Crewing of Sea Vessels Taking into Account Project Risks and Technical Condition of Ship Equipment

Oleg V. Zakharchenko[1,*], Dmytro I. Bedrii[2], Olena V. Bileha[1], Oksana Y. Savina[3] and Oksana V. Haidaienko[4]

[1]*Department of Management and Marketing, Odessa State Academy of Civil Engineering and Architecture, Odessa, Ukraine*

[2]*State Enterprise "Ukrainian Scientific Research Institute of Radio and Television", Odessa, Ukraine*

[3]*Department of Technological and Civil Security, Admiral Makarov National University of Shipbuilding, Mykolayiv, Ukraine*

[4]*Information Management System and Technologies Department, Admiral Makarov National University of Shipbuilding, Mykolayiv, Ukraine*

Abstract: *Motivation*: One of the main concepts in project management is the concept of "team" in the project, and in project management - the human resources management of the project, which includes the processes of planning, forming and creating a team, its development and support activities, transformation or disbandment of the team. Despite the great attention paid to the formation of project management teams, existing studies do not fully highlight the specifics and features of crew operations. Criteria for the quantitative optimization of the ship's crew should be consistent with the main objectives of the project.

Novelty: The research paper proposes an approach that allows optimizing the quantitative composition of the crew of a ship by more accurately assessing the level of project risks and costs associated with the maintenance of ship equipment. The practical application of this approach will optimize the quantitative composition of the ship's crew, which will both satisfy the needs of managing the technical equipment and minimize the risks and costs of the shipowner.

Methodology and Methods: Risk management tools were used to achieve the objective and test the hypotheses suggested in the research, namely: methodology for estimating the net present value of the project; the method of estimating internal rate of return for the project; the method of estimating the return on investment in the project; the method of estimation for the period of return on investment costs in the project; the method of estimating the discounted payback period for the project, as well as the tools of simulation modelling (Monte Carlo simulation method). The method of identification and grouping in the process of classification of project risks in the sphere of marine transportation, methods of systematization, grouping and logical generalization were also applied for systematization of information, drawing conclusions and making scientific suggestions in the research.

Policy Considerations: Shipping plays an important role in the trade and tourism industry; human factor is the most important aspect that determines the efficiency of shipping development; maintaining of technical and technological processes of the ship puts certain requirements to the quantitative and qualitative composition of the team, deviation from which leads to the occurrence of certain risk events; formation of an effective model of ship's crew manning is the main link in ensuring effective shipping project management.

Keywords: Optimization model, ship's manning, crew size, shipping risks, project effectiveness evaluation, project team, ship's stuffing, maritime industry.

1. INTRODUCTION

The maritime industry belongs to dynamically developing as evidenced by the annual increase in passenger traffic by 7.2 percent since 1990 (Wang *et al*. 2016). Total volume of the world seaborne trade in 2016 is about 10.3 billion tons of cargo; the rate of increase in volumes during 1974-2014 amounted to 3 percent, in 2015 was 1.8 percent, and in 2016 was 2.6 percent. According to the forecast of the world's seaborne trade the rate of increase in volumes in 2019-2024 will be 3.4 per cent (United Nations 2019).

Each voyage is a project that requires effective management, as well as justification of financial efficiency and analysis of potential risks and their likelihood. According to theory, project effectiveness can be evaluated by methods: measurement of investments based on discounting revenue streams; assessment of the total value of investments; analysis of investment attractiveness; analysis of the breakeven of investment projects; assessment of the effectiveness of investment projects; estimation of investment projects, the realization of which foreign investors are involved.

1.1. Relevance of the Research Topic

Early studies emphasize that evaluation of shipping project effectiveness includes net present value (Alluisi,

*Address correspondence to this author at 4, Didrichson str., Odessa, 65000, Ukraine; Tel: +38(048) 723-33-42; Fax: +38(048) 732-43-01;
E-mail: olegzakharchenko@yahoo.com

E-ISSN: 1929-7092/20

Hall and Chiles 1962), internal rate return (Mazur, Shapiro and Olderogge 2001a), profitability of investments (Alluisi, Hall and Chiles 1962), payback period of investment costs (Mazur, Shapiro and Olderogge 2001b), and discounted payback period (Altman and Terauds 1960). Though these methods provide static data that is only relevant at present moment, they do not take into account the likelihood of a positive and negative scenario, and therefore do not provide comprehensive information.

Modern shipping companies face a number of problems that need conceptual solutions. Human resources are at the heart of shipping companies' potential, and they are a source of potential risks (Barnett and Pekcan 2017; Ilina, Miloradov and Kovaltchuk 2019). Modern scientists highlight a number of issues associated with human factor (Livingstone, Cahoon, and Fei 2014), namely:

- poor HR practices of employers;
- increasing the load on one crew member due to the excessive size of the crew;
- ship's crew retention costs;
- shipboard technology and reduced crew size.

Entrepreneurship is an activity aimed at maximizing profits, which is possible with the biggest difference between income and expenses. The operation of the ship's systems imposes specific requirements for managing the quantitative and qualitative composition of the team. The cost of maintaining the crew of the ship is a considerable part of the production costs, but the costs of covering the risks caused by the understaffed team can exceed them. Ship-owners try to minimize their costs by reducing crew size, but it leads to a wide range of potential operational risks (Sawik 2015). Thus, by reducing the cost for crew maintaining, the ship-owner increases the likelihood of risk events leading to even greater financial losses.

The aim of the study is to develop models and improvement of methods for the quantitative and qualitative composition of project teams as a variable component of the project team on the example of the crew of ships.

Achieving this goal involves the consistent solution of the following research tasks:

1) Research and disclosure of the specifics of methodology for evaluating:

   - the internal rate return of the project;

   - the index of profitability of investments in the project;

   - the index of profitability of investments in the project;

   - the payback period of investment costs in the project;

   - the discounted payback period of the project.

2) Research and disclosure of the specifics of methodology for simulation modeling for its application in the field of project risk management of sea freight.

3) Determination of stages of the risk analysis process in simulation modeling.

4) Improving the methodology of formation of a project team based on simulation modeling for determining:

   - the effect of the balance and compatibility of the crew on the amount of risk;

   - the dependence of the functional state of the ship's technical equipment and ship structures on the optimal team composition and the cost of the ship-owner.

2. MATERIALS AND METHODS

Risk management tools were used to achieve the objective and test the hypotheses suggested in the research, namely: methodology for estimating the net present value of the project; the method of estimating internal rate of return for the project; the method of estimating the return on investment in the project; the method of estimation for the period of return on investment costs in the project; the method of estimating the discounted payback period for the project, as well as the tools of simulation modelling (Monte Carlo simulation method).

The method of identification and grouping in the process of classification of project risks in the sphere of marine transportation, methods of systematization, grouping and logical generalization were also applied for systematization of information, drawing conclusions and making scientific suggestions in the research.

2.1. Methodology for Evaluating Net Present Value of the Project

The criterion for a quantitative analysis of the effectiveness of capital investments is the most widely used criterion in the project for the net present value *NPV*. The calculation of the criterion is based on the discounting of cash flows received for all years of the project with respect to the time the project began (Alluisi, Hall and Chiles 1962). As you know, the calculation of NPV is carried out according to the following formula:

$$NPV = \sum_{i=1}^{T} \frac{CF_i}{(1+p/100)^i} * -I_0 + \frac{L}{(1+p/100)^i} *,$$

where *CFi* is the cash flow for the *i*th year of operation of the investee, defined as the difference between the income and the percentage of cash during the year *i*; *p* is the discount rate; *I0* – one-time costs at the time of the start of project activities; *L* - revenue from the liquidation of fixed assets of the project at the time of its completion.

Based on the obtained value of the criterion, we can draw a preliminary conclusion about the effectiveness of the investment project:

- If NPV = 0, the project cannot be called either profitable or unprofitable, all income goes to reimburse the costs of project activities.
- If NPV> 0, a conclusion is made on the acceptability of the project, and of several alternative projects, before adoption, one with NPV is higher is recommended.
- If NPV <0, such a project is considered unacceptable, since it is inherently unprofitable.

Based on the features of the formation of cash flow as the difference between income and interest on cash during the year *i*, formalized CF can be expressed as follows:

$$CF_i = D_i - R_{ivar} - R_{ifixed} - R_{iloan}$$

where D_i is the income received from the operation of the investee for the year; R_{ivar} – variables operating costs for the year *i;* R_{ifixed} – fixed costs for the year *i;* R_{iloan} – loan costs for the year *i.*

2.2. Methodology for Evaluating the Internal Rate Return of the Project

The criterion of the internal rate return for the project IRR. IRR is the discount rate at which the difference between investment costs and the value added of all income and cash interest is zero. The value of calculating the internal rate of return when analyzing the effectiveness of an investment project, as a rule, is as follows: IRR shows the expected profitability of project *i*, as well as the maximum allowable relative level of costs that can be associated with this project (Chapanis 1961).

If the whole project is carried out only at the expense of credit funds, then the internal rate of return is equal to the highest percentage under which you can take a loan in order to be able to pay on income from the project, then IRR = i, at which NPV = 0.

Finding the IRR indicator is a step-by-step process for which the following algorithm is used:

- the NPV value is found for some predetermined interest rate p. The value of p is determined empirically by assessing the rate of increase in equity of a given enterprise or enterprises of competitors;
- NPV value is compared with 0. If NPV> 0, p should be increased by Δp, where Δp is set arbitrarily and can be from 1 to 5%, which affects the number of steps and the accuracy of the calculation. If NPV <0, then p should be reduced by Δp;
- NPV calculation is repeated for p ± Δp, etc. until the NPV reverses its sign.

For analytical determination of the IRR value, the formula is used:

$$IRR = P_1 + \frac{NPV(P_1)}{NPV(P_1) - NPV(P_2)} * (P_2 - P_1),$$

where p_1 is the last interest rate at which NPV> 0; p_2 – first interest rate at which NPV <0; *NPV* (p_1) – last positive value of NPV; *NPV* (p_2) – first negative value of NPV.

Thus, the analysis of the project based on the IRR criterion is reduced to comparing it with the value of the interest rate at which it is possible to obtain a loan.

If IRR = p, the project cannot be considered either profitable or unprofitable (its NPV = 0).

- If IRR> p, the project is considered profitable.
- If IRR <p, the project is considered unprofitable.

Moreover, the project efficiency is higher, the greater the excess of the internal rate of return over the interest rate (Mazur, Shapiro and Olderogge 2001a).

2.3. Methodology for Evaluating the Index of Profitability of Investments in the Project

In most cases, analysis of the project according to the criteria of NPV and IRR leads to the same conclusion about the advantages of the project. However, in cases where extraordinary cash flows occur, conclusions based on *NPV* and *IRR* criteria may be contradictory. Then the advantage is preserved by the NPV criterion, since it has absolute dimension and shows a clean, modern project result. Index of profitability of investments PI (Profitability Index). This criterion also allows you to correlate the amount of investment costs with the future net cash flow for the project and is inherently an in-depth use of the calculation of the NPV criterion. The calculation of the profitability index is carried out according to the formula:

$$PI = \frac{\sum_{i=1}^{T} PV(CF_i)}{I_0} = \frac{\sum_{i=1}^{T} \frac{CF_i}{(1+p/100)^i}}{I_0},$$

where *PI* – index profitability on investment; *CFi* – cash flow for the *i*th year of operation of the investee, defined as the difference between income and interest on cash during the year *i*; I_0 – one-time costs at the time of the start of project activities.

The criterion of profitability index is closely linked to the criterion of net present value. It is built from almost the same elements. If NPV> 0, then PI> 1, if NPV <0, then PI <1.

Consequently:

- if PI> 1, the project is considered profitable;
- if PI <1, the project is considered unprofitable;
- if PI = 1, the project is neither profitable nor unprofitable.

In contrast to NPV, the profitability index is a relative indicator characterizing the level of income per unit of cost, i.e. the amount of net present value per unit of non-recurring costs. The higher the return on each monetary unit invested in the project, the greater the IRR value, the higher the investment efficiency.

This indicator should be used when choosing one project from a number of alternative ones having close NPV values, but different volumes of required investments. Then, naturally, the project is more profitable, in which the investment efficiency is higher.

2.4. Methodology for Evaluating the Payback Period of Investment Costs in the Project

The payback period (PP) of investment costs. Payback period estimates the liquidity of the project. He considers how soon the project will pay for itself, that is, return the investment (Mazur, Shapiro and Olderogge 2001a).

Analysis by this criterion reduces to the fact that the smaller the payback period, the faster the project will recoup costs, and therefore, it is better. PP takes into account cash flows during the implementation of the project and the rate of receipt of these flows. Revenues during the implementation of the project can take place according to two different schemes:

a) cash flows are constant over the years, then:

$$PP = \min T, \text{ at which } \sum_{k=1}^{T} CF_k \geq I_0 \quad (CFk = \text{const}).$$

In this case, the payback period is calculated by dividing the one-time costs by the amount of annual income due to them. Upon receipt of a fractional number, it is rounded up to the nearest integer.

b) cash flows are not constant, then:

$$PP = \min T, \text{ at which } \sum_{i=1}^{T} CF_i = I_0 .$$

Moreover, in this case, both the integer number of payback years and the fractional part of the year are calculated from the assumption that revenues in each year pass with the same intensity (Altman and Terauds 1960).

The PP criterion is very simple in calculations, however, it has a number of disadvantages that must be taken into account in the analysis.

First, it does not take into account the effect of recent incomes. This shortcoming reflects a short-term orientation. Using the PP criterion for making investment decisions rejects projects designed for a long payback period and accepts those that provide a quick return, even if this return by absolute value is less (Mazur, Shapiro and Olderogge 2001a).

Secondly, since this method is based on undiscounted estimates, it does not distinguish between projects with the same amount of cumulative income, but its different distribution by year.

Thirdly, it does not have the additivity property, i.e. the choice of projects individually or when they are jointly implemented may be controversial.

2.5. Methodology for Evaluating the Discounted Payback Period of the Project

The second drawback can be eliminated by using the discounted payback period (DPP).

The formula for calculating the discounted payback period is:

$$DPP = min\ T, \text{ at which } \sum_{i=1}^{T} CF_i / (1+p/100)^i \geq I_0 .$$

Obviously, when discounting, the payback period increases, i.e. always *DPP*> