CALCULATION OF THE FLEET NEED FOR THE TRANSPORT AND LOGISTICS SYSTEM

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ABSTRACT

The article considers the transport and logistics system (TLS) with routes passing through sea and river basins, which is designed to enhance the possibilities of transportation. With the help of such multimodal routes, the country will receive a transport network with much greater throughput, which will ensure sustainable growth rates of the regional economy. The authors solve the problem of developing methodological approaches to justifying the need for the fleet, adapted to the conditions of transportation of road trains on ferries of ro-ro type following the emergence of new sea transport routes. A model calculation of the need for a fleet for a cargo line of TLS using sea and river vessels is provided.

Keywords: *transport and logistics system, cargo line, ferries of ro-ro type, road train, multimodal transportation, economic and mathematical model, profit, need for the fleet, sea and inland waterways.*

Background. *Shipping companies while developing structure of freight transportation consider the need for the fleet as an integral part of operation and economic substantiation of further activities. The expenditure for fleet's maintenance and the cost of cargo transportation depend on the scientific and methodological approach to solution of that problem.*

In current works [1, pp. 24–26; 2, pp. 75–100; 3, pp. 3–6; 4, pp. 25–27] aspects of organization of the ferry transport logistics systems, which involve inland waterways (IWW) are considered.

Objective. *The objective of the authors is to provide methodological approach to the substantiation of the need for fleet that will account for transportation of road train by ferries of ro-ro type by sea and internal land routes, within the transport and logistics system using multimodal technology.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, evaluation approach, graph construction, mathematical methods.*

Results.

The suggested transport and logistics system (TLS) will allow to build a water route consisting of existing (inland water ways) and new itineraries (sea routes) of goods delivery with the objective to reduce the land part of transportation route.

The TLS will ensure three possible variants of organization of transportation using, respectively:

- *trucks (road trains) on federal highways and ferries on the sea routes;*
- *trucks on federal highways, ferries on the sea routes and on inland waterways;*
- *trucks on federal highways and ferries on IWW.*

Cargo line (CL) within TLS may include any IWW and sea routes, located within the boundaries of the route of goods transportation.

The effectiveness of carriage by road using j-th CL is determined by the coefficient α_j [5, p. 91].

If α_j = 1, then road train transportation is performed by the j-th CL.

Table 1

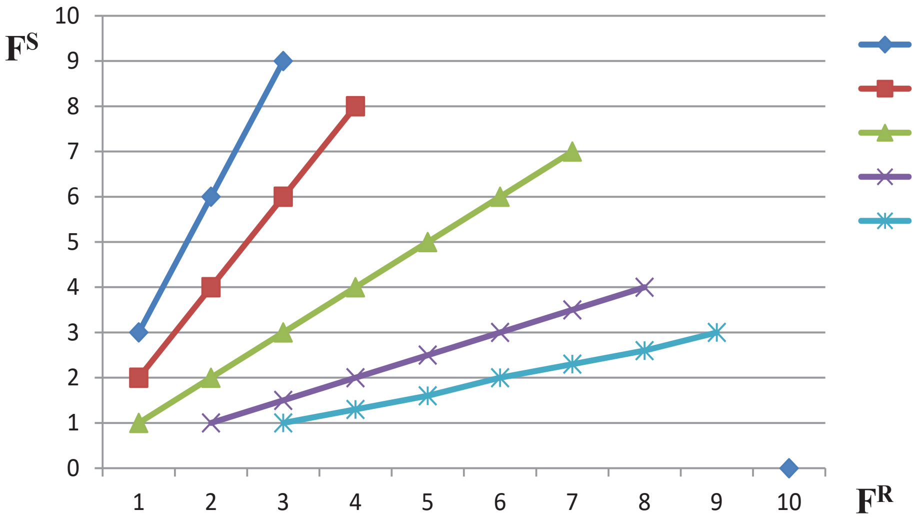
Fleet use options

No.	CL (port of departure and port of destination)	Section of CL			*z*-th types of ferries for a sea section of CL				*z*-th types of feries for an inland water section of CL			
		α_j	u_j	v_j	z_1	z_2	...	z_k	z_1	z_2	...	z_k
1		1	0	1	1	0	...	1	1	0	...	0
2		1	1	0	0	1	...	0	1	1	...	0
3		1	1	1	1	0	...	1	0	1	...	1
...	...	...	...	...	...	...	...	...	...	...	...	...
n		1	1	0	0	0	...	0	0	0	...	0

Table 2

Making decisions

No.	CL (port of departure and port of destination)	Sections of CL			*z*-th types of ferries for a sea section of CL				*z*-th types of ferries for an inland water section of CL				Carriage by road
		α_j	u_j	v_j	z_1	z_2	...	z_k	z_1	z_2	...	z_k	β_j
1		1	0	1	1	0	...	0	1	0	...	0	0
2		1	1	0	0	1	...	0	1	0	...	0	0
3		1	1	1	0	0	...	1	0	0	...	1	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...
n		1	1	0	0	0	...	0	0	0	...	0	1



Pic. 1. The need for fleet for a sea F^S and a river section F^R depending on the values of the circular voyage coefficient k_{cir}.

