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Model for enhancing the vessel competitive advantages at the local freight market

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There are several issues that are be considered in this research: the problem of optimization of the process of the vessel repairing by using economic and mathematical models that would provide a shipping company within a free market and full liberalization of the tramp shipping a sustainable position in the relevant local freight market and would contribute to obtaining the greatest possible profits by holding a particular cargo base and regular customers.
Keywords: competition, competitiveness, optimization, chartering, repair base, fleet repair program.

Леонов О.О., Леонова Т.М. МОДЕЛЬ ПІДВИЩЕННЯ КОНКУРЕНТНИХ ПЕРЕВАГ СУДНА НА ЛОКАЛЬНОМУ ФРАХТОВОМУ РИНКУ

У статті розглядаються питання оптимізації організації ремонту суден, вирішення яких дозволило б судноплавної компанії забезпечити стійке положення на відповідному локальному фрахтовому ринку та отримання максимально можливого прибутку шляхом закріплення за собою певної вантажної бази і постійної клієнтури.
Ключові слова: конкуренція, конкурентоспроможність, оптимізація, фрахтування, ремонтна база, програма ремонту флоту.

Леонов А.А., Леонова Т.М. МОДЕЛЬ ПОВЫШЕНИЯ КОНКУРЕНТНЫХ ПРЕИМУЩЕСТВ СУДНА НА ЛОКАЛЬНОМ ФРАХТОВОМ РЫНКЕ

В статье рассматриваются вопросы оптимизации организации ремонта судов, решение которых позволило бы судоходной компании обеспечить устойчивое положение на соответствующем локальном фрахтовом рынке и получение максимально возможной прибыли путем закрепления за собой определенной грузовой базы и постоянной клиентуры.
Ключевые слова: конкуренция, конкурентоспособность, оптимизация, фрахтование, ремонтная база, программа ремонта флота.

Introduction. Problem formulation. An optimum compromise of vessels technical and operational characteristics, the way of operation used by ship-owners or operators and the requirements of a specific local freight market is one of the conditions for vessels effective market positioning.

In this study we consider the operation of the vessel on the local freight market. You can specify different signs of allocating markets of this kind. Such, for example, as the type of cargo, directions and modes of transportation, the size of the ship's lot, determining the deadweight group of ships, types of vessels as well as the temporal and spatial parameters. For a combination of these factors or for a group of factors, sometimes even one factor, it is possible to allocate local markets [1].

These markets gradually decline due to a gradual but permanently increasing competition of the fleet of industrial companies as well as the commercial and industrial shipping [2]. Other local markets may influence the competitive environment as well. For example, tramp and liner carriers can be competitors on the same freight flows; particularly during the periods of reduced freight rates when liner carriers charter vessels from tramp market for linear work in order to expand their tonnage [3].

To a greater or lesser extent cargo owners can influence the competition, too, especially during the periods of drop in demand.

Fig. 1 presents a model of competitive forces. These forces have a combined effect and a great impact on companies' end results of work on local freight markets.

In addition it should be also taken into account the increasingly severe requirements for the safety of navigation [4]. As a result, many countries are moving to the practice

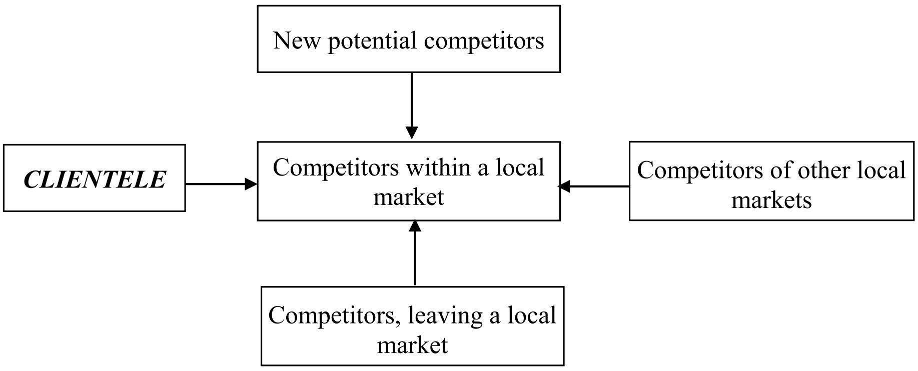

Fig. 1. Model of competitive forces

of standardizing tonnage with subsequent certification of vessels to meet the specified standards. According to the leadership of the Transport Committee of the European Union in time the right to participate in transportation on the European transport network will be given only to vessels that have been certified regardless of the flag under which they swim.

