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## RISK MANAGEMENT IN SHIP REPAIR PROJECTS

*Entropy model for risk management implemented during the ship repair is proposed in this article. The greatest difficulty of ship repair projects is the one in compliance with the contractual terms, taking into account the fact that at the time of signing the contract, amount of repair is not completely defined. The developed model will increase the probability of performance of the contractual terms at the stage of negotiation of the contract.*
***Keywords**: entropy model, project-oriented management, compromise, Social Welfare Function.*

*Предлагается энтропийная модель управления рисками в процессе реализации проектов ремонта судна. Наибольшая сложность судоремонтных проектов состоит в соблюдении договорных сроков при том, что на момент подписания контракта объем ремонта окончательно не определен. Разработанная модель позволит увеличить вероятность выполнения договорных сроков контракта на стадии согласования контракта.*
***Ключевые слова:** энтропийная модель, проектно-ориентированное управление, компромисс, функция коллективного благосостояния.*

*Пропонується ентропійна модель управління ризиками в процесі реалізації проектів ремонту судна. Найбільша складність судноремонтних проектів полягає в дотриманні договірних термінів при тому, що на момент підписання контракту обсяг ремонту остаточно не визначений. Розроблена модель дозволить збільшити ймовірність виконання договірних термінів контракту на стадії узгодження контракту.*
***Ключові слова:** ентропійна модель, проектно-орієнтоване управління, компроміс, функція колективного добробуту.*

**Introduction.** The statistical analysis of the ship-repair industry and analytical overview of current thinking about the development of project management methodologies, programs and portfolios allowed to come several conclusions [1-3]:

- In the last decade the development of maritime navigation is going through the path of increasing complexity and loading amounts of marine hardware and marine structures, while reducing the number of crew members. This fact leads to increase in the required amount of repair work performed by specialized companies;

- Despite the obvious competitive advantages of domestic shipyards (highly qualified workers and engineering professionals, considerable experience of ship repair work, as well as fixed assets and technology) the industry is in a deep economic and financial crisis over the past decades;
- The main cause of the crisis, according to the majority of scientists and practical specialists, is the imperfection of enterprise management system. Historically, the plants were built and operated by analogy with the shipbuilders and ignoring the distinct type of the ship repair unit of production. While the development of the fleet was followed by the path of construction of a dozen series of identical ships, their assignment to repair bases allowed to perform repair work affectively;
- The most effective form of business management of unit character production is considered to be project-oriented management, the effectiveness of which is proved by many examples of business;
- Methodology for managing project-oriented organizations is to be science rapidly developing in recent decades. A large number of publications in this field not only indicates a strong interest in this issue from the world's leading specialists in the field of project management, but illustrates the lack of effective mechanisms (models, methods and techniques) to solve the practical problems of management.
- In our opinion the main problem of the areas investigated is the complexity of the resolution of conflicts arising between the interests of the shipowner and the repair facility at the stage of concluding the contract in determining the main parameters (volume and range of work, cost and duration of the repair)[6].

In this paper, we propose a method for determining these parameters on the basis of risk theory, successfully used in recent years in the methodology of project-oriented management.

**Analysis of the main achievements and literature.** In order to improve the efficiency of complex technical systems in recent years actively used an integrated approach to the optimization of the complete life cycle from design to its recycling. Wherein said on the step of system repair the methodology of project-oriented management has been successfully applied [1]. Recently, project management as a branch of knowledge, methods, tools and management techniques is going through a phase of active development. At the same time the greatest success was achieved in project management organizations with a single type of production, which is particularly related to ship repair. The basis of the relationship of the shipowner and the repair facility is a contract.

Contractual relationship in project management are the backbone and institutionalized factors enabling project participants to regulate and implement coordinated activities with the external environment to achieve the final result.

The results of analysis of specificity of contractual relations in project management and the possibility of using the known mechanisms of active systems management allow us to conclude that the actual solution is solving theoretical problems of contract management:

- Determination of the parameters of the contract;
- Planning;
- Selection of contractors;
- Operational management [4].

