ISSN 2226-3780

UDC 656.6
DOI: 10.15587/2312-8372.2017.92965

Vyshnevska O.,
Vyshnevsky D.

INVESTIGATION OF THE EFFECT OF SHIP SIZE AND MARINE TRANSPORTATION DISTANCE ON THE POSSIBLE DECREASE OF VOYAGE EFFICIENCY

Сформульовано вираз відхилення показника ефективності виконання судном рейсу (тайм-чартерного еквівалента) як функції від характеристик судна (вантажопідйомності) і рейсу (дальності перевезення). Зроблено висновки про вплив розміру судна і дальності перевезення на можливі відхилення ефективності рейсу. Отримані результати дозволяють здійснювати практичну оцінку можливих відхилень ефективності рейсу під впливом факторів ризику.

Ключові слова: *регресійна залежність, відхилення, тайм-чартерний еквівалент, дальність перевезення, вантажопідйомність, ймовірність.*

1. Introduction

Maritime business is highly risky from several points of view. Any planned results even at the operational level is practically not achievable in fact due to a significant effect of climatic conditions, the presence of extensive interconnections of members of the ship and cargo service process and other on transportation process.

Therefore, even at the level of a particular voyage, the decision-maker of commercial management of the ship must take into account the possible deviations of various parameters characterizing the marine transportation process, and their effect on ship efficiency. This accounting will allow make more informed decisions and improve the efficiency of the ship company as a whole.

2. The object of research and its technological audit

The object of this research is the voyage efficiency of ship in terms of its deviation under the influence of risk factors.

As is known, one of the key efficiency parameters of the ship within a particular voyage is «time charter equivalent (TCE)» – parameter that is different from the value of daily profit on standard of fixed costs for the ship. There are following formula for time charter equivalent calculation:

$$TCE = \frac{f \cdot Q - R_{var}(t_s, t_l, c_{port}, c_{bunk})}{t_s + t_l}, \quad (1)$$

where f – the freight rate (marine transportation cost); Q – the number of transported cargo; R_{var} – variable costs for the ship, which consist of expenses for bunker and port charges, fees, costs for passing through the channels; t_s – sailing time; t_l – laytime; c_{bunk} – the cost of the bunker; c_{port} – rates of port charges and fees, as well as the cost of passing through the channels.

This parameter (1) is used as in the pre-voyage review of commercial conditions, and upon its execution.

At the stage of preliminary evaluation of voyage efficiency, the main parameters that can't be reliably determined, because they are the random variables: t_s, t_l, c_{bunk}. Therefore, mathematical expectation (mean values) are used as the projected values of these parameters in (1). The actual values of these parameters cause a deviation of actual achieved efficiency from the planned. It is naturally that increase in these parameters results in a decrease in the voyage efficiency by the value ΔTCE – the difference between the planned and actual efficiency.

In turn, almost all the components of (1) are defined by voyage characteristics (for example, the specificity of the ports of call, transport distance) or ship characteristics (the main of which is the size of the ship).

The interest for the study is to establish the nature of the effect of ship size and voyage conditions for the possible reduction of the TCE parameter, which can be used as a basis for decision-making and further research related to commercial and operational management of the ships.

3. The aim and objectives of research

The aim of this research is to establish the effect of the main characteristics of the ship and the voyage to the possible deviation of the ship efficiency.

Achieving the aim is related to the solution of the following main objectives:

1. Set a fundamental type of income and ship cost elements dependencies on the ship size and marine transportation distance.
2. Form a parameter for deviation of the ship efficiency, as a function of parameters characterizing the ship size and voyage specifics.
3. Form conclusions on the effect of ship size and marine transportation distance on the voyage efficiency on the basis of functional analysis.

4. Research of existing solutions of the problem

The problem of the effect of ship size on the various economic and operational parameters of its operation is the subject of various studies.

Many modern publications are devoted to the issues related to the environmental impacts of the ships operation and the relationship of this impact (CO emissions) with the ship size (for example, [1]).

Relationship «ship size – economic parameters» was studied in [2].

Effect of ship size on its cost and efficiency of ship acquisition project was considered in [3]. Particularly relevant this issue was due to the increase in the size of modern container ship and sufficient instability of container flow. Determination of certain balance «ship size – efficiency» for container ships was considered in [4, 5].

Considering the volatility of oil prices and, as a consequence, the bunker cost, the problem of determining the optimal ship speed during the voyage on the basis of a balance of revenues and expenditures sides in profit formation isn't lose its urgency. The series of works are devoted to this subject. One of them [6] is based on the regression dependence of the ship speed and fuel consumption.

The problem of risk in an economic context, namely, reducing the ship efficiency in terms of the ship size effect or the voyage characteristics wasn't considered. There are a number of publications in which these issues have been addressed, but in the context of the operational period of the ships, rather than a particular voyage. In [7], the ratio of «cash flow – risk» is studied depending on the ship size (deadweight) and VAR-method is used as a measure of risk.