This circumstance makes it particularly relevant to study how technical aspects of vessels as well as technical management influence on the short and long term competitive position of vessels in freight markets. This primarily concerns the issues of maintenance and repair, searching for new approaches to optimize repair programs when operating on local freight markets, because repair withdrawals can significantly affect a shipping company's position in the market. This brings up a problem of choosing options of withdrawal of the vessels from operation and options for chartering an additional tonnage for retaining the developed cargo flows in order to avoid reducing the level of competitiveness in a specific local freight market. Therefore, the optimization of technical characteristics of vessels and repair program of fleet is one of the main challenges for ship-owners and shipping companies.

Repair expenses exert a significant impact on fixed charges due to their simultaneous payment and considerable amount. In order to reduce the expenses without compromising the technical condition of vessels optimum repair programs should be developed providing with a minimum necessary repair duration, as well as minimum ballast passages to a repair base and from it to a place of first loading after the repair.

Technical departments are meant to select a repair base and to develop withdrawal of the vessels from operation, docking and repair schedules in an interaction with commercial departments and in accordance with terms of repair and docking.

The problem is how to choose the optimal variant of the repair base and, if possible, minimize the costs associated with the transition to this base and the repair itself.

The solution to this problem would increase the competitive advantages of ships and, as a result, increase the efficiency of their use.

Background. Both domestic and foreign researchers have always paid much attention to the fleet planning optimization. A lot of questions related to functioning and development of the national navigation [5; 6], planning and organization of merchant marine [7], problems of competitiveness due to an optimal choice of local freight markets [2] have been explored, as well as approaches have been examined to optimize merchant marine scheduling based on different economic and mathematical models [8; 9].

Unresolved issues. However, it is difficult to find a study of a forced repair withdrawal of vessels directly related to the competitiveness of a shipping company in a specific local freight market. Some integrated solutions were come up with to this problem [11; 12]. One of approaches to a complete solution to this actual problem was investigated in [13].

The problem of a planned repair withdrawal of vessels and its related loss of competitiveness have been still understudied. It is clear that a shipping company should charter vessels of other companies for the repair period of its own ships to hold the cargo flows that have already been mastered at a particular local freight market.

The problem lies in choosing an optimum alternative of many possible options for the repair withdrawal and the temporary charter the vessels of other companies.

The urgent need for such a study has predetermined its goal.

The target problem for the analysis. The purpose of this article is to develop a new, science-based approach, which would allow a shipping company making better decisions when choosing a particular repair base for its vessels, as well as optimizing the repair time when operating in a local freight market.

Key research findings. Based on the best practice of fleet planning and taking into account that the choice of repair facilities and terms of factory repair are the elements of the fleet's activity plan and the main criteria for its realization are the optimization of the cost-income ratio and the percentage of presence on the relevant local market the model of optimization of fleet shipping company was proposed [13].

The disadvantages of this model of optimization are the uncertainty of the duration of the repair period per repair bases and linking the time budget constraint with the withdrawal of vessels for repair from service, except for an adequate replacement by an additional chartered tonnage.

As it was noted, such models work well at the medium-term planning level, where the task of optimization was coped with by the best balance between benefit and cost and a company's presence in a relevant local market.

The task of arranging ships in concrete repair places should be coped with at the current level of planning. And, finally, the task of optimizing the repair duration at an appropriate ship repair base (SRB) should be coped with at the operational level of planning (quarterly and monthly). Thus would be close the above noted flaw of the medium-term planning model.

In this regard, it is of interest to consider an economic and mathematical model for optimizing the repair of ships of the shipping company by the places of repair and by the criterion of minimum repair costs.

