Rusanova, Svitlana; Piterska, Varvara; Onyshchenko, Svitlana

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Svitlana Rusanova,
Varvara Piterska,
Svitlana Onyshchenko

MODELLING THE PROJECT TRANSPORT SUPPORT OPTIMAL OPTION

The object of research is the processes of planning transport provision of projects. The vast majority of projects involve the creation of tangible objects as a product. The implementation of such projects is associated with the use of various types of materials and equipment, which necessitates transport services for the functioning of the project logistics system. Vehicles with different characteristics can be used to solve the same transportation problems. Also, for large-scale infrastructure projects, rental of vehicles is often used for the duration of the project. This allows, on the one hand, to save on transportation costs, on the other hand, to gain complete control over the transportation processes in the project.

As a research result, an optimization model has been developed for determining the option of transport support for the project. The variant of transport support of the project is understood as a set of combinations of types and types of vehicles, their characteristics and conditions of use in the project for the work of the project that provide for transport services. Acquisition, lease or transport services from the project suppliers are considered as conditions for the use of vehicles in the project.

The optimization criterion is the cost of transport support, taking into account their possible increase, as well as the potential risks of losses associated with the failure to complete the work. Constraints take into account costs, time to receive a project product, and availability of transportation options.

Experimental calculations, a fragment of which is presented in the research, demonstrated the efficiency of the developed model, its adequacy and reliability of the results obtained with its help.

The area of practical use of the model is making decisions about transportation at the stage of project planning. The model allows for «what-if» experiments, which reflect various scenarios that are possible in the transportation of the project. And this, in turn, allows at the stage of project planning to assess the possible risks associated with transportation, and to establish their impact on the project as a whole.

Keywords: *infrastructure projects, project risks, project network schedule, vehicles, project product, project life cycle.*

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1. Introduction

The vast majority of projects involve the creation of tangible objects as a product (for example, construction or reconstruction of a road, bridge, pier, terminal, etc.). The implementation of such projects is associated with the use of various types of materials and equipment throughout almost the entire life cycle of the project. In other words, the functioning of the project's logistics system [1] necessitates transport services. Let's note that for some projects, transport services are reduced to the delivery of materials and equipment by road. For projects, for example, offshore oil and gas production, the construction of «cloud» ports, etc., both land and sea transport are used. Moreover, for offshore oil and gas production projects, various types of sea vessels are involved [2–4]: universal – for the transportation of oversized equipment and parts of platforms, tugs – for food, people and equipment of small size.

As a rule, the transport service of the project logistics system allows for a certain variation. So, to solve the same transportation problems, vehicles with different characteristics can be used. Moreover, for large-scale projects, rental of vehicles is often used for the duration of the project. This allows, on the one hand, to save on transport costs, on the other hand, to gain full control over the transportation processes in the project [5]. Thus, taking into account the variability of transport provision, at the stage of project planning, it is necessary to make a decision about which vehicles should be used and under what conditions.

Despite the significant development in recent years of the theoretical basis for project management, it should be noted that there is almost complete absence of research on the transport support of projects. So, given the relevance of transport and infrastructure projects, a number of publications can be noted. For example, [6–8], in which the specifics of transport and logistics projects are considered. The features of the products of infrastructure projects are studied in [9]. But at the same time, attention is not paid to the issues of transport support, which plays a crucial role specifically for these projects, given the significant volumes of materials and equipment used in these projects.

It should be noted that the works [2, 3, 10] consider the planning of transport services for offshore oil and gas production projects. Nevertheless, the presented results are aimed at optimizing transport costs for the already selected variant of the composition of vehicles and the conditions for their use in the project.

Following the project management methodology [11] suggests that any individual aspects of project activities should be considered from the perspective of the project as a whole. Thus, «classical» minimization of transportation costs can disrupt the progress of work on the project and lead to a delay in the delivery of the project product.

The main manifestations of the influence of transport provision on the project are costs and risks [12]. But in modern sources devoted to the risks of transport projects [13, 14], they do not touch upon the risks associated with transport services. Similarly, for works devoted to the costs [15, 16] of transport and infrastructure projects.