It should be noted that these publications deal with the risk of reducing the financial parameters exclusively by market factors – deviations of the freight rates from planned in the justification of the results of the ship operation and evaluate the efficiency of their acquisition projects. But the risk of changes in freight rates, and changes in the ship efficiency under its influence may be considered only in the medium-term and long-term planning (which was done in [8, 9]).

However, even when the particular voyage in accordance with the signed contract (transportation contract – charter), ship operation is associated with the presence of a plurality of risk factors not related to the volatility of freight rates (as shown above), and, therefore, their influence is also evident in a possible decrease in the efficiency of ship operation.

This problem nowadays is practically not considered, so it is the subject of this research.

5. Methods of research

This research is performed in accordance with the logic of the system methodology. The next methods are used taking into account a specifics of the tasks:

- regression analysis – to establish a kind of connection between the characteristics of the ship (voyage) and elements of the operating costs and income;
- apparatus of probability theory (characteristics and properties of the normal distribution law) – to assess possible deviations of voyage time;
- functional analysis to investigate the effect of voyage and ship characteristics on possible decrease in the voyage efficiency.

6. Research results

6.1. Dependence of voyage efficiency deviation on the ship size and transportation distance. It is above noted that the weather and climate conditions, the human factor, as well as the dynamics of the market situation may increase in parameters describing the ship voyage process. First of all, we are talking about possible deviations of voyage time as well as increase the cost of the bunker and each port of the call.

Time charter equivalent deviation from the planned values can be expressed as follows:

$$\Delta TCE = \frac{f \cdot Q}{t_s + t_l} - \frac{f \cdot Q}{t_s + \Delta t_s + t_l + \Delta t_l} - \frac{c_{bunk}(q_s \cdot t_s + q_l \cdot t_l) + c^1_{port} + c^2_{port}(t_l)}{t_s + t_l} + \frac{(c_{bunk} + \Delta c_{bunk})(q_s \cdot (t_s + \Delta t_s) + q_l \cdot (t_l + \Delta t_l))}{t_s + \Delta t_s + t_l + \Delta t_l} + \frac{c^1_{port} + \Delta c^1_{port} + c^2_{port}(t_l + \Delta t_l) + \Delta c^2_{port}(t_l + \Delta t_l) + R_{add}}{t_s + \Delta t_s + t_l + \Delta t_l}, \quad (2)$$

where Δt_s, Δt_l – an increase of sea time and laytime, respectively; Δc_{bunk} – changes in the bunker cost.

The bunker costs are determined by the fuel consumption values during sea time q_s and laytime q_l (the fuel consumption in the sea corresponds to economical speed of the ship). In (2) the change in the bunker costs reflects:

- by increasing the time parameters at the planned cost of the bunker:

$$C_{bunk}\left(q_s \cdot \Delta t_s + q_l \cdot \Delta t_l\right);$$

- by changing the bunker cost, taking into account changes in voyage time:

$$\Delta c_{bunk}\left(q_s \cdot \left(t_s + \Delta t_s\right) + q_l \cdot \left(t_l + \Delta t_l\right)\right).$$

$c^1_{port} + c^2_{port}(t_l)$ – dependence of port costs from time. Earlier in (1) it is assumed that c_{port} is an amount of various types of charges and fees for considered ship. C_{port} decomposition allows to obtain two components:

c^1_{port} – a component of port charges, fees and costs of passage through the channels, which are depend on the ship laytime at the port (for example, ship, lighthouse, etc.);

c^2_{port} – charges that depend on the ship laytime at the port (for example, sanitary at Ukrainian ports).

Taking into account this, a change in the port charges, costs for passing through the channels can be explained as follows:

$$\Delta R_{port} = \Delta c^1_{port} + \Delta c^2_{port}(t_l + \Delta t_l), \quad (3)$$

where Δc^1_{port} – increase of charges and fees are not dependent on the ship laytime at the port; Δc^2_{port} – an increase in charges and fees, dependent on the ship laytime.

Planned sea time t_s (days) and laytime (days) are determined based on their desired characteristics of the ship, route and intensity of cargo operations at ports of call.

ISSN 2226-3780

The main characteristic of the ship, affecting the laytime is a load Q (tons). For dry bulk ships and the majority of the bulk cargo, it is determined by the cargo capacity D_c (tons). Therefore, in such cases, without loss of meaning, it can be taken as:

$$Q = K \cdot D_c,$$

where K – coefficient, which takes into account the share of the cargo capacity used on the voyage reserves (primarily fuel).

Also, if we assume that the laytime at port equals to time for cargo operations and averaged intensity of execution of cargo loading and unloading works (tons/days) are identical to simplify further formalization, then:

$$t_l = \frac{2 \cdot Q}{M_n} = \frac{2 \cdot K \cdot D_c}{M_n}. \quad (4)$$

This assumption is not contrary to the essence of the problem, since in terms of the solved problem deviation of time parameters Δt_s and Δt_l are interesting as against the time parameters.