In order to build the model let's assume the following notations:

m – number of runs (ports, passage) of a vessel in operation, $i=\overline{1,m}$, (units);

n – number of ship repair base (SRB), $j=\overline{1,n}$, (units);

L – number of vessel operated by a shipping company, $l=\overline{1,L}$, (units);

K_l – number of repairs of vessel l during the period under review, $k=\overline{1,K_l}$, (units);

$\overline{t}_l^k, \overline{\overline{t}}_l^k$ – dates (the earliest and the latest) of docking for k-repair of l-vessel (calendar);

$T(j,l,k)$ – duration of k- repair of l- vessel on j- SRB, (twenty-four hours);

$z(j,l,k)$ – costs of k- repair of l – vessel on j- SRB, (USD);

$t(i,j,l)$ – steaming time of vessel l from working site i to SRB j, (twenty-four hours);

$\tilde{t}(i,j,l)$ – steaming time of vessel l from SRB j to working site i, (twenty-four hours);

$R(i,j,l)$ – costs of the steaming time of vessel l from working site i to SRB j, (USD);

$\tilde{R}(i,j,l)$ – costs of the steaming time of vessel l from SRB j to working site i, (USD);

$c(i,l,t)$ – costs of the steaming time of a vessel, freighted instead of vessel l, to working site i at time point t, (USD);

$d(l)$ – costs of the working time of the vessel, freighted instead of vessel l, (USD);

$i(l,t)$ – index of the working site, where vessel l must be at time point t (the values of these parameters are a timetable of vessel l); $i\left(l,t\right)=\overline{1,m}$.

Introduce variables:

i_l^k – SRB's index for repair k of vessel l, $i_l^k=\overline{1,n}$

t_l^k – date of docking of vessel l for repair k, (calendar);

τ_l^k – date of sailing of vessel l after repair k, (calendar);

thus $\left(\tau_l^k - t_l^k\right)$ – duration of repair k of vessel l between the date of docking t_l^k and the date of sailing τ_l^k, (twenty-four hours).

Then the economic and mathematical model will look as follows:

$$\sum_{l=1}^{L}\sum_{k=1}^{K_l} R(i(l,t_l^k),j_l^k,l)+z(j_l^k,l,k)+\tilde{R}(j_l^k,i(l,\tau_l^k),l)+ \\ +c(i(l,t_l^k),l,t_l^k)+d(l)\cdot(\tau_l^k-t_l^k)\xrightarrow[\{j_l^k\},\{t_l^k\},\{\tau_l^k\}]{}\min \quad (1)$$

$$\overline{t}_l^k \le t_l^k \le \overline{\overline{t}}_l^k,\ l=\overline{1,L},\ k=\overline{1,K_l}, \quad (2)$$

$$\tau_l^k - t_l^k \ge t(i(l,t_l^k),j_l^k,l)+T(j_l^k,l,k)+\tilde{t}(j_l^k,i(l,\tau_l^k),l), \\ l=\overline{1,L},\ k=\overline{1,K_l} \quad (3)$$

Here the objective function (1) expresses the expenses (for all vessels and for all types of repair) for all the steaming time from an SRB and back (to next work sites), for the repair process, as well as for the steaming time of vessels, freighted for the repair period.

The restriction (2) ensures that vessels will be under repair at a given period of time.

The restriction (3) reflects the fact that a vessel remains out of operation during the period of steaming to an SRB, repair process and sailing to operation sites.

Thus, the developed economic and mathematical model allows a shipping company minimizing its total repair costs due to the optimal choice of an SRB for each vessel, as well as the optimal choice of repair time (within specified periods) and sailing back to operation sites. At this, we believe that the market share held by the company is secured due to the vessel, freighted instead of that one under repair. The disadvantage of this model is that the duration of repair at each shipyard is considered to be set and the ability to "speed up" or "slow down" the duration of repairs by increasing or reducing costs is absent. To eliminate the last drawback, let us consider the task of the lower level "optimizing the duration of ship repair at the n-th SRB".

Let the repair duration is *t*, then the function of idle time losses during time *t* is written as $V(t) = f \times t$, where *f* is the average profit from a vessel in service per unit time. Function *V(t)* is linear which facilitates its construction: the only slope *f* must be found.

It is not so easy to construct function *R(t)* of repair costs during period *t*. Of course, $R(0) = \infty$ (the duration of repair cannot be null), at $t \to \infty$ $R(t) \to r > 0$ (any repair process needs certain expanses even if it is a very sluggish one). In virtue of general economic considerations function *R(t)* must be decreasing and downward-convex, because each further reduction of repair duration per unit time will cost more.

Vessel repair network scheduling is one of the means to construct function *R(t)*. Assigning values for different resources (with a total value equal to *R*) and optimizing their distribution in accordance with the vessel repair network schedule, we receive certain values of critical path, the smallest of which will be the value of *t* corresponding to this *R*. The desired functional connection *R(t)* is constructed based on the assembly of points (R_i, t_i), $i = 1, \dots, n$, by using methods of mathematical statistics.

