{i,l} \begin{cases} = 0, Y_k^i = 0, i = \overline{1, n}, k = \overline{1, K'}; \\ \geq 1, Y_k^i = 1, i = \overline{1, n}, k = \overline{1, K'}. \end{cases} \quad (10)$$

Taking into account the existing conditions on the delivery time $T_i, \Delta T_i$, time limits for each typical work can be determined. Let's note that the specificity of transport and related operations is that many of them are performed simultaneously [7]. Therefore, $T_i, \Delta T_i$ decomposition is a task that goes beyond the scope of this study and is associated with the production specifics of each typical work within the network schedule.

Thus, let's believe that as a result of the $T_i, \Delta T_i$ decomposition, the following $T_k^i, \Delta T_k^i, i = \overline{1, n}, k = \overline{1, K'}$ are established (based on the network schedule for each project), which are then used to form restrictions for each work:

$$(T_k^l + \Delta T_k^l) \cdot x_k^{i,l} \leq T_k^i + \Delta T_k^i, i = \overline{1, n}, k = \overline{1, K'}, l \in \Omega_{ik}. \quad (11)$$

Let's note that in practice, to implement this model, it is necessary to use not only values $T_i, \Delta T_i, T_k^l, \Delta T_k^l$, but also dates (for example, departure and arrival of a ship of a sea carrier). This can be done without any problems within the framework of the corresponding information and software.

The costs of performing work for each supplier are:

$$R_k^l(Q_k^l) = R_k^l \left(\sum_{i=1}^n q^i \cdot x_k^{i,l} \right), k = \overline{1, K'}, l \in \Omega_{ik}. \quad (12)$$

Thus, the costs of all work related to suppliers for all current projects are:

$$R = \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l(Q_k^l) = \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l \left(\sum_{i=1}^n q^i \cdot x_k^{i,l} \right). \quad (13)$$

A freight forwarding company, as an integrator and coordinator of delivery-related processes, sets, as a rule, certain costs F_i for each project (the cost of its services) as its income. In addition, the company may receive a certain percentage of the cost of performing some work. In any case, minimization (12) allows the company to get at least a difference in costs on the basis of the «wholesale-retail» principle. Therefore, minimization (13) reflects the efficiency of supplier selection for a portfolio of operating projects for a freight forwarding company. Therefore, as an optimality criterion:

$$R = \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l(Q_k^l) = \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l \left(\sum_{i=1}^n q^i \cdot x_k^{i,l} \right) \rightarrow \min_{x_k^{i,l}}. \quad (14)$$

At the same time, restrictions on the cost of each project must be met:

$$R_i = \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l(q^i \cdot x_k^{i,l}) \leq R_i + \Delta R_i, i = \overline{1, n}. \quad (15)$$

Thus, the model for forming the optimal composition of suppliers for a portfolio of operating projects of a freight forwarding company includes (7), (9), (11), (14), (15), taking into account the condition:

$$x_k^{i,l} \in \{0;1\}, i = \overline{1, n}, k = \overline{1, K'}, l \in \Omega_{ik} \subset \Omega_k.$$

Let's note that the value:

$$S = \sum_{i=1}^n R_i - \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l \left(\sum_{i=1}^n q^i \cdot x_k^{i,l} \right) = \sum_{i=1}^n \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l(q^i \cdot x_k^{i,l}) - \sum_{k=1}^{K'} \sum_{l \in \Omega_k} R_k^l \left(\sum_{i=1}^n q^i \cdot x_k^{i,l} \right), \quad (16)$$

is a synergistic effect of the integrated management of a portfolio of operational projects, which is formed due to economies of scale in the costs of performing certain works at suppliers. As a rule, this value is positive (in the worst case it is 0).