Sea time t_s depends on the ship speed (taking as an average for the ballast voyage and the load voyage) and the transportation distance L. In view of the made above comments about the assumptions, for this problem we can be neglected passage of areas with limited speed, so sea time is defined as:

$$t_s = \frac{2 \cdot L}{V}. \quad (5)$$

Freight rate (USD/tons) at the relevant point in time (for a given market situation) is depend on voyage characteristics (primarily, transportation distance) and cargo capacity D_c, so:

$$f = f(D_c, L). \quad (6)$$

Bunkering costs are determined by daily fuel consumption values q_s, q_l (tons/days), depending on the ship speed and performance of ship propulsion plants, which, in turn, are in regression dependence on the ship size.

According to the characteristics of dry bulk ships of 10000–22000 tones, presented in [10], regression dependence «ship displacement – normative voyage fuel consumption» is built (Fig. 1).

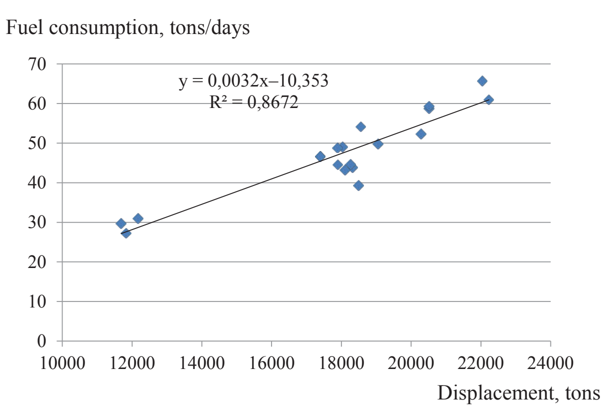

Fig. 1. Dependence of fuel consumption on displacement

Several ships are excluded from the considered statistical base because they have a certain structural specificity, which is not inherent to the basic set. As can be seen, for the ship with considered displacement, dependences have a distinct linear character.

For power determination of main propulsion plant of the ships in a wide range of displacement, various two-component formulas [11] are used. They establish the dependence of the power main propulsion plant (kW) on displacement D (tons) and the ship speed (knots). In particular, Davydov formula has the following form:

$$N = \frac{D^{0,5} \cdot V^{3,25}}{C}, \quad (7)$$

where C – coefficient, which changes in the range of 103–119.

Taking into account the fact that displacement D and cargo capacity D_c are in direct dependency (e. g., Fig. 2 shows a similar dependence for bulk carriers with a displacement of 10000–22000 tons), the above considerations lead to the conclusion on the validity of the submission of fuel consumption values in the form of dependencies:

$$q_s = q_s(D_c), \quad q_l = q_l(D_c), \quad (8)$$

considering that $q_s(D_c)$ is considered for received speed level.

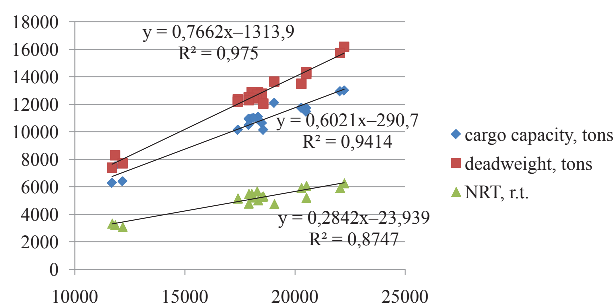

Fig. 2. Dependence of cargo capacity, deadweight and NRT on displacement

Port charges and fees in the various ports of the world are taken either with net and gross register tonnage (NRT, BRT), or with a deadweight or with conditional module of the ship (the product of the length, width and height). In view of a dependence between these characteristics and their regression relationship with the cargo capacity (Fig. 2), can be taken:

$$c^1_{port} = c^1_{port}(D_c),$$

$$c^2_{port} = c^2_{port}(D_c, t_l). \quad (9)$$

According to the practice of ships for the cargo transportation, within the time frame of a particular voyage, it is almost certain that:

$$\Delta c^1_{port} = 0, \quad \Delta c^2_{port} = 0,$$

and the most meaningful deviations are time deviations Δt_s, Δt_l, the bunker cost ΔC_{bunk}, as well as additional costs R_{add}.

