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Ishchenko N. M.,
candidate of economic sciences, associate professor
Petro Mohyla Black Sea State University, Mykolaiv, Ukraine

MINIMIZATION OF FORWARDING COSTS IN THE LOGISTICS PROCESS

Relevance of the topic is determined by the fact that in recent years around the world there is increasing demands for forwarding the process of maritime transport. It is necessary to generate optimal logistic schemes of cargo delivery from the manufacturer to the recipient with the participation of various types of transport, to optimize workflow associated with the preparation and transport of goods, its transfer, storage, insurance, etc.

Keywords: *logistics; shipping; optimization methods.*

Formulation of the problem in general and its connection with important scientific and practical tasks. Relevance of the topic is determined by the fact that in recent years around the world there is increasing demands for forwarding the process of maritime transport. It is necessary to generate optimal logistic schemes of cargo delivery from the manufacturer to the recipient with the participation of various types of transport, to optimize workflow associated with the preparation and transport of goods, its transfer, storage, insurance, etc.

Analysis of recent research and publications. Problems of optimization of logistic process of forwarding considered in K. Pluzhnikov [1], N. Panibratez, V. Suchotskiy [2], B. Broukhis [3], Y. Nerush, Y. Lozovoj, B. Shabanov [4].

The definition of the problem, which has not been resolved earlier. The practical task of organizing the logistics process is quite capacious and includes a number of practical problems:

– optimization of the workflow defined in the forwarding of goods;

– development of routes;

– the choice of vessels for transportation of goods given on the basis of transport and performance of vessels and delivery times;

– consolidation of the vessel for each specific version of the work;

– minimizing the cost of delivery.

The existing mathematical apparatus is not always suitable for the practical problems posed. There is therefore a need to establish procedures that are using modern mathematical apparatus and computer hardware, that will help to minimize the costs in the logistics process of transportation on maritime transport.

The purpose of this article. The purpose of this article is to provide an efficient method of minimizing of forwarding costs in the logistics process of cargo on maritime transport.

The presentation of the main contents of the article.

A mathematical model of the problem of minimizing costs in the logistics forwarding cargo during sea transport has the next form:

$$\sum_{c=1}^{C}\sum_{j=1}^{J_C} R_{cj} \cdot x_{cj} \to \min; \qquad (1)$$

$$\sum_{c=1}^{C}\sum_{j=1}^{J_C} q_{icj} \cdot x_{icj} \le Q_i; \ \text{(i=1,I)} \qquad (2)$$

$$\sum_{j=1}^{J_c} x_{cj} = 1 \ \text{(c=1,C)} \qquad (3)$$

$$x_{cj} \in (0,1), \qquad \text{(c = 1, C; j = 1, } J_c\text{)}, \qquad (4)$$

where R_{cj} – expenditures of vessel of type C of the i-th version of the work or the cost of shipowner of vessel type C in the j-th pattern;

x_{sj} – control parameter.

The objective function represents a consolidation of the courts according to the schemes of work, which provides the minimum cost of the cargo relating to the delivery of the goods to their destination. Restrictions (2) states that the weight of the cargo transported by vessels between the ports can not exceed the amount claimed. Restrictions (3) characterize the inadmissibility of the simultaneous use of the vessel on several versions of the work.

Let's say it is needed to solve the problem of minimizing the costs of forwarding the logistical process of freight traffic on the maritime transport of cargo for the following:

– equipment (27 000 tonnes) in the direction of Mariupol – Piraeus;

– metal (29 000 tonnes) in the direction of Kerch – Genoa;

– corn (30 000 tonnes) in the direction of Mariupol – Barcelona.

Routes of vessels consist of one, two or more pairs of ports. In observed case, the scheme of cargo flows will be as follows:

1. Mariupol (loading equipment) – Piraeus (unloading).
2. Kerch (loading of metal) – Genoa (unloading).
3. Mariupol (loading grain) – Barcelona (unloading).
4. Mariupol (loading equipment) – Kerch (loading of metal) – Piraeus (unloading equipment) – Genoa (unloading metal).

5. Mariupol (loading equipment and grain) – Piraeus (unloading equipment) – Barcelona (unloading grain).

6. Mariupol (loading grain) – Kerch (loading of metal) – Genoa (unloading metal) – Barcelona (unloading grain).

7. Mariupol (loading equipment and grain) – Kerch (loading of metal) – Piraeus (unloading equipment) – Genoa (unloading metal) – Barcelona (unloading grain).

Selection of the vessel is mainly guided by the following parameters:

– the time of delivery;

– minimum cost for transportation of the specified cargo.

Since all the goods offered are general, then, consequently, general vessel should be selected.

The size of the ship's tonnage has an impact on the level of economic performance of the vessel. At short range and low load rates in the ports of transshipment it is preferable to use small ships. The value of the ship carrying capacity should be close to the maximum range of movement and an average rate of cargo handling, and it should also correspond to the volume of shipping. Estimated value of the ship's tonnage in this case should be more than 10 thousand tonnes.

It is proposed to use «Pula», «Izvestiya» and «Warnemünde», whose technical and operational characteristics are presented in Table. 1.

Table 1

Technical and economic parameters of the selected ships

Indexes	«Pula»	«Izvestiya»	«Warnemünde»
Maximal lenth, m	159,0	132,0	150,0
Width, m	21	20	22
Draft, m	9,7	9,7	8,8
Capasity, t.	12300	11450	10137
Volume, m^3	20370	20000	17037
Velocity with cargo, knots	18,4	15	18
Velocity withoutrgo, knots	20,5	16	20
Disrance, miles	19000	12600	12500
Exploitation costs: On ride, UAH/day At berth, UAH/day	 3486 2149	 4800 3200	 4762 4138

In Schemes 1, 2 and 3, where the vessel carries a homogeneous «heavy» cargo, ship carries cargo to the load capacity.

In case when the ship is loaded by different loads (scheme 4, 5, 6 and 7), the amount of each is proportional to the load carrying capacity:

$$q_{icj} = \frac{Q_{ij}}{\sum_{j=1}^{J} Q_j} \cdot D_ч, \quad (5)$$

where q_{icj} – volume of cargo of vessel type C by i-load on the j-th pattern of movement.

For example, the amount of cargo 1st on the 4th scheme for the ship «Pula» is:

$$q_{114} = \frac{27000}{27000 + 29000} \cdot 12300 = 5930(m). \quad (6)$$

Number of 2nd cargo on the 4th circuit for vessel "Pula" is as follows:

$$q_{214} = \frac{29000}{27000 + 29000} \cdot 12300 = 6370(m). \quad (7)$$

Thus, the vessel «Pula» can be uploaded by 5930 m and 6370 m of equipment and metal. Then, the total cargo of the vessel is: Q = 5930 + 6370 = 12300 tonnes.

The costs of shipping cargo are:

$$R_{cj} = r_j \cdot q_{icj}, \quad (8)$$

where R_{cj} – the cost of the cargo;

r_{cj} – tariff rate for the transportation of the i-th goods;

q_{icj} – loading of vessel type C i-th cargo on the j-th pattern of movement.

The tariff rate for transportation of one ton of cargo is chosen by swtatistics of year 2015.

1. The rate for the equipment transported from Mariupol to Piraeus, is $ 14,95 / ton.

2. The rate for the metal transported from Kerch to Genoa, is $ 22,90 / t.

3. The rate of grain transported from Mariupol to Barcelona is $ 19,24 / ton.

The cost of the cargo during transportation of goods were calculated. For example, the cost of the cargo at the 7th traffic pattern for the ship «Pula» are:

$$R_{17} = 14{,}95 \cdot 3862 + 22{,}90 \cdot 4148 + 19{,}24 \cdot 4291 = 235266(\$).$$

The values of the cost of traffic schemes are listed in the Table 2.