(16) can also act as an optimization criterion, that is, in the model, cost constraints for each project already take into account their admissible level. Maximization (16) will provide the company with the greatest difference between the «declared» delivery costs and the «actual» ones, which are formed taking into account the amount of work for all projects. Since the freight forwarding company is the «holder» of the portfolio of all deliveries/projects, a certain part of the synergy effect can be used to reduce delivery costs for customers in order to increase competitiveness and attractiveness.

The scheme of organization in practice of solving the problem of forming the optimal composition of suppliers of a freight forwarding company is shown in Fig. 1.

Let's note that a prerequisite for the technical feasibility of the practical implementation of the ideas expressed is the presence of a virtual project management office – an integral information system of a project-oriented freight forwarding company.

Experimental studies of the developed model were carried out for the following for three projects with four types of typical work, while considering five possible suppliers for each typical work. It was also accepted that not all potential suppliers can provide services for each project, taking into account their specifics.

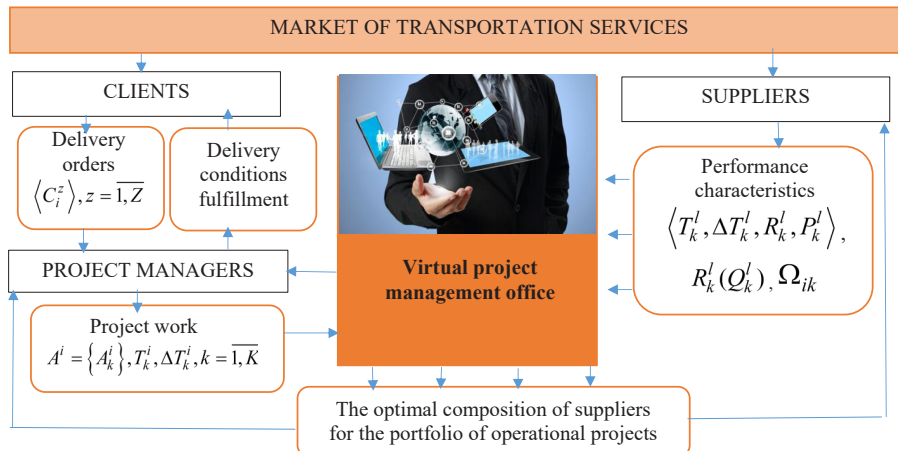


Fig. 1. Scheme of practical implementation of the formation of the optimal composition of suppliers of a project-oriented transport and forwarding company

The calculations were performed for three options for the scope of work on projects (in this case, the number of containers with cargo):

$$q^1 = \{6;12;24\}, q^2 = \{5;10;20\}, q^3 = \{4;8;16\}.$$

An example of the dependence of the costs of performing work by suppliers on the volume $R_k(Q_k)$ for certain typical works is shown in Fig. 2, 3.

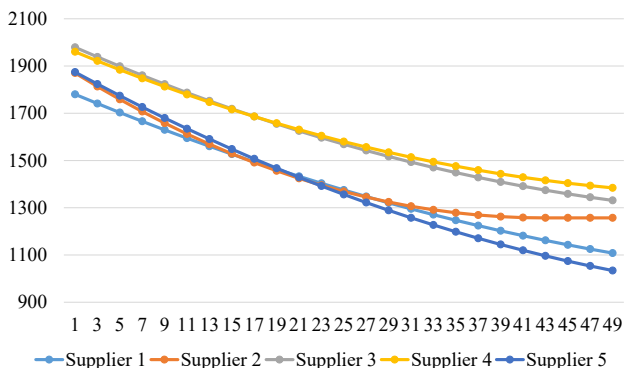


Fig. 2. Dependences of the costs of performing work by suppliers on the volume for a typical work $k = 1$

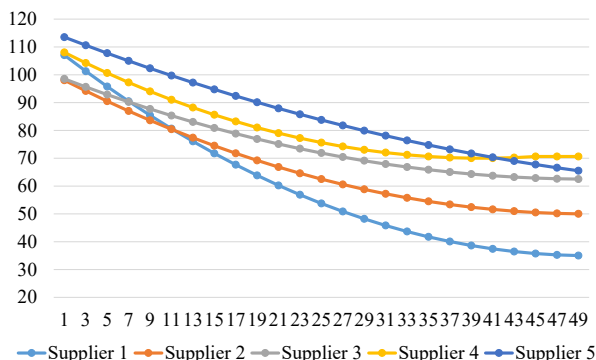


Fig. 3. Dependences of the costs of performing work by suppliers on the volume for a typical work $k = 3$

A fragment of the output of the results of composition optimization of suppliers is shown in Fig. 4–6.

The values of the optimality criterion (costs) and the synergistic effect for various values of the total scope of work are presented in Table 1.

The results show how the systemic effect increases with an increase in the volume of work on projects – from 9 % to 32 %. At the same time, project costs naturally decrease per unit of product – in this case, the delivery of one container with cargo.

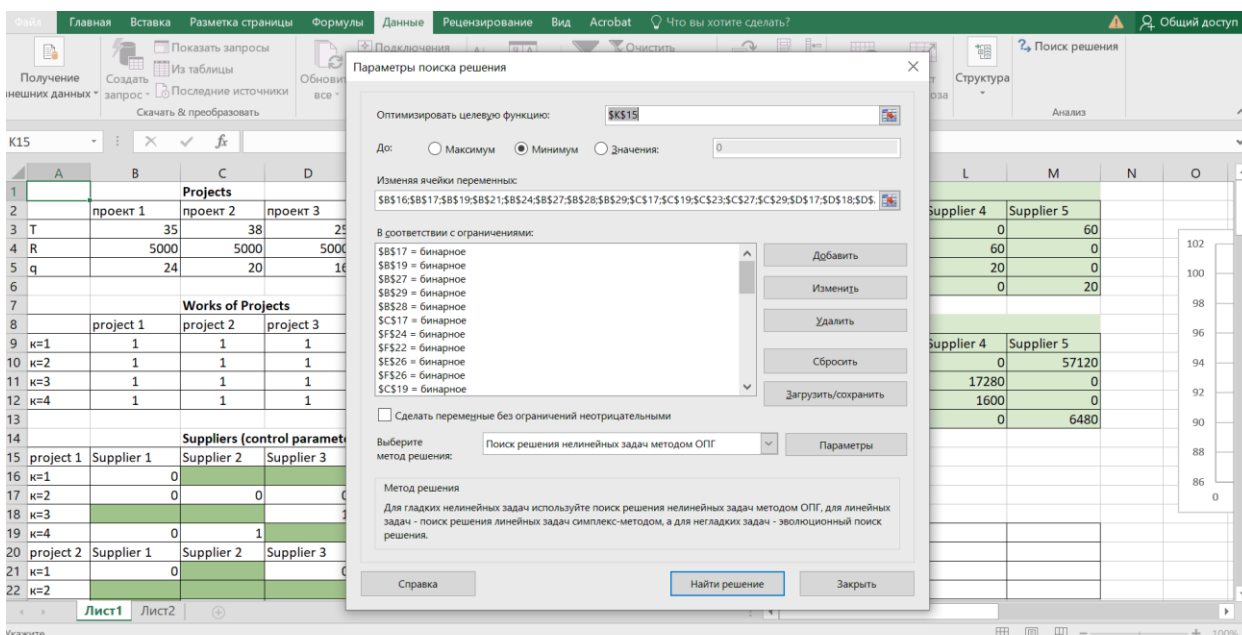


Fig. 4. A fragment of the implementation of the model in Search for a solution, Excel

		Suppliers (control parameters)				
project 1	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	
k=1	0	0	0	0	1	
k=2	0	0	0	1	0	
k=3	0	0	1	0	0	
k=4	0	1	0	0	0	
project 2	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	
k=1	0	0	0	0	1	
k=2	0	0	0	0	1	
k=3	0	0	0	1	0	
k=4	0	0	0	0	1	
project 3	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	
k=1	0	0	0	0	1	
k=2	0	0	0	1	0	
k=3	1	0	0	0	0	
k=4	1	0	0	0	0	

Fig. 5. Values of Boolean variables $x_k^{i,l}, i = \overline{1,3}, k = \overline{1,4}, l \in \Omega_k$ for variant $q^1 = 24; q^2 = 20; q^3 = 16$

Suppliers (supply volume)					
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
k=1	0			0	60
k=2	0	0		40	20
k=3	16	0	24	20	0
k=4	16	24		0	20
Suppliers (Integreted Value)					
	Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5
k=1	0	0	0	0	57120
k=2	0	0	0	17120	10640
k=3	1128.96	0	1743.36	1600	0
k=4	5406.72	7249.92	0	0	6480
Optimization criterion	Z=		108488.96		
Synergistic effect	35352				

Fig. 6. Allocation of the scope of work between suppliers for a variant $q^1 = 24; q^2 = 20; q^3 = 16$

Table 1 Optimality criterion (costs) and synergistic effect values for different values of the total scope of work

Total Volume	Project Volume	Optimization criterion	Synergistic effect	Synergistic effect, %
60	$q^1 = 24; q^2 = 20; q^3 = 16$	108488.96	35352	0.3259
30	$q^1 = 12; q^2 = 10; q^3 = 8$	69272.12	13000	0.1877
15	$q^1 = 6; q^2 = 5; q^3 = 4$	40343.015	3751.5	0.0930

A fragment of the results of calculating the costs per unit of product of projects is shown in Fig. 7.

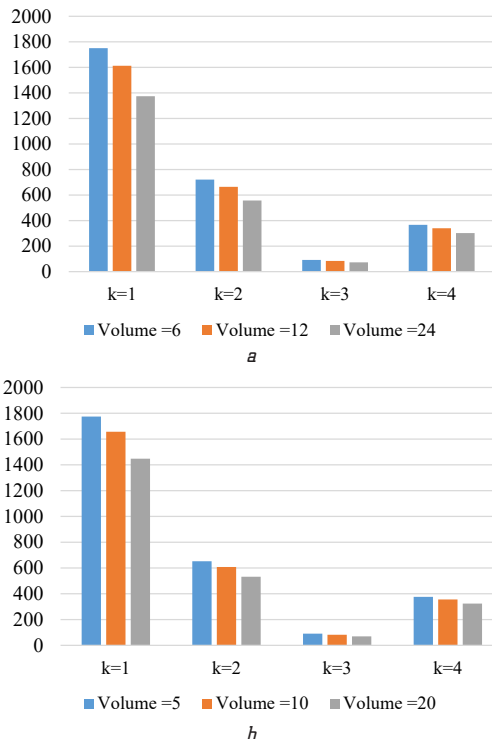


Fig. 7. Fragment of the results of calculating the costs per unit of product of projects for typical work for various volumes of work on projects: a – project 1; b – project 2

Experimental studies have substantiated the reliability of the results of the developed model and confirmed its practical applicability.

This model is quite universal and can be supplemented with restrictions that take into account the specifics of

a project-oriented organization, its projects and requirements for suppliers.

4. Conclusions

This study proposes an optimization model that allows to determine the composition of the suppliers of a project-oriented organization in order to obtain the maximum systemic effect. The proposed approach is based on the creation of a virtual project management office, the work of which is based on the corresponding information system. The proposed model is a flexible tool that allows to quickly form the composition of suppliers of a project-oriented company. The model was developed for the service sector and, in particular, for the transport industry, where suppliers are not responsible for material objects, resources, but for services, the set of which forms the essence of the project. Thus, the product of the project and its parameters in such a situation are directly formed due to the specifics of suppliers and the parameters of their services. For the transport industry, this approach has not been used before and can serve as a theoretical basis for building a project-oriented management system in the transport sector.

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