Thus, the individual elements of the ship costs are represented in the form of dependence on the ship and voyage characteristics. Substituting (4)–(6), (8), (9) in (2), we obtain an expression for change of the time charter equivalent $\Delta TCE(L, D_c)$ in the form of dependence on the ship characteristics (cargo capacity D_c) and voyage characteristics (transportation distance L):

$$\Delta TCE(L,D_c)=\frac{f(D_c,L)\cdot K\cdot D_c}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}}-\frac{f(D_c,L)\cdot K\cdot D_c}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}+\Delta t_s+\Delta t_l}-$$
$$-\frac{c_{bunk}\left(q_x(D_c)\cdot\frac{2\cdot L}{V}+q_l(D_c)\cdot\frac{2\cdot K\cdot D_c}{M_n}\right)+c^1_{port}(D_c)+c^2_{port}\left(D_c,\frac{2\cdot K\cdot D_c}{M_n}\right)}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}}+$$
$$+\frac{(c_{bunk}+\Delta c_{bunk})\left(q_s(D_c)\cdot\left(\frac{2\cdot L}{V}+\Delta t_s\right)+q_l(D_c)\cdot\left(\frac{2\cdot K\cdot D_c}{M_n}+\Delta t_l\right)\right)}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}+\Delta t_s+\Delta t_l}+$$
$$+\frac{c^1_{port}(D_c)+c^2_{port}\left(D_c,\frac{2\cdot K\cdot D_c}{M_n}+\Delta t_l\right)+R_{add}}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}+\Delta t_s+\Delta t_l}. \quad (10)$$

In [12] to estimate the possible deviations of efficiency parameters of ships it is proposed to use a method based on the parameters of a normal distribution law. The presented results of statistical studies have proved a validity of this approach. Generalization of this approach allows to estimate the time and bunker cost deviations as follows:

$$\Delta t_s = k(\alpha)\cdot\sigma_{t_s}, \quad (11)$$

$$\Delta t_l = k(\alpha)\cdot\sigma_{t_l}, \quad (12)$$

$$\Delta c_{bunk} = k(\alpha)\cdot\sigma_{c_{bunk}}, \quad (13)$$

where

$$\alpha = P(t_s \ge \overline{t_s}+\Delta t_s), \quad (14)$$

$$\alpha = P(t_l \ge \overline{t_l}+\Delta t_l), \quad (15)$$

$$\alpha = P(c_{bunk} \ge \overline{c_{bunk}}+\Delta c_{bunk}), \quad (16)$$

where $\overline{t_s}$, $\overline{t_l}$, $\overline{c_{bunk}}$ – the average values of the sea time, laytime and bunker cost. Thus, (14)–(16) express the probability that the increase in the sea time, laytime and bunker cost will not exceed the considered deviations Δt_s, Δt_l, Δc_{bunk}. The values $\overline{t_s}+\Delta t_s$; $\overline{t_l}+\Delta t_l$; $\overline{c_{bunk}}+\Delta c_{bunk}$ are a kind of threshold values of the considered parameters with a given probability. Let's note that in (1) as t_l, t_s, c_{bunk} used the average values (expectations); σ_{t_s}, σ_{t_l}, $\sigma_{c_{bunk}}$ – standard deviations of sea time, laytime and bunker cost; $k(\alpha)$ is determined according to the tables of the Laplace function.

R_{add} may be taken on the basis of statistical data or expert way. Given the lack of appropriate information base, in this study to draw conclusions about the nature of R_{add} behavior is not possible. It should be noted that in assessing a possible decrease in the efficiency of a particular voyage in R_{add} are recorded various unforeseen costs associated with the call at the ports and doesn't take into account possible costs due to unforeseen breakdowns and related repairs.

These factors are taken into account in the annual planning of the results of the shipping company's ships in general.

Thus, taking into account time variance estimations and increase of the bunker cost, (11) can be transformed as follows:

$$\Delta TCE(L,D_c,\alpha)=\frac{f(D_c,L)\cdot K\cdot D_c}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}}-\frac{f(D_c,L)\cdot K\cdot D_c}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}+k(\alpha)(\sigma_{t_s}+\sigma_{t_l})}-$$
$$-\frac{c_{bunk}\left(q_s(D_c)\cdot\frac{2\cdot L}{V}+q_l(D_c)\cdot\frac{2\cdot K\cdot D_c}{M_n}\right)+c^1_{port}(D_c)+c^2_{port}\left(D_c,\frac{2\cdot K\cdot D_c}{M_n}\right)}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}}+$$
$$+\frac{(c_{bunk}+k(\alpha)\cdot\sigma_{A_{bunk}})\left(q_s(D_c)\cdot\left(\frac{2\cdot L}{V}+k(\alpha)\sigma_{t_s}\right)+q_l(D_c)\cdot\left(\frac{2\cdot K\cdot D_c}{M_n}+k(\alpha)\sigma_{t_l}\right)\right)}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}+k(\alpha)(\sigma_{t_s}+\sigma_{t_l})}+$$
$$+\frac{c^1_{port}(D_c)+c^2_{port}\left(D_c,\frac{2\cdot K\cdot D_c}{M_n}+k(\alpha)\sigma_{t_l}\right)+R_{add}}{\frac{2\cdot L}{V}+\frac{2\cdot K\cdot D_c}{M_n}+k(\alpha)(\sigma_{t_s}+\sigma_{t_l})}. \quad (17)$$

Depending on the probability α, which affects the accounted maximum possible deviations of sea time and laytime Δt_s, Δt_l, (17) makes it possible to assess the possible deviation of the time charter equivalent for ships of various cargo capacity during voyages of various distance.