Thus, on the one hand, the problem of transport support for projects is relevant given a significant number of projects (transport and infrastructure), in which transport services play a central and decisive factor in the success of these projects. On the other hand, the modern theoretical framework does not provide the necessary tools to support decision-making on this issue. In addition, the conclusion that should be made: the choice of the option of transport support for projects should be carried out within the framework of implementation planning processes [17], taking into account its impact on the stages of the project life cycle and the integral results of the project [11]. This approach is taken as a basis in this study.

Thus, *the aim of this research* is to develop a model for determining the optimal option for transport provision of projects to increase their efficiency and success.

The object of research is the processes of planning transport provision of projects.

2. Methods of research

In [11], it is proposed to consider the transport support of projects at three levels:

1) at the level of a separate work from a set of works on the project;

2) at the level of time periods of the implementation stage of the project life cycle;

3) at the level of the project as a whole.

This differentiation is necessary for different levels of project management and different project management tasks. For example, restrictions on the costs of transportation, for certain reasons, can be formed over time intervals or for the project as a whole. Depending on this, when choosing the optimal option for transport support for the project, the necessary option for aggregating information on transport support is used.

So, under *the option of transport support for the project*, let's mean a set of combinations $\bigcup_{A_{ij}\in\Omega} \langle A_{ij},k,g,l,b\rangle$ for the work of the project, which provide for transport services (let's denote this set Ω):

– A_{ij}, $i=\overline{1,n-1}$, $j=\overline{2,n}$ – project work (n is the number of project work in accordance with the network schedule);
– vehicle kind k;
– vehicle type g;
– a vehicle with certain characteristics l;
– b – condition for using the vehicle in the project (b=1 service, b=2 lease, b=3 purchase).

Possible values of the listed components of the project transport support:

$$k=\overline{1,K},\quad g=\overline{1,G_k},\quad l=\overline{1,L_{kg}},\quad b=1,2,3.$$

For example, k (mode of transport) – sea, river, road; for sea transport g (type of transport) – a universal ship, barge, tug, etc.; l for a ship, this is a specific set of characteristics – carrying capacity, speed, etc.

The values Q_{kij}^{g} characterize the need for transport services for work A_{ij} by a particular type and type of vehicle, that is, they act as initial data for the project.

In [11], expressions were obtained for the costs and risks associated with one or another option of transport support of the project, which is used in this study as the main characteristics of the option of transport support:

– R_{klbij}^{g} – costs of transportation for each project work;
– ΔR – risks of increased costs for the project as a whole for transportation;
– ΔT^{prod} – risks of increasing the time to receive the project product.

These indicators are determined by both the kind and type of vehicle and its characteristics. At the same time, ΔR_b and ΔT_b^{prod} formed as a result of the *integral impact of risk factors* of transport provision for each project work, that is, ΔR_b and ΔT_b^{prod} act as the final impact of transport provision throughout the project on the project results.

The presented forms the basis for the development of a model to determine the optimal option for transport support for the project.

3. Research results and discussion

Let's introduce the notation:

– a variable characterizing the number of vehicles of a specific kind k and type g, with specific characteristics specified by l, and a specific condition for their use in the project for each project work:

$$x_{klbij}^{g}\in Z^{+}\cup 0,\quad i=\overline{1,n-1},\quad j=\overline{2,n},\quad k=\overline{1,K},$$

$$g=\overline{1,G_k},\quad l=\overline{1,L_{kg}},\quad b=1,2,3.$$

Thus, vehicles with a specific set of characteristics C_{kij}^{g} are matched to x_{kblij}^{g}. The index $l=\overline{1,L_{kg}}$ is responsible for a specific set of characteristics C_{kij}^{g};

– a possible increase in transportation costs for each project work:

$$\Delta R_{klbij}^{g},\quad i=\overline{1,n-1},\quad j=\overline{2,n},\quad k=\overline{1,K},$$

$$g=\overline{1,G_k},\quad l=\overline{1,L_{kg}},\quad b=1,2,3;$$

– duration of work, taking into account the option of its transportation:

$$t_{klbij}^{g},\quad i=\overline{1,n-1},\quad j=\overline{2,n},\quad k=\overline{1,K},$$

$$g=\overline{1,G_k},\quad l=\overline{1,L_{kg}},\quad b=1,2,3;$$

– possible increase in work execution time under the influence of transport support for each project work:

$$\Delta t^g_{klbij},\ i=\overline{1,n-1}, j=\overline{2,n}, k=\overline{1,K}, g=\overline{1,G_k},\ l=\overline{1,L_{kg}},\ b=1,2,3;$$