Table 2

The costs of the cargo during transportation of goods

«Pula»						
Scheme1	**Scheme2**	**Схема 3**	**Схема 4**	**Схема 5**	**Схема 6**	**Схема 7**
12300	0	0	5930	5826	0	3862
0	12300	0	6370	0	6046	4148
0	0	12300	0	6474	6254	4291
183885	281670	236652	234524	211657	258779	235266
Mean value	**234633**					

End table 2

«Izvestiya»						
Scheme1	**Scheme2**	**Схема 3**	**Схема 4**	**Схема 5**	**Схема 6**	**Схема 7**
11450	0	0	5521	5424	0	3595
0	11450	0	5929	0	5628	3861
0	0	11450	0	6026	5822	3994
171178	262205	220298	218317	197030	240896	219008
Mean value	**218419**					
«Warnemünde»						
Scheme1	**Scheme2**	**Схема 3**	**Схема 4**	**Схема 5**	**Схема 6**	**Схема 7**
10137	0	0	4887	4802	0	3183
0	10137	0	5250	0	4983	3418
0	0	10137	0	5335	5154	3536
151548	232137	195036	193282	174436	213272	193894
Mean value	**193372**					

Each vessel must be assigned to a specific route of movement so as to ensure the cargo as a result of minimal costs. The mass of cargo transported between the two ports, should not exceed the amount claimed. It should also be noted that the simultaneous use of several variations on the vessel operation is unacceptable.

The sequence of the courts depends on the $\overline{R}_c$:

$$\overline{R}_c = \frac{1}{J_c} \cdot \sum_{j=1}^{J_C} R_{cj} \ , \qquad (9)$$

where $\overline{R}_c$: – the average cost of each of the vessels in all variants of schemes;

J_c – the amount of traffic patterns;

R_{cj} – the costs of transporting of the cargo ship of type C in the j-th route.

Average consumption Rc is arranged in descending order: R3 ≤ R2 ≤ R1. After streamlining of the mean cost of the work of these ships, we obtain the following inequality:

193 372 < 218 419 < 246 842.

Next, for each ship versions of their work are arranged in a similar sequence. The first option provides the minimal cost of cargo in freight traffic, and the last – the maximum costs.

Write a mathematical model in coordinate form:

The objective function:

$R_{11}x_{11}+ R_{12}x_{12}+ R_{13}x_{13}+ R_{14}x_{14}+ R_{15}x_{15}+ R_{16}x_{16}+ R_{17}x_{17}+ R_{21}x_{21}+ R_{22}x_{22}+ R_{23}x_{23}+ R_{24}x_{24}+ R_{25}x_{25}+ R_{26}x_{26}+ R_{27}x_{27}+ R_{31}x_{31}+ R_{32}x_{32}+ R_{33}x_{33}+ R_{34}x_{34}+ R_{35}x_{35}+ R_{36}x_{36}+ R_{37}x_{37} \rightarrow \min;$

Restrictions:

$q_{111}x_{11}+ q_{112}x_{12}+q_{113}x_{13}+ q_{114}x_{14}+ q_{115}x_{15}+ q_{116}x_{16}+ q_{117}x_{17}+ q_{121}x_{21}+ q_{122}x_{22}+ q_{123}x_{23}+ +q_{124}x_{24}+ q_{125}x_{25}+ q_{126}x_{26}+ q_{127}x_{27}+ q_{131}x_{31}+ q_{132}x_{32}+ q_{133}x_{33}+ q_{134}x_{34}+ q_{135}x_{35}+ q_{136}x_{36}+ q_{137}x_{37} \le Q_1;$

$q_{211}x_{11}+ q_{212}x_{12}+q_{213}x_{13}+ q_{214}x_{14}+ q_{215}x_{15}+ q_{216}x_{16}+ q_{217}x_{17}+ q_{221}x_{21}+ q_{222}x_{22}+ q_{223}x_{23}+ +q_{224}x_{24}+ q_{225}x_{25}+ q_{226}x_{26}+ q_{227}x_{27}+ q_{231}x_{31}+ q_{232}x_{32}+ q_{233}x_{33}+ q_{234}x_{34}+ q_{235}x_{35}+ q_{236}x_{36}+q_{237}x_{37} \le Q_2;$

$q_{311}x_{11}+ q_{312}x_{12}+q_{313}x_{13}+ q_{314}x_{14}+ q_{315}x_{15}+ q_{316}x_{16}+ q_{317}x_{17}+ q_{321}x_{21}+ q_{322}x_{22}+ q_{323}x_{23}+ +q_{324}x_{24}+ q_{325}x_{25}+ q_{326}x_{26}+ q_{327}x_{27}+ q_{331}x_{31}+ q_{332}x_{32}+ q_{333}x_{33}+ q_{334}x_{34}+ q_{335}x_{35}+ q_{336}x_{36}+ q_{337}x_{37} \le Q_3;$

$x_{11}+ x_{12}+ x_{13}+ x_{14}+ x_{15}+ x_{16}+ x_{17}=1;$

$x_{21}+ x_{22}+ x_{23}+ x_{24}+ x_{25}+ x_{26}+ x_{27}=1;$

$x_{31}+ x_{32}+ x_{33}+ x_{34}+ x_{35}+ x_{36}+ x_{37}=1.$

So:

The objective function:

183885x11 + 281670x12 + 236652x13 + 234524x14 + 211655x15 + 258779x16 + 235266x17 + 171178x21 + 262205x22 + 220298x23 + 218317x24 + 197030x25 + 240896x26 +219008x27 + 151548x31+ 232137x32 + 195036x33 + 193282x34 + 174436x35 + 213272x36 + 193894x37 → min;

Restrictions:

12300x11 + 5930x14 + 5826x15 + 3862x17 + 11450x21 + 5521x24 + 5424x25 + 3595x27 + 10137x31 + 4887x34 + 4802x35 + 3183x37 ≤ 27000;

12300x12 + 6370x14 + 6046x16 + 4148x17 + 11450x22 + 5929x24 + 5628x26 + 3861x27 + 10137x32 + + 5250x34 + 4983x36 + 3418x37 ≤ 29000;

12300x13 + 6474x15 + 6254x16 + 4291x17 + 11450x23 + 6026x25 + 5822x26 + 3994x27 + 10137x3 + 5335x35 + 5154x36 + 3536x37 ≤ 30000;

$$\begin{aligned} x11 + x12 + x13 + x14 + x15 + x16 + x17 = 1; \\ x21 + x22 + x23 + x24 + x25 + x26 + x27 = 1; \\ x31 + x32 + x33 + x34 + x35 + x36 + x37 = 1; \end{aligned} \qquad (10)$$

$X_{cj} = \{0; 1\};$ C = 1, 2, 3; j = 1, 2, 3, 4, 5, 6, 7.

Build pivot table of calculation (Table 3). The final two lines of the table indicate the ship and how they work in accordance with the priority ranks. The last line indicates the cost of the cargo corresponding to such series. The lower part of the table contains the amount of goods transported between the ports intended for carriage.

Table 3

Securing the courts of options works (Phase 1)

Cargo	«Warnemünde»						
	Схема 1	**Схема 5**	**Схема 4**	**Схема 7**	**Схема 3**	**Схема 6**	**Схема 2**
Equipment	10137	4802	4887	3183	0	0	0
Metal	0	0	5250	3418	0	4983	10137
Corn	0	5335	0	3536	10137	5154	0
Costs	151548	174436	193282	193894	195036	213272	232137
Mean costs	**193372**						
«Izvestiya»							
	Схема 1	**Схема 5**	**Схема 4**	**Схема 7**	**Схема 3**	**Схема 6**	**Схема 2**
Equipment	11450	5424	5521	3595	0	0	0
Metal	0	0	5929	3861	0	5628	11450
Corn	0	6026	0	3994	11450	5822	0
Costs	171178	197030	218317	219008	220298	240896	262205
Mean costs	**218419**						
«Pula»							
	Схема 1	**Схема 5**	**Схема 4**	**Схема 7**	**Схема 3**	**Схема 6**	**Схема 2**
Equipment	12300	5826	5930	3862	0	0	0
Metal	0	0	6370	4148	0	6046	12300
Corn	0	6474	0	4291	12300	6254	0
Costs	183885	211657	234524	235266	236652	258779	281670
Mean costs	**234633**						