If $\alpha_j = 0$, then transportation within the TLS along the j-th CL is considered as non-effective and delivery of goods is performed by a road train on a highway.

If $\alpha_j = 1$, $u_j = 1$ and $\nu_j = 1$, then the j-th CL with sea and inland water sections is used, where u_j and ν_j are variables, which show the presence of sea and inland water sections of the j-th CL.

If $\alpha_j = 1$, $u_j = 1$ and $\nu_j = 0$, then the j-th CL with sea sections is used.

If $\alpha_j = 1$, $u_j = 0$ and $\nu_j = 1$, then the j-th CL with inland water sections is used.

To assess the efficiency of carriage by road, a constraint is introduced using the coefficient β_j [5, p. 91].

If $\beta_j = 1$, then road transportation on the i-th route is more efficient than the alternative multimodal transportation using the j-th CL.

If $\beta_j = 0$, then road transportation on the i-th route is less efficient than the alternative multimodal transportation using the j-th CL [5, p. 91].

The profitability of TLS is chosen as a function of the objective of the economic-mathematical model of a TLS for all cargo lines using optimization solution [6, p. 121; 7, p. 50]:

$$\left(\sum_{j=1}^{n} P_j^{CL(S)} \cdot u_j + \sum_{j=1}^{n} P_j^{CL(R)} \cdot \nu_j\right)\alpha_j \Rightarrow \max, \qquad (1)$$

where $P_j^{CL(S)}$ – profit of a shipping company operating the j-th CL, consisting of sea routes;

$P_j^{CL(R)}$ – profit of a shipping company operating the j-th CL, consisting of inland waterways.

Table 1 illustrates the solution of TLS organization tasks. It shows the z-th types of ferries that can be used for sea and inland water sections of CL and bring profit.

If it is possible to use several ferries on one CL, a single type of ferry is selected that provides maximum profit, according to the objective function (1).

The Table 2 was developed on that basis, to show decision-making process regarding the choice of the method of transportation using sea and inland water sections of CL and of the type of ferry that provides maximum profit.

The column «Carriage by road» with $\beta_j = 1$ shows that none of the proposed types of ferries can be used on the j-th CL, transportation is carried out by a road train.

Table 2 is focused on the type of ferries that provides maximum profit, and does not determine the required number of ferries for a CL, as that depends on the volume of cargo transportation (and respective required number of road trains).

This task is relevant in connection with unification of the sea and inland water sections of a cargo line into a single water main line.

The ultimate goal of calculating the characteristics of CL is to determine the need for the fleet F [8, p. 96]:

$$F^{S(R)} = f \cdot t_{cir}^{s(r)} \left(1 + k_{res}\right) = \frac{t_{cir}^{s(r)}}{t_I}\left(1 + k_{res}\right), \text{ unit vessels, (2)}$$

where $F^{S(R)}$ is the need for fleet for sea (river) section of CL;

f – frequency of ferries departure;

$t_{cir}^{s(r)}$ – time of a circular voyage for sea (river) section of CL;

k_{res} – fleet reserve.

The exact value of the need for the fleet $F^{S(R)}$ is calculated according to the types of ferries for specific cargo lines in terms of duration of the circular voyage of CL of sea and inland water sections.

The ratio of time of a circular voyage on the inland water section to time of a circular voyage on the sea section of CL is denoted by the coefficient of the circular voyage k_{cir}:

$$k_{cir} = t_{cir}^{r} / t_{cir}^{s} = F^R / F^S. \qquad (3)$$

The circular voyage ratio shows the need for fleet for CL by type of ferries for sea and inland water sections (assuming the same load with road trains) [7, p. 51].

For example, with $k_{cir} \approx 1$, one should have one ferry of the z-type on the sea section and one ferry of the z-type on the inland water section.

If $k_{cir} \approx 2$, one ferry and two ferries of z-th type are required, respectively, for the sea and inland water sections of CL.

The need for fleet of CL for the sea section F^S and the inland waters section F^R are shown in Pic. 1.

The value of the circular voyage coefficient k_{cir} when using the sea and inland water sections is

determined by the z-th type of a ferry, its loading and the transportation volume of a cargo line for the calculated period.

Conclusion. *The shown methodological approach to selection of the fleet for TLS allows:*

• to assess the possibility of using a particular type of a ferry for delivery of cargoes by sea and inland water sections of cargo lines using Table 1;

• to make a decision on choice of ferries, to adjust a transportation plan, to obtain the optimal result of calculations of the need for the fleet, using Table 2;

• to determine, taking into account the coefficient of circular voyage k_{cir}*, the need for the fleet for a cargo line by types of ferries for sections of a cargo line (sea and inland water sections).*

The authors of the article so have justified and developed methodological approach to the selection of the fleet. It is adapted to the conditions of transportation of road trains on ro-ro type ferries and considers the emergence of additional sea transport routes. The proposed methodological approach should provide the sufficient expediency of the calculation of the need for the fleet for TLS using the sea and inland water (river) routes.

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Article received 10.12.2018, accepted 04.05.2019.