– $R^{\max}$ – limitation on expenses for transport support of the project;
– ΔR^{perm} – permissible increase in the cost of transporting the project;
– T^{prod} – time limit for receiving the project product;
– ΔT^{prod}_{perm} – permissible increase in the time of receiving the project product;
– the number of vehicles of a certain type and type available for the project, taking into account the option of their use in the project (that is, for purchase, lease or service), is determined by the market opportunities:

$$N^{g\max}_{klb},\quad k=\overline{1,K},\quad g=\overline{1,G_k},\quad l=\overline{1,L_{kg}},\quad b=1,2,3.$$

Let's note that for the same work, transport service can be performed by different types of vehicles. The admissibility of such a variation is formed by specifying exogenously $x^g_{klbij}=0$ for those types and types of vehicles that can't be used to perform this service.

As an optimization criterion, let's take the cost of transport services for the project, taking into account possible risks $\Delta R\left(x^g_{klbij}\right)$. These risks are associated both directly with an increase in transport costs $\Delta R^{\exp}\left(x^g_{klbij}\right)$ and with *losses due to the time* of the project (an increase in its duration):

$$\sum_{i=1}^{n-1}\sum_{j=2}^{2}\sum_{k=1}^{K}\sum_{g=1}^{G_k}\sum_{l=1}^{L_{kg}}\sum_{b=1}^{3} R^g_{klbij}\cdot x^g_{klbij}+\Delta R\left(x^g_{klbij}\right)\to\min_{x^g_{klbij}}, \tag{1}$$

where

$$\Delta R\left(x^g_{klbij}\right)=\Delta R^{\exp}\left(x^g_{klbij}\right)+\Delta R^{time}\left(x^g_{klbij}\right), \tag{2}$$

$$\Delta R^{\exp}\left(x^g_{klbij}\right)=\sum_{i=1}^{n-1}\sum_{j=2}^{2}\sum_{k=1}^{K}\sum_{g=1}^{G_k}\sum_{l=1}^{L_{kg}}\sum_{b=1}^{3}\Delta R^g_{klbij}\cdot x^g_{klbij}, \tag{3}$$

$$\Delta R^{time}\left(x^g_{klbij}\right)=\varphi\left(\Delta T^{prod}\right)= =\varphi\begin{pmatrix}\Delta t^g_{klbij}\cdot x^g_{klbij}, i=\overline{1,n-1}, j=\overline{2,n},\\ k=\overline{1,K}, g=\overline{1,G_k}, l=\overline{1,L_{kg}}, b=1,2,3\end{pmatrix}. \tag{4}$$

Let's note that $\Delta R^{\exp}\left(x^g_{klbij}\right)$ is the sum of a possible increase in the cost of transport support for all project works. The determination of $\Delta R^{time}\left(x^g_{klbij}\right)$ is more complex and is based on the analysis of the project network. Thus, using the network diagram, it is possible to determine the increase in the time to receive the project product ΔT^{prod}. Further, this makes it possible to assess the losses, both actual and potential from the late receipt of the project product.

The system of restrictions logically takes into account both the restrictions of the project itself and market opportunities for the use of one or another option of transport support for each work. The limitations associated with the project are both local in nature (for each work involving transportation) and global (integral) for the project as a whole.

Thus, the following model constraints are formed.

The limitation on the costs of transport provision can be formed in two versions – taking into account their possible increase (5) and without (6). The choice of option depends on the risk attitude of the decision maker:

$$\sum_{i=1}^{n-1}\sum_{j=2}^{2}\sum_{k=1}^{K}\sum_{g=1}^{G_k}\sum_{l=1}^{L_{kg}}\sum_{b=1}^{3}\left(R^g_{klbij}+\Delta R^g_{klbij}\right)\cdot x^g_{klbij}\le R^{\max}+\Delta R^{perm}, \tag{5}$$

$$\sum_{i=1}^{n-1}\sum_{j=2}^{2}\sum_{k=1}^{K}\sum_{g=1}^{G_k}\sum_{l=1}^{L_{kg}}\sum_{b=1}^{3} R^g_{klbij}\cdot x^g_{klbij}\le R^{\max}. \tag{6}$$

Time limit for project product receipt:

$$T\left(x^g_{klbij}\right)= =\varphi\left(\max_{x^g_{klbij}>0}\left\{\begin{matrix}t^g_{klbij}, k=\overline{1,K}, g=\overline{1,G_k},\\ l=\overline{1,L_{kg}}, b=1,2,3\end{matrix}\right\},\ i=\overline{1,n-1}, j=\overline{2,n}\right)\le T^{prod}, \tag{7}$$

taking into account the possible increase in time for each work:

$$T\left(x^g_{klbij}\right)= =\varphi\left(\max_{x^g_{klbij}>0}\left\{\begin{matrix}\left(t^g_{klbij}+\Delta t^g_{klbij}\right),\\ k=\overline{1,K}, g=\overline{1,G_k},\\ l=\overline{1,L_{kg}}, b=1,2,3\end{matrix}\right\},\ i=\overline{1,n-1}, j=\overline{2,n},\right)\le T^{prod}+\Delta T^{prod}_{perm}, \tag{8}$$

where $\varphi\left(\max_{x^g_{klbij}>0}\left\{\left(t^g_{klbij}+\Delta t^g_{klbij}\right)\right\}\right)$, $\kappa\left(\max_{x^g_{klbij}>0}\left\{t^g_{klbij}\right\}\right)$ – duration of the period until the project product is received in accordance with its network schedule, taking into account and without possible deviations in the time of work execution. So, with the simplest version of the network schedule, that is, with the sequential execution of all project work, (7) is transformed into:

$$T\left(x^g_{klbij}\right)=\sum_{i=1}^{n-1}\sum_{j=2}^{n}\max_{x^g_{klbij}>0}\left\{\begin{matrix}t^g_{klbij}, k=\overline{1,K}, g=\overline{1,G_k},\\ l=\overline{1,L_{kg}}, b=1,2,3\end{matrix}\right\}\le T^{prod}. \tag{9}$$

Thus, when several types of vehicles are operating within the framework of a particular job, the maximum duration of the vehicle's operation is taken as the time of its execution.

Restrictions on the volume of transport work for the project work are formed for the option of lack of interchangeability of vehicle types:

$$\sum_{b=1}^{3}\sum_{l=1}^{L_{kg}} P^g_{klij}\cdot x^g_{klbij}\ge Q^g_{kij},$$

$$i=\overline{1,n-1},\quad j=\overline{2,n},\quad k=\overline{1,K},\quad g=\overline{1,G_k}, \tag{10}$$

$$\sum_{g=1}^{G_k}\sum_{l=1}^{L_{kg}}\sum_{b=1}^{3} P_{klij}^{g}\cdot x_{klbij}^{g} \ge Q_{kij}, \quad A_{ij}\in M, \quad k=\overline{1,K}, \qquad (11)$$

where P_{klij}^{g} – carrying capacity of the vehicle; M – set of works for which the interchangeability of vehicles of various types is possible.

Let's note that the specification in (10) and (11) of strict equality is impossible due to the integer number of variables, but minimizing costs as a criterion will ensure "going" out of the border Q_{kij}^{g} within the acceptable range. In addition, in spite of the fact that x_{klbij}^{g} are positive integers, nevertheless, for the option b=1, that is, services from providers x_{klbij}^{g}, it is possible not to specify the integer requirement. Indeed, when using services from transport companies, the supplier can vary their vehicles to provide the required volume of traffic. At the same time, several vehicles, depending on their schedule, may be involved in project maintenance. So, a similar situation arises during sea transportation under a long-term charter contract, when the ship owner has the right to replace the vessel with a similar one.