The standard means of solving optimization problems (for example, «Search for a solution» – Solver, included in the package Microsoft Office), in this case do not provide optimal solutions due to insufficient limits of a mathematical model (10). Thus, the model does not take into account the limitations:

1) the possibility of redistribution of the number of cargo if the rest of the goods offered for carriage does not exceed the carrying capacity of the ship;

2) the redistribution of costs;

3) the possibility of multiple use of the vessel in the scheme of transportation;

4) the cost of ballast transitions when returning of vessels in the ports of loading.

In this regard, continue to use formal heuristic method for solving the problem.

The ship «Warnemünde» is assigned to the 1st scheme of work; the costs of the cargo are $ 151,548. The vessel «Izvestiya» will also work on the 1st scheme, while the cost of transporting freight will be $ 171,178. The ship «Pula» has secured the 5th option and, as the remainder of the first load (equipment) is 27,000 – 10,137 – 11450 = 5413 (t), load of vessel is recounted. Deadweight of «Pula» is 12300 tonnes, thus loading the ship equipment will be 5413 tons, and grain: 12300 – 5413 = 6887 m. The cost of cargo vessel «Pula» are: 5413 × 14,95 + 6887 × 19,24 = $ 213,430. The total cost of the cargo at this stage amounted to 151549 + 171178 + 213430 = 536156 $.

Balance of cargo: 29,000 tons of metal and 23 113 tons of grain.

Balance of cargo offered for carriage is given in Table 4.

Table 4

Balance the load (the first stage)

Volume of cargo, Q_i	Q_1	Q_2	Q_3
Mariupol – Piraeus (equipment)	16863	5413	0
Kerch – Genoa (metal)	29000	29000	29000
Mariupol – Barcelona (grain)	30000	30000	23113

The specified goods traffic on these schemes can not be mastered, as the total amount of the goods presented for carriage, exceeds the total capacity of selected ships.

For the export of the remaining cargo traffic use such schemes, which downloads the first load (equipment) is 0. It – Scheme 2, 3 and 6.

Vessels operating on these schemes will have to make a ballast voyage from the port of unloading in the ports of loading:

1. Piraeus – Mariupol (Scheme 1): a distance of 883 miles;

2. Barcelona – Mariupol (Scheme 5): a distance of 2037 miles.

$$T_X^{б} = \frac{L_{б}}{V_э^{б}}, \qquad (11)$$

where L_b – the length of the ballast voyage, a mile;
V_e – cruising speed of the ship, knots.

The calculation for ballast voyage of ship «Pula» is shown below:

$$T_X^{б} = \frac{883}{24 \cdot 20{,}5} = 1{,}79(days.). \qquad (12)$$

Define the cost of the ship during ballast voyage:

$$R_c^б = T_x^б \cdot C_x, \quad (13)$$

where T_x – duration of the ballast voyage, days;
C_x – the cost of the ship on the move, UAH / day.
$R_c^б = 1,79 \times 3486 = 6256$ UAH = 1227 $.

Similarly, duration of the ballast voyage of the ship «Izvestiya» is 2.30 days; while the operating costs of the vessel during the ballast voyage amounted to $ 1572. Time ballast of voyage of ship «Warnemünde» is 4,24 days; while the operating costs of the vessel during the ballast voyage amounted to $ 2901.

The calculation results are summarized in Table 5.

Table 5

The costs of the fleet during the ballast voyage

Vessel	Time of ballast, days	Costs of voyage with cargo, UAH/day	Costs of voyage without cargo, UAH/day
«Warnemünde»	4,24	4762	2901
«Izvestiya»	2,30	4800	1572
«Pula»	1,79	3486	1227

Next, define the general running costs of the ballast of ships, taking into account the transition. They are equal to the sum of the costs associated with the transport of cargo and ballast costs of transition. Since the cost of cargo increased, built a new table (Table 6) for fixing the ship work options.