Finally, the function of total repair losses is constructed $W(t) = V(t) + R(t)$ and *t*, which minimizes them, is found (Fig.2).

At minimum point t^* $\frac{dW(t^*)}{dt} = \frac{dV(t^*)}{dt} + \frac{dR(t^*)}{dt} = f + \frac{dR(t^*)}{dt} = 0$, hence follows $\frac{dR(t^*)}{dt} = -f$, which is presented in Fig. 2.

The line, which is symmetrical with the line of lost profit along the horizontal axis, touches the curve of repair costs exactly at optimal point t^*.

The second derivative $\frac{d^2W(t^*)}{dt^2} = \frac{d^2R(t^*)}{dt^2} > 0$, because function $R(t)$ is downward-convex; thus, the minimum is exactly at point t^*.

Basically, not profit *V(t)* lost due to the repair, but savings $F(t) = f \times (T - t)$ obtained due to its early termination during time $t < T$ can be considered if at least an average standard repair duration *T* is set. Accordingly, *R(t)* is treated as additional costs to shorten the duration of repair compared to the standards, $R(T) = 0$. Then the

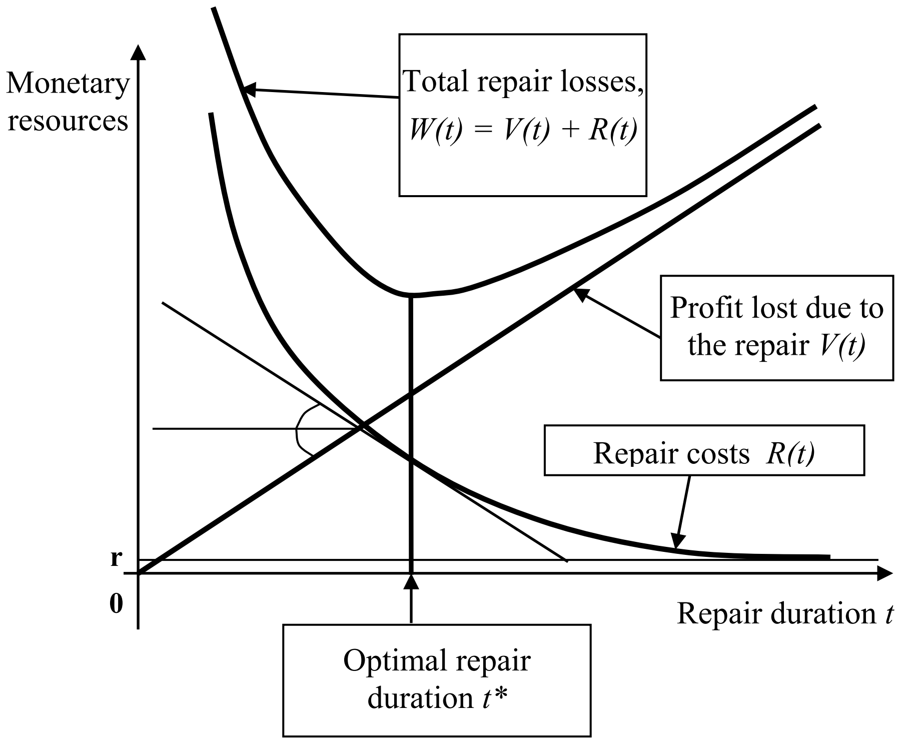

Fig. 2. Optimization of repair duration by minimization of total repair losses

task turns to maximize economic benefits from the early termination of repair *D(t) = F(t) – R(t)* → → max (Fig. 3)

This profit is presented in an explicit form in Fig. 4.

At optimal point t^* $\frac{dD(t^*)}{dt} = \frac{dF(t^*)}{dt} - \frac{dR(t^*)}{dt} =$ $= -f - \frac{dR(t^*)}{dt} = 0$, hence follows $\frac{dR(t^*)}{dt} = -f$, which corresponds to the previously set condition of optimality, i.e. the considered approaches, having certain economic differences, are mathematically identical.

The second derivative $\frac{d^2D(t^*)}{dt^2} = -\frac{d^2R(t^*)}{dt^2} < 0$, because function $R(t)$ is downward-convex; thus, the maximum is at point t^*.