Restrictions on vehicle availability:

$$\sum_{i=1}^{n-1}\sum_{j=2}^{2} x_{klbij}^{g} \le N_{klb}^{g\max},$$

$$k=\overline{1,K}, \quad g=\overline{1,G_k}, \quad l=\overline{1,L_{kg}}, \quad b=1,2,3. \qquad (12)$$

Let's note that (12) provides for restrictions for the period of the entire project. If necessary (for example, for projects of considerable duration) this restriction can be transformed into a series of restrictions for specific periods of time based on the aggregation of information on the need for transportation in accordance with [11].

Thus, (1), (5), (7), (9)–(12) form a model for optimizing the transport support of the project for a situation when the project time and costs of transport support are specified without their possible increase. (1), (6), (8)–(12) form a model for a situation where project time and costs can be increased by a given amount.

Experimental calculations by the model were carried out for the following initial data (a fragment is presented in Tables 1, 2). Works A_{12}, A_{23}, A_{34}, A_{45} are performed sequentially. Main project constraints:

$R^{\max}$=1200 (m. u.), ΔR^{perm}=200 (m. u.), T^{prod}=120 (days), ΔT^{prod}=15 (days).

A fragment of optimization in Excel is shown in Fig. 1

As a result of optimization, the following values of the variables and the main characteristics of the project were obtained (Fig. 2).

Table 1

Traffic volumes for project work (c. u.)

Works	A_{12}	A_{23}	A_{34}	A_{45}
k=1				
g=1	20	30	40	50
g=2	30	40	–	–
k=2				
g=1	40	40	40	50
g=2	–	50	40	–

Table 2

Costs by options of transportation R_{klbij}^{g}, m. u.

	Works	A_{12}	A_{23}	A_{34}	A_{45}
b=1	k=1				
	g=1				
	l=1	24	18	21	34
	l=2	23	19	22	36
	l=3	30	25	28	41
	l=4	35	26	29	42
	k=1				
	g=2				
	l=1	23	26	–	–
	l=2	22	24	–	–
	k=2				
	g=1				
	l=1	34	56	89	55
	l=2	31	54	83	48
	k=2				
	g=2				
	l=1	–	11	7	–
	l=2	–	8	5	–
b=2	k=1				
	g=1				
	l=1	28.8	21.6	25.2	40.8
	l=2	27.6	22.8	26.4	43.2
	l=3	45	37.5	42	61.5
	l=4	52.5	39	43.5	63
	k=1				
	g=2				
	l=1	27.6	31.2	–	–
	l=2	26.4	28.8	–	–
	k=2				
	g=1				
	l=1	30.6	50.4	80.1	49.5
	l=2	27.9	48.6	74.7	43.2
	k=2				
	g=2				
	l=1	–	9.9	6.3	–
	l=2	–	7.2	4.5	–

For the given initial data, in particular, it was concluded that it was necessary to use the services of transport service providers for k=1, g=1, while the vehicle l=4 was chosen for all project activities. It is advisable to rent the rest of the types and types of vehicles, for all types and types l=2 was chosen. This option is optimal from the point of view of costs, taking into account possible risks, the value of the optimality criterion was 1300 m. u., while the possible risks in monetary terms amounted to 236.45 m. u. The total time of work is 91 days, an increase of 10.8 days is possible.