Table 6

Securing the vessels for traffic pattern (the second stage)

Cargo	«Warnemünde»			«Izvestiya»			«Pula»		
	Scheme 3	Scheme 6	Scheme 2	Scheme 3	Scheme 6	Scheme 2	Scheme 3	Scheme 6	Scheme 2
Equipment	0	0	0	0	0	0	0	0	0
Metal	0	4983	10137	0	5628	11450	0	6046	12300
Corn	10137	5154	0	11450	5822	0	12300	6254	0
Costs	196293	214530	233395	221870	242468	263777	239482	261609	284500
Mean costs	214739			242705			261864		

Average costs R_c are arranged in descending order: R3 ≤ R2 ≤ R1. Streamlining the mean cost of the work of these ships, we obtain the following inequality:

$$214,739 \le 242,705 \le 261,864.$$

A mathematical model of the problem with numerical data is as follows:

The objective function:

$$284500x_{12} + 239482x_{13} + 261609x_{16} + 263777x_{22} + 221870x_{23} + 242468x_{26} + 233395x_{32} + 196293x_{33} + 214530x_{36} \to \min. \quad (14)$$

Restrictions:

$$12300x_{12} + 6046x_{16} + 11450x_{22} + 5628x_{26} + 10137x_{32} + 4983x_{36} \le 29000;$$
$$12300x_{13} + 6254x_{16} + 10137x_{23} + 5154x_{26} + 11450x_{33} + 5822x_{36} \le 23113; \quad (15)$$
$$x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} + x_{17} = 1;$$
$$x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} + x_{27} = 1; \quad (16)$$
$$x_{31} + x_{32} + x_{33} + x_{34} + x_{35} + x_{36} + x_{37} = 1.$$

The ship «Warnemünde» is assigned to the third scheme of work; the costs of the cargo is $ 196,293. The vessel «Izvestiya» will also work on the third circuit, and thus the cost of cargo transportation will be $ 221,870. The ship «Pula» has secured the 6th option and, as the remainder of the third cargo (grain) is 23113 – 10137 – 11450 = 1526 (t), can be counted loading vessel. Deadweight «Pula» is 12300 tonnes, thus loading the vessel will be 1526 tons of grain and metal: 12300 – 1526 = 10774 t. The costs of cargo vessel «Pula» are: 1526 × 14,95 + 10774 × 19,24 = $ 276,085. The total cost of the cargo at this stage amounted to 196293 + 221870 + 276085 = 694248 $.

The balance of goods: 29000 – 10774 = 18226 tons of metal.

Balance cargo offered for carriage is given in Table 7.

Table 7

Balance the load (the second stage)

Volume of cargo, Q_i	Q_1	Q_2	Q_3
Mariupol – Piraeus (equipment)	0	0	0
Kerch – Genoa (metal)	29000	29000	18226
Mariupol – Barcelona (grain)	12976	1526	0

From Table 7 it is seen that in the second stage all the freight is not mastered. The remainder is 18 226 tons of metal. The results of calculations the cost of ballast transitions are summarized in Table 8.

Table 8

The costs of the fleet during the ballast voyage after the second stage

Vessel	Time of ballast, days	Costs of voyage with cargo, UAH/day	Costs of voyage without cargo, UAH/day
«Warnemünde»	4,24	4762	2901
«Izvestiya»	5,30	4800	3626
«Pula»	4,14	3486	2830

Next, define the general running costs of the ballast of ships, taking into account the transition. They are equal to the sum of the costs associated with the transport of cargo and ballast costs of transition. Since the cost of cargo increased, it built a new table (Table 9) for fixing the vessels for work options.

Table 9

Securing the courts for traffic pattern (the third stage)

Cargo	«Warnemünde»	«Izvestiya»	«Pula»
	Scheme 2	Scheme 2	Scheme 2
Equipment	0	0	0
Metal	10137	11450	12300
Corn	0	0	0
Costs	236295	267403	287330

In the third stage the ship «Warnemünde» is assigned to the 2nd circuit, the cost of transportation will be 236 295 $, the rest of the consignment is 18226 – 10137 = 8089 tonnes. The vessel «Izvestia» also assigned to the 2nd circuit, but the loading of the ship will change accordingly cargo residues – 8089 m. The cost of carriage for the vessel «Izvestiya» made 8089 × 22,90 = $ 185,238. The cost of delivery at this stage was 236295 + 185238 = $ 421,534.