If the repair duration is less than t^*, an increased profit from a vessel's operation will not compensate an increased expense for the reduction of repair time. If the repair duration is more than t^*, the value of idle time losses will exceed the value of additional costs to speed up the repair process.

Conclusions. This article discusses the issues of optimizing the process of vessel repair, which would allow shipping companies to be in good standing in appropriate local freight markets, to maintain their competitive advantages and getting the maximum possible profit by securing their certain cargo base and constant clientele, which is especially important for promising markets, where positions have to be kept in the conditions of tough competition.

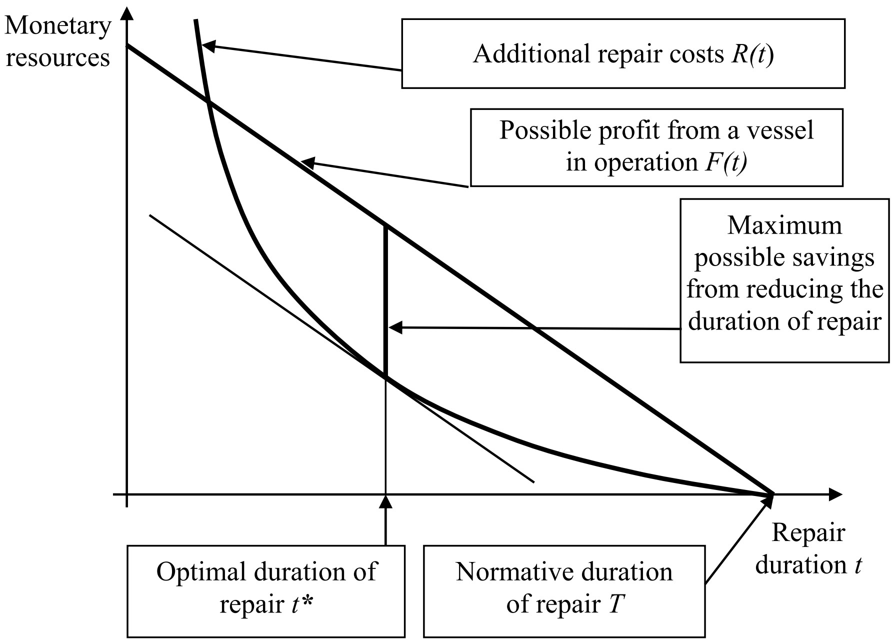

Fig. 3. Optimization of repair duration by maximization of profit

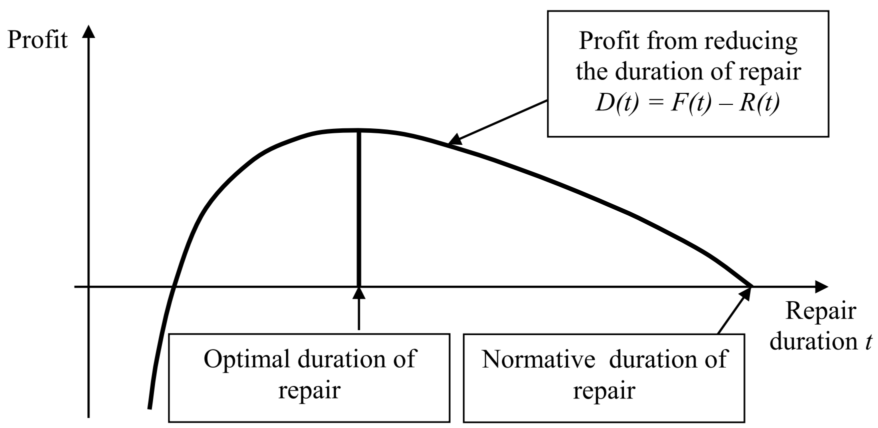

Fig. 4. Dependence of profit from the duration of repair

Taking into account that the choice of the repair base and the dates of the factory repair are elements of the fleet work plan, a mechanism for the integrated application of optimization models is proposed, when at the medium-term planning level the task of optimizing the fleet's work is to maximize the ratio of results to costs and the degree of the company's presence in the relevant local market; at the current level – the task of placing ships at the repair locations by the criterion of minimum costs, and at the operational level – the task of optimizing the duration of the ship repair on the relevant repair base.

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