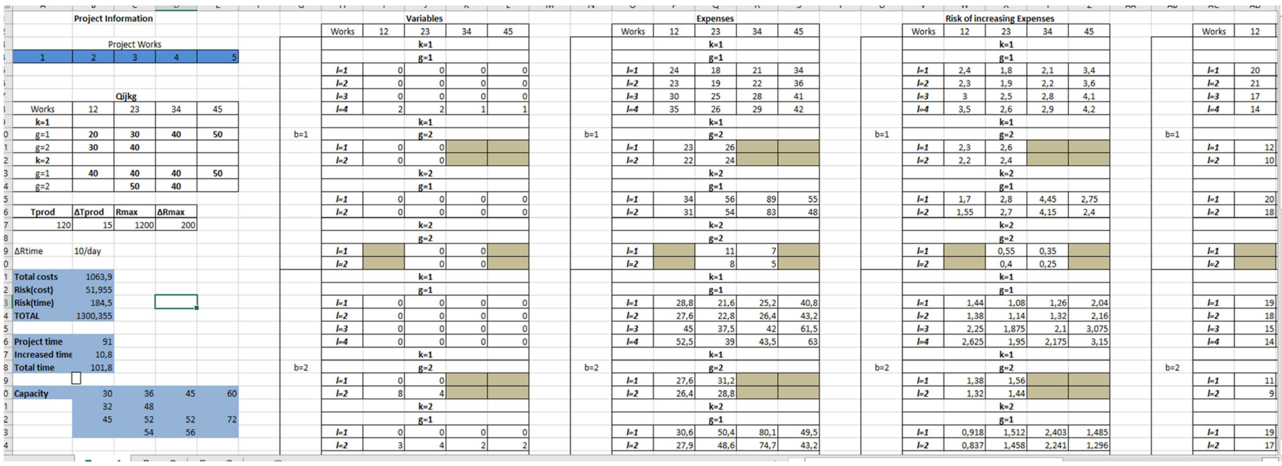

Fig. 1. A fragment of optimization in Excel

				Works	A12	A23	A34	A45		Works	A12	A23	A34	A45
						k=1						k=1		
						g=1						g=1		
Total costs	1063,9			l=1	0	0	0	0		l=1	0	0	0	0
Risk(cost)	51,955			l=2	0	0	0	0		l=2	0	0	0	0
Risk(time)	184,5			l=3	0	0	0	0		l=3	0	0	0	0
TOTAL	1300,355			l=4	2	2	1	1		l=4	0	0	0	0
						k=1						k=1		
Project time	91		b=1			g=2			b=2			g=2		
Increased time	10,8			l=1	0	0				l=1	0	0		
Total time	101,8			l=2	0	0				l=2	8	4		
						k=2						k=2		
						g=1						g=1		
				l=1	0	0	0	0		l=1	0	0	0	0
				l=2	0	0	0	0		l=2	3	4	2	2
						k=2						k=2		
						g=2						g=2		
				l=1		0	0			l=1		0	0	
				l=2		0	0			l=2		3	2	

Fig. 2. Optimization results

In the process of experimental calculations, various initial data were varied, in particular, R^g_{klbij}, ΔR^g_{klbij}, t^g_{klbij}, Δt^g_{klbij}. The solutions obtained adequately corresponded to the change in the initial data and corresponded to the logic of the choice laid down in the model at the meaningful level. Thus, experimental studies have confirmed the reliability of the results obtained.

The area of practical use of the model is making decisions about transportation at the stage of project planning. The model allows for «what-if» experiments that reflect various scenarios that are possible in the transportation of the project. And this, in turn, allows at the stage of project planning to assess possible risks associated with transport, and to establish their impact on the project as a whole.

4. Conclusions

In the course of research, an optimization model was developed for determining the option of transport support for the project. By the variant of transport support of the project, let's mean a set of combinations of types and types of vehicles, their characteristics and conditions of use in the project for the work of the project, which provide for transport services. Acquisition, lease or transport services from the project suppliers are considered as conditions for the use of vehicles in the project.

The optimization criterion is the cost of transport provision, taking into account their possible increase, as well as the potential risks of losses associated with the failure to complete the work. Constraints take into account costs, time to receive a project product, and availability of transportation options.

Experimental calculations, a fragment of which is presented in the study, demonstrated the efficiency of the developed model, its adequacy and reliability of the results obtained with its help.

These results are of both theoretical significance, developing the theory of project management in terms of transport provision, and practical significance, being a decision-making tool in the real conditions of project planning.

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Svitlana Rusanova, *Assistant, Department of Port Operating and Handling Technologies, Odessa National Maritime University, Odessa, Ukraine, e-mail: rusanova20140909@gmail.com, ORCID: http://orcid.org/0000-0003-3624-6582*

Svitlana Onyshchenko, *Doctor of Economic Sciences, Professor, Director, Educational and Scientific Institute of Marine Business, Odessa National Maritime University, Odessa, Ukraine, e-mail: onyshenko@gmail.com, ORCID: http://orcid.org/0000-0002-7528-4939*

Varvara Piterska, *Doctor of Technical Sciences, Professor, Department of Port Operating and Handling Technologies, Odessa National Maritime University, Odessa, Ukraine, e-mail: varuwa@ukr.net, ORCID: http://orcid.org/0000-0001-5849-9033*