Due to the inability to transport a given amount of cargo per one route mastering the entire cargo was divided into three stages. The second and third stages the costs of the cargo on the cargo delivery includes the cost of the vessel during the ballast voyage. The general cargo vessel costs for the delivery of the goods are as follows:

$R_{general}$ = 536156 + 694248 + 421534 = 1651937 $.

Conclusions. On the basis of technical and operational parameters provided by the vessels, as well as taking into account the time of delivery and range of transportation, three types of vessel were chosen. Duration of the course of the project was determined by the cost of the cargo for transportation of goods specified on the specific job options. Since the cost to be minimized, the selected scheme and placement of ships on their way to the cargo costs were lowest.

Since the amount claimed for shipping does not coincide with the total capacity of the fleet, navy work was divided into several stages.

Step 1. The vessel «Warnemünde» is assigned to the 1st scheme of work; the costs of the cargo amounted to $ 151,548. The vessel «Izvestiya» has also been fixed for the 1st circuit, while the cost of cargo transportation was $ 171,178. The vessel «Pula» is assigned to the 5th option and the cost of transport of goods amounted to $ 213,430. The total cost of the cargo at this stage is $ 536,156.

Balance of cargo: 29,000 tons of metal and 23 113 tons of grain.

Step 2: The ship «Warnemünde» is assigned to the third scheme of work; The costs of the cargo amounted to $ 196,293. The vessel «Izvestiya» also assigned to the 3rd circuit, and thus the cost of cargo transportation was $ 221,870. The vessel «Pula» is assigned to the 6th option, and the cost of transport of goods amounted to $ 276,085. The total cost of the cargo at this stage is $ 694,248.

Balance of cargo: 18,226 tons of metal.

Step 3: Ship «Warnemünde» is assigned to the 2nd circuit, the cost of transportation was $ 236,295. The vessel «Izvestiya» also assigned to the 2nd circuit. Spending on transportation to the ship «Izvestiya» made $ 185,238. The total cost of the cargo at this stage is $ 421,534.

Mastering all traffic was divided into three stages. The second and third stages of the costs of the cargo on the cargo delivery includes the cost of the vessel during the ballast voyage. The total cost of the cargo vessel cargo delivery totaled $ 1651937.

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Іщенко Н. М.,

Чорноморський державний університет імені Петра Могили, м. Миколаїв, Україна

Мінімізація експедиторських витрат у логістичному процесі

Актуальність теми обумовлена тією обставиною, що останнім часом у всьому світі спостерігається підвищення вимог до експедиційного процесу на морському транспорті. Потрібно формувати оптимальні логістичні схеми доставки вантажів від виробника до одержувача за участю різних видів транспорту, оптимізувати документообіг, пов'язаний із підготовкою та перевезенням вантажів, їх передачею, зберіганням, страхуванням і т. д.

Ключові слова: *логістика; морські перевезення; оптимізаційні методи.*

Ищенко Н. М.,
Черноморский государственный университет имени Петра Могилы, г. Николаев, Украина

Минимизация экспедиторских затрат в логистическом процессе

Актуальность темы обусловлена тем обстоятельством, что в последнее время во всем мире наблюдается повышение требований к экспедиционному процессу на морском транспорте. Требуются оптимальные логистические схемы доставки грузов от производителя к получателю с участием различных видов транспорта, оптимизирование документооборота, связанного с подготовкой и перевозкой грузов, их передачей, хранением, страхованием и т. д.

Ключевые слова: *логистика; морские перевозки; оптимизационные методы.*

Рецензенти: ***Кузьменко О. Б.,*** д-р екон. наук, професор;
Якубовський С. О., д-р екон. наук, професор.

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