6.2. Effect of ship cargo capacity and transportation distance on ship efficiency deviation. On the basis of (17) it is possible to investigate an effect of ship size and marine transportation distance on time charter equivalent deviation, and possible reduction in voyage efficiency.

Let's carry out some researches for ships with cargo capacity of 5000–30000 tons, which are the most characteristic for the domestic cargo base and Ukrainian ports.

To perform these studies the following types of dependencies of individual cost elements on the ship and voyage characteristics have been taken in accordance with the results of statistical researches of specialists in marine transport.

Conducted statistical studies allow to take the dependence of freight rates on the cargo capacity and transportation distance in the form of a linear relationship:

$$f = a_0 + a_1 D_c + a_2 L,\ a_0 > 0. \quad (18)$$

Despite the fact that most of the researches proved that the freight rate has a nonlinearly dependence on the ship size, however, a linear relationship also ensures sufficient confidence level (Fig. 3).

The following regression model is obtained by regression data analysis on freight rates transportation of bulk cargo in the Black Sea-Mediterranean region, which is accepted as a basis below:

$$f = 19{,}2 + 0{,}006\cdot L - 0{,}0001\cdot D_c. \quad (19)$$

The costs of port charges and fees can be represented as linear relations taking into account common practice of determining the rate of port charges for the unit of used ship characteristics (deadweight, conventional volume, etc.):

$$c^1_{port} = c_0\cdot D_c,\ c^2_{port} = c_1\cdot D_c, \quad c_0,\ c_1 > 0. \quad (20)$$

 ISSN 2226-3780

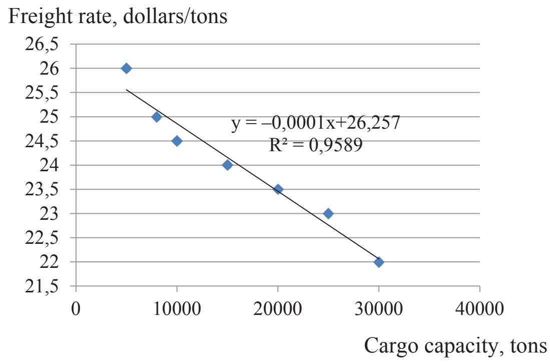

Fig. 3. Dependence of freight rates on the cargo capacity of marine transportation 1,000 miles (Black Sea-Mediterranean Basin)

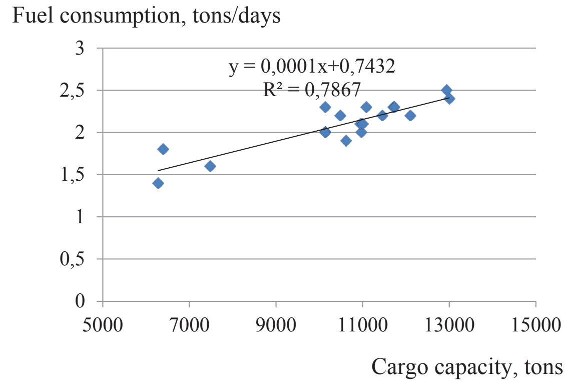

Fig. 5. Dependence of laytime fuel consumption (tons/days) on the cargo capacity (tons)

In most of the world ports there is a practice of charging that implies consideration, as a rule, the two slots for port charges, which depend on the time (such as moorage charge – up to 10 days and more than 10 days). Given the relatively small size of the ships that are considered in this research, we assume that laytime of the ships, even taking into account their possible delays at the port, fits in the first determined time range. Therefore, based on the results obtained by the analysis of port charges at the ports of Ukraine, Turkey, Romania, we accept:

$$c_{port}^{1}+c_{port}^{2}=3{,}04\cdot D_c. \qquad (21)$$

Fuel consumption values can be taken as a linear function on cargo capacity:

$$q_s=b_0+b_1D_c,\quad q_l=b_2+b_3D_c,\quad b_0,b_1,b_2,b_3\geq 0. \qquad (22)$$

In further experimental calculations let's assume the following dependencies of fuel consumption (Fig 4, 5):

$$q_s=0{,}46+0{,}0044\cdot D_c,$$

$$q_l=0{,}743+0{,}0001\cdot D_c. \qquad (23)$$

For experimental researches let's note: ship speed – $V=12$ knots $=288$ miles/day, $K=0{,}95$, cargo operation norms – $M_n=3000$ (which is average norms of cargo operations for bulk cargo), bunker cost – $C_{bunk}=$ $=300$ dollars/ton. The standard deviation of the bunker cost – $\sigma_{c_{bunk}}=10$ dollars/ton.

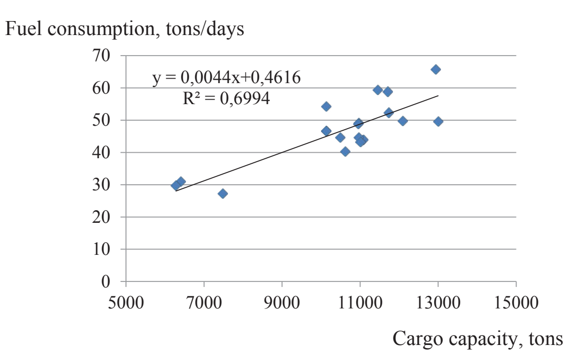

Fig. 4. Dependence of voyage fuel consumption rate (tons/day) on the cargo capacity (tons)

σ_{t_s}, σ_{t_l} may depend and aren't depend on the transportation distance and the ship size, although it would be logical to assume a link between the time deviation and transportation distance. Given the lack of an adequate information base for the formulation of such conclusions (it could be the object of separate researches), the standard deviations of sea time and laytime (days) will take 5–8 % of the average (which corresponds to the results of statistical analysis). Next, we denote their equivalent value in a percentage as σ, considering that an increase in laytime isn't required for cargo operations and isn't a responsibility of the cargo owner.

Unforeseen expenditures in the test studies can't be taken into consideration, taking into account the specifics of the problem.

After all the above expression for elements of incomes and expenses, assumptions and transformations, we get the following:

$$\Delta TCE\left(L,D_c,\alpha\right)=\frac{\left(19{,}2+0{,}006\cdot L_c-0{,}0001\cdot D_c\right)\cdot 0{,}95\cdot D_c-3{,}04D_c}{\dfrac{2\cdot L}{288}+\dfrac{2\cdot 0{,}95\cdot D_c}{3000}}-$$
$$-\frac{\left(19{,}2+0{,}006\cdot L-0{,}0001\cdot D_c\right)\cdot 0{,}95\cdot D_c-3{,}04D_c}{\left(\dfrac{2\cdot L}{288}+\dfrac{2\cdot 0{,}95\cdot D_c}{3000}\right)\left(1+k(\alpha)\sigma\right)}-$$
$$+\frac{k(\alpha)\cdot 10\left(\left(0{,}46+0{,}0044\cdot D_c\right)\cdot\dfrac{2\cdot L}{288}+\left(0{,}743+0{,}0001\cdot D_c\right)\cdot\dfrac{2\cdot 0{,}95\cdot D_c}{3000}\right)}{\dfrac{2\cdot L}{288}+\dfrac{2\cdot 0{,}95\cdot D_c}{3000}}. \qquad (24)$$

The graphs of time charter equivalent change for different values σ (5 %, 7 %, 8 %) are made for given $k(\alpha)=1{,}65$ for ships of various deadweight and for voyages of different duration in Fig. 6 in accordance with (24).

As can be seen, possible reduction in the time charter equivalent with an increase in voyage duration is less significant than at shorter distances. Naturally, possible decrease in time charter equivalent for larger ships is more significant. It should be noted that σ – standard deviation of voyage time has a significant effect on $\Delta TCE(L,D_c,\alpha)$ behavior.

Fig. 7 is a graphic illustration of (24) for two levels of freight rates, the difference between which is 10 %.

As we can see, this influence is also quite essential, along with a standard deviation of voyage time.

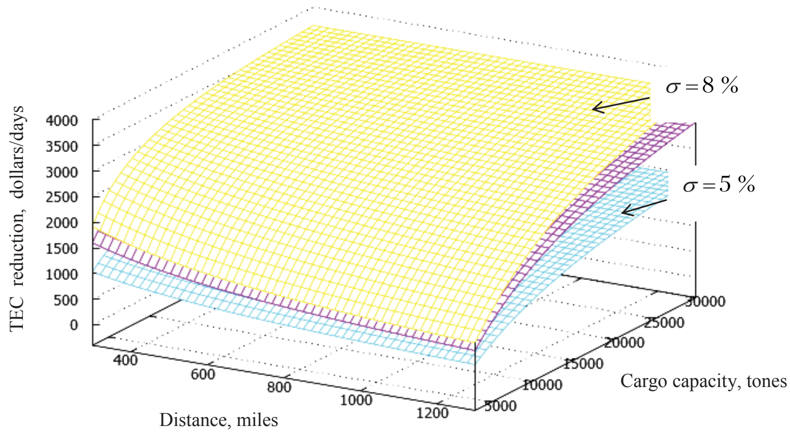

Fig. 6. Possible time charter equivalent deviation for ships of various deadweight and for voyages of different duration

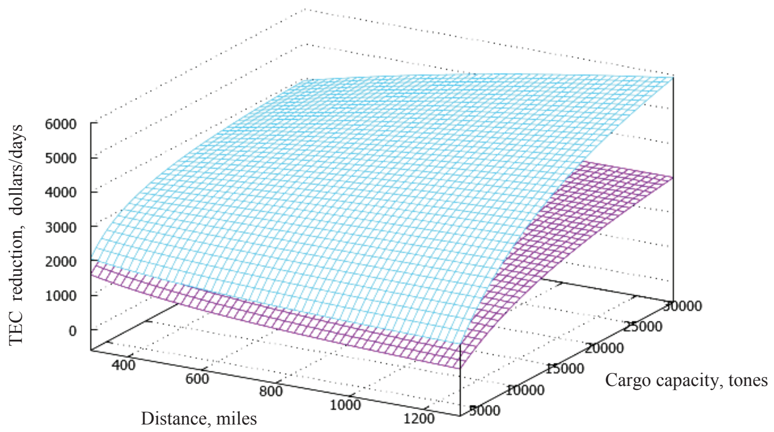

Fig. 7. Possible time charter equivalent deviations for ships of various deadweight and for voyages of varying duration for two levels of freight rates

7. SWOT analysis of research results

These results allow to estimate the possible deviations of voyage efficiency under the influence of risk factors. $\Delta TCE(\alpha)$ value can serve as an additional criterion for decision about ship charter, along with parameters of the daily incomes and time charter equivalent, being a kind of risk assessment of voyage efficiency reduction.

Results are based on the regression relationships of the individual elements of the ship costs on its size and marine transportation distance. However, information about bulk ships up to 30,000 tons and transportation distance of 1,300 miles are used as statistical base. So it would be interesting to conduct similar studies in larger statistical material.

In addition, the weakness of this research is the lack of practical information, which would allow to make a conclusion about the specifics of the standard deviations of voyage time for different traffic directions and ships of various sizes – this parameter is considered as independent of these characteristics. It largely determines the possible deviation of the efficiency parameter

It should be noted that the main external factors that have a negative effect on the efficiency of ship voyage and its possible deviation are the specificity of Ukrainian ports of call, which results in increase of costs for call at the port. And, as a consequence, the formation of a significant level of R_{add} value.

8. Conclusions

1. Principal types of dependencies of income and cost elements for ship (freight rate, fuel consumption, port charges) in voyage on cargo capacity and transportation distance are established on the basis of regression analysis, as well as the mathematical relationships between the individual characteristics of the ship and the voyage.

2. These patterns allow to formulate expression of efficiency parameter deviation of the voyage ship as a function of voyage and ship characteristics. Time charter equivalent deviation – the quantity characterizing the daily profit of the ship, excluding standard fixed costs, is considered as this parameter. This equation describes the nonlinear dependence of this parameter on the ship size (cargo capacity) and voyage characteristics (transportation distance).

3. Conclusions on the effect of ship size and transportation distance on the possible deviations of voyage efficiency. In particular, it is found that possible reduction in the time charter equivalent with an increase in voyage duration is less significant than at shorter distances. Also, it is determined that a significant effect, along with the standard deviation of voyage time has a level of freight rates – even a slight its increase results in a notable difference in efficiency «losses».

References

1. Lindstad, H. Reductions in cost and greenhouse gas emissions with new bulk ship designs enabled by the Panama Canal expansion [Text] / H. Lindstad, E. Jullumstro, I. Sandaas // Energy Policy. – 2013. – Vol. 59. – P. 341–349. doi:10.1016/j.enpol.2013.03.046
2. Lindstad, H. Assessment of profit, cost and emissions by varying speed as a function of sea conditions and freight market [Text] / H. Lindstad, B. E. Asbjornslett, E. Jullumstro // Transportation Research Part D: Transport and Environment. – 2013. – Vol. 19. – P. 5–12. doi:10.1016/j.trd.2012.11.001
3. Onyshchenko, S. Regression models for the dependence of ship's cost from deadweight and age: before and after the crisis [Text] / S. Onyshchenko, T. Bernevek, N. Gonchar // Vodnyi transport. – 2015. – Vol. 1. – P. 126–133.
4. Ng, A. K. Y. The optimal ship sizes of container liner feeder services in Southeast Asia: a ship operator's perspective [Text] / A. K. Y. Ng, J. K. Y. Kee // Maritime Policy & Management. – 2008. – Vol. 35, № 4. – P. 353–376. doi:10.1080/03088830802198167
5. Notteboom, T. E. The effect of high fuel costs on liner service configuration in container shipping [Text] / T. E. Notteboom, B. Vernimmen // Journal of Transport Geography. – 2009. – Vol. 17, № 5. – P. 325–337. doi:10.1016/j.jtrangeo.2008.05.003
6. Bialystocki, N. On the estimation of ship's fuel consumption and speed curve: A statistical approach [Text] / N. Bialystocki, D. Konovessis // Journal of Ocean Engineering and Science. – 2016. – Vol. 1, № 2. – P. 157–166. doi:10.1016/j.joes.2016.02.001
7. Onyshchenko, S. P. Peculiarities of market risks and measures for their reduction in contemporary shipping business [Text] /