The main parameter of the contract is the nomenclature of repairs, which until recently was determined using accepted industry system of continuous inspection of vessels in operation, which regulates the frequency of work on individual technical facilities and ship constructions. In recent years, in order to increase the effectiveness of using the vessels the strategy of repair by condition is increasingly used as the repair strategy built on risk-based approach for ensuring the safety of navigation.

In 2001, the International Maritime Organization (IMO) as part of a unified scientific management methodology navigation safety was developed "Guidelines for formal safety assessment (FSA) for use in the rulemaking process." Formalized safety assessment (FSA) is a systematic method of improving the safety of navigation of ships and fixed offshore platforms operating by use of risk assessment in order to select the most efficient and economical means of improving security.

FSA is intended to cover the design, operation and maintenance issues and to ensure getting the correct information about the hazards, risks, risk management options, as well as the related costs and benefits in a rational, structured and auditable form. FSA allows to improve the decisions that relate to management of identified risk failures to reduce their frequency and severity of the possible consequences.

As a core, FSA is an approach based on an assessment of the risk of an undesirable situation and aimed at identifying hazards before they cause accidents. Using FSA methodology allows to optimize the range and volume of repair work on the criterion of minimum operating costs, taking into account the impact of the actual condition of the vessel on changes in operating costs and the risk of accidents [5].

**The purpose of the study.** The purpose of this article is to develop a method for determining the main parameters of the contract to perform ship repair works on the basis of risk management models in the projects.

**Results.** Ship repair project in the specialized companies are characterized by the following main indicators:

- The amount of work;
- Deadlines;
- The quality of work;
- The necessary financial and material resources.

Examine the model of ship repair project, which is based on an agreement between two parties - the customer (the shipowner) and contractor (ship-repair enterprise). The subject of the contract is to change the state of the system ship, i.e. its transfer from the current state Sт to the final concerted state Sк. Moreover, the state Sк must belong to the set of admissible (workable) states of the system. In turn, the state vessel after the repair depends on the content of the project - the volume of repairs Wp, quality Kp, cost Cp and duration of repair Tp. Thus, an agreement between two fixed sides - customer and supplier - can be described by a tuple

$$D = \{S_T; S_K; W_P; K_P; T_P; C_P\}. \quad (1)$$

Obviously, in the case of ship repair, almost always a conflict of interests of the parties - the shipowner tries to minimize the amount of work, cost and time, which is contrary to the purposes and interests of the contractor. This problem is solved today through negotiations and is not based on any evidence-based model. We propose to determine the optimal content of the project on the basis of usage of Social Welfare Function. Decision-making task is to select the distribution utilities that maximize Social Welfare Function.

In the proposed game-theoretic model the analogue of the Social Welfare Function is the sum of the objective functions of the customer and the supplier, so the solution of the optimization tasks of the project is a set of works, maximizing the amount of the profits received by the customer and supplier

$$E = \left( \Pi p_{CB} + \Pi p_{CP3} \right) \xrightarrow{W_p; T_p} . \quad (2)$$

where $Пр_{CB}$ − shipowner profit from operation of the vessel for a period of time between overhauls;

$Пр_{СРЗ}$ − profits from the sale of the shipyard repair project.

Value E can be interpreted as "profit" of the whole system - the maximum total output (in units of utility), which can be achieved by the data interaction of customer and supplier.

It should be noted that the project cost of repair does not affect the value of Social Welfare Function, and therefore is not a control parameter of the objective function. The shipowner income is determined primarily by the time the vessel is in operation, and rising of operating costs is its actual state, i.e. the amount and quality of repair work. Also, expenses of the vessel shall include the amount of increase (or decrease) of the risk of damage due to the occurrence of an emergency during the ship's operations. Method for calculating this value, based on the basis of the general theory of risk methodology, is presented in [1, 2].

From the point of view of the decision-making theory the task of bargaining is to find such an alternative, which would provide a Pareto efficient Nash equilibrium for the parties of the contract that would satisfy the conditions of individual rationality. The multiplicity of such equilibria can be interpreted as an area of compromise - a multiplicity of alternatives (or distribution utility), to which both parties agree a priori. The specific parameters of the contract - a point of compromise, belonging to the domain of compromise, is determined in decision theory axiomatically, i.e. by introducting collective welfare functions satisfying some features. Selecting a point of compromise can be made on the basis of certain (and sometimes agreed between customers and suppliers in advance) rules and procedures – mechanisms of compromise.

Basic research tool is the task of stimulation [4], which consists of finding a depending reward to managed entity from the governing body, which would induce the first to take action in the interests of the latter. The analogy with contractual relationship is direct - customer assigns the dependence of the contract value (remuneration amount of the supplier) from the actions of the latter, and specifies what action is to be expected from him.

The supplier strategy is to choose an action in € A, belonging to the multiplicity of possible actions A. In models of contractual relations action is the amount of works by the contract. Strategy of the customer is the choice of the incentive function σ (y) € M, belonging to the admissible set M and associates an action of the supplier with a non-negative remuneration paid to him by the customer. In models of contractual relations incentive function reflects the dependence of the contract value from the amount of works performed by the supplier.

Selecting an action y € A requires expenses from supplier c(y) and brings revenue to the customer H(y). Expenses function of the supplier c(y) and the function of the customer's income H(y) will be assumed as known (problems of identification are discussed in [4]. Interests of the participants (the customer and contractor) are reflected by their objective functions, which are denoted by F and f (payoff functions, utility, etc., in records of which the customer's dependence on the strategy will be descended), represent: for the supplier - the difference between stimulation and costs

$$f(y) = s(y) - c(y), \qquad (3)$$

and for the customer - the difference between income and expenses for customer incentives - remuneration paid to the supplier

$$F(y) = H(y) - s(y). \qquad (4)$$

We introduce the following assumptions:

- The set of possible actions of the supplier is the positive half. If supplier refuses to sign the agreement with the customer (inaction) it is a zero effect;

- The expenses function of the supplier is nondecreasing, continuous and expenses on the choice of zero action are zero;

- Customer revenue function is continuous, non-negative, and the income of the customer in case of failure of the concluding a contract with a supplier is zero.

Rational behavior of both parties of the contract is to maximize (choosing its own strategy) the objective function taking into account all available information.

Assume that the function H(y) of the income of the customer - increasing and concave (property of diminishing marginal utility), and the supplier expenses function c(y) is convex (marginal costs increase with the amount of work). The picture shows the graphs of the functions: H(y) and c(y). From the perspective of the customer incentives can not exceed the income derived from the activities of the supplier (since abandoning interaction with the supplier, the customer can always get zero utility). Therefore, a feasible solution lies below the function H(y). From the perspective of supplier the promotion can not be less than the sum of expenses and backup utility (which supplier can always obtain by choosing a zero effect). Therefore, a feasible solution lies above the function c(y).

Multiplicity of actions of the supplier and corresponding remuneration values that satisfy both the customer and the supplier simultaneously on all of the above mentioned limitations (coordination, individual rationality, etc.) is called the domain of compromise, which is shaded in pic.

Optimality condition in this model (assuming differentiability of income and expenses, as well as the concavity of function of the customer income and convexity of function of supplier expenses) has the form

$$H_x = -\sum_{i=1}^{n}\left[p(i)\ln p(i)\right]. \tag{5}$$

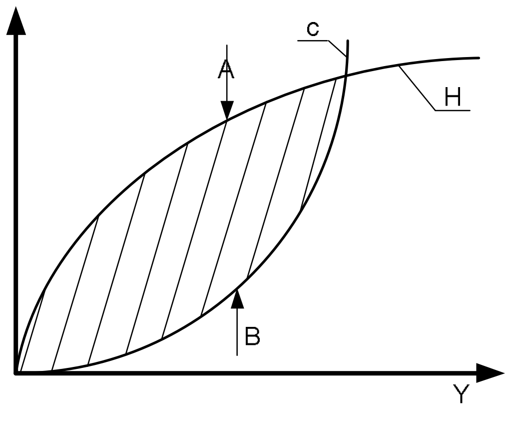


*Fig. 1. The domain of compromise*

In economy the left side is called the marginal productivity of the supplier, and the right - its marginal costs.

By finding with the help of the maximum value of the Social Welfare Function the optimal cost and maintenance repair project, WBS structure can be created and built a network model for repair. Timing parameters of this model allows us to estimate the duration of the critical path, ie the repair timing of contract.

It should be stated that the critical path method for solving this problem is inefficient, due to the existence of significant uncertainty in the planning stage of the project. To find the probability of completion of the project to a certain date or in a certain time interval, entropic risk management models can be used.

Entropy is a fundamental feature of any system with an ambiguous or probabilistic behavior. The entropy as a quantitative measure of uncertainty, unpredictability, confusion, chaos, disorganization of probabilistic systems is universal. Scientists in the XX century had shown that we live in the world of macro-instability and therefore took entropy as a generic parameter - a quantitative measure of uncertainty or disorder[2]. Method of quantitative determination of entropy is adequately developed in information theory. Let the random value x can take n different values with probabilities p (i), i = 1 , 2 , ..., n. Then the entropy of the event x is given by

$$H_x = -\sum_{i=1}^{n} \left[ p(i) \ln p(i) \right] \tag{6}$$

This expression defines the basic mathematical properties of the entropy:

- Nonnegativeness $- H(x) \geq 0 \quad \forall x$;

- Limitations $- H(x) \leq \ln n$;

- Additiveness $- H(x \cdot y) = H(x) + H(y)$.

In addition, by analogy with the Markov model of the first order for interdependent events the concepts of conditional and mutual entropy can be used.

For each of the repair operations its entropy can be calculated as a function of the probabilities of the following events:

- The end of all previous operations - $P_1$;

- Availability of the necessary material resources and spare parts at the beginning of work - $P_2$;

- Necessary specialists with qualifications ready to work - $P_3$ and required technological equipment - $P_4$;

- The probability of maintaining the speed of the operation - $P_5$.

Then the entropy of the j-th operation will be

$$H(j) = -\sum_{1}^{5} \sum_{i=1}^{n} \left[ p(i)_j \ln p(i)_j \right] \tag{7}$$

Entropy of the entire project will be the sum of entropies of the project works

$$H = \sum_j H(j) \tag{8}$$

During the realization of the project and achievements of individual events the entropy of the project will decrease. This will increase the likelihood of fulfillment of contractual obligations. Analysis of the performance of repair projects showed that the decrease of entropy during the time occurs abruptly as the most uncertain events accomplishment.

Points of the graph corresponding to an abrupt change of entropy should be considered as milestones of the project. Precisely these points should be considered as controlling points to adjust or make significant changes of terms of the project or its implementation methods (changing technology of repair, the equipment used, repair materials, the composition of the project team). Another method of risk management repair projects is to increase the volume of work phase zero, which can be performed before signing the contract for performing repairs. Such works should include repair materials sour-cing, designing means of tooling, perform maintenance and repair of fixed assets, etc. This will increase the probability of occurrence of certain events timely and that will reduce the value of the total entropy at the time of signing the contract.

**Conclusion.** The effectiveness of maritime navigation is largely determined by the perfection of the strategy used by ship repairs performed on specialized repair enterprises.

Relations between the shipowner and the ship repair plant are regulated by the contract for ship repair activities, at the conclusion of which each of the parties comes from their own often conflicting aims and interests. The aim of this study is to develop a science-based method for determining the basic parameters of the ship repair contract, which would be mutually acceptable.

The main parameters of the range of ship repair contracts are nomenclature, cost and duration of the repair. The method proposed in the article advises to define the range of activities on the basis of the methodology of formal safety assessment adopted by the International Maritime Organization. Thus it is necessary to take into account that the nomenclature of repair affects the following indicators of efficiency of vessel operation:

• the cost of repair;

• operating expenses for fuel and lubricants and for technical inspection works;

• change of the risk of an accident occurrence.

The repair contract value is calculated basing on the profitability of the parties using the Social Welfare Function (Nash Function). The peculiarity of the ship repair projects is great uncertainty at the stage of concluding the contract. Therefore the duration of vessel stay in the repair is proposed to estimate based on the entropy model of risk measurements developed by the authors.

The proposed research may be used either by technical managers of shipping companies or by specialists at ship repair yards.

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