ISSN 2226-3780

S. P. Onyshchenko, T. M. Shutenko // Actual problems of economics. – 2012. – № 2 (128). – P. 85–98.

8. Koekebakker, S. Are Spot Freight Rates Stationary? [Text] / S. Koekebakker, R. Adland, S. Sodal // Journal of Transport Economics and Policy. – 2016. – Vol. 40, № 3. – P. 449–472.
9. Adland, R. The stochastic behavior of spot freight rates and the risk premium in bulk shipping [Text]: Ph.D. Thesis / R. Adland. – Massachusetts Institute of Technology, 2003. – P. 141–146.
10. RD 31.03.01-90. Tehniko-ekonomicheskie harakteristiki sudov morskogo flota [Electronic resource] // Internet arhiv zakonodatel'stva SSSR. Bolee 20000 normativno-pravovyh aktov. – Available at: \www/URL: http://www.libussr.ru/doc_ussr/usr_17959.htm
11. Artiushkov, L. S. Sudovye dvizhiteli [Text]: Textbook / L. S. Artiushkov, A. Sh. Achkinadze, A. A. Rusetskii. – Leningrad: Sudostroenie, 1988. – 296 p.
12. Onyshchenko, S. P. Evaluation of market risk of projects of vessel acquisition [Text] / S. P. Onyshchenko, T. Ye. Korniets // Innovative economy. – 2015. – № 4. – P. 198–205.

ИССЛЕДОВАНИЕ ВЛИЯНИЯ РАЗМЕРА СУДНА И ДАЛЬНОСТИ МОРСКОЙ ПЕРЕВОЗКИ НА ВОЗМОЖНОЕ УМЕНЬШЕНИЕ ЭФФЕКТИВНОСТИ РЕЙСА

Сформулировано выражение отклонения показателя эффективности выполнения судном рейса (тайм-чартерного эквивалента) как функции от характеристик судна (грузоподъемности) и рейса (дальности перевозки). Сделаны выводы о влиянии размера судна и дальности перевозки на возможные отклонения эффективности рейса. Полученные результаты позволяют осуществлять практическую оценку возможных отклонений эффективности рейса под влиянием факторов риска.

Ключевые слова: регрессионная зависимость, отклонение, тайм-чартерный эквивалент, дальность перевозки, грузоподъемность, вероятность.

Vyshnevska Olha, *Senior Lecturer, Department of Marine Transportation, Odessa National Maritime University, Ukraine, e-mail: vishn.ol.24@mail.ru, ORCID: http://orcid.org/0000-0003-1021-3176*

Vishnevsky Dmitry, *PhD, Assistant, Department of Marine Transportation, Odessa National Maritime University, Ukraine, e-mail: system013@mail.ru, ORCID: http://orcid.org/0000-0002-1270-713X*

UDC 656.081
DOI: 10.15587/2312-8372.2017.93458

Dolya C.

MODELING OF PASSENGER TRANSPORT CORRESPONDENCE BETWEEN REGIONAL CENTERS IN UKRAINE

Досліджено процес надання послуг з перевезення пасажирів на міжобласних маршрутах загального користування. За отриманими даними фактичних кореспонденцій було проведеного дослідження можливості застосування відомих методів щодо розрахунку пасажирських транспортних кореспонденцій. Винайдено параметри складових, при яких застосування розглянутих методів є можливим в рамках дослідженої системи.

Ключові слова: *транспортна система, гравітаційна модель, пасажирські транспортні кореспонденції, міжміські перевезення.*

1. Introduction

Modern transport systems need to make informed decisions about their development, change and adaptation to the operational environment of these systems. Operational environment of the transport system is man-made, artificially created to meet the needs of humanity with the carriage of passengers or goods. To achieve the state in which transport system has the ability to satisfy the needs of transportation, we must carefully decide on the change of the elements of transport system.

All elements of the transport systems are required to be revised and adapted to modern conditions. It should be noted that the transport systems have the elements, which production is costly time, financial and human resources. Place of passenger transport systems in the development of society can't be overemphasized. Therefore, the decisions to reform elements of the transport system have taken relying on calculations made in terms of modernity.

Passenger is the basis for all calculations in organization of passenger transportation. It is well-known that schedule, the number and type of vehicles, vehicle traffic scheme are depend on the volume and characteristics of passenger transportation. Traffic volumes cause cash flow of the company. The importance of establishing traffic volumes for passenger transport system is significant.

2. The object of research and its technological audit

The object of research is the modern intercity passenger transport system in Ukraine. Intercity passenger transport correspondence, which is formed in the current system, is considered in this research.

One of the problem areas is to study actual sustainable intercity correspondence, which is in obtaining still not defined corrective coefficients for calculation of potential intercity correspondence. The knowledge provides an opportunity in the use of this method of correspondence calculations between cities towards the passenger transportation market in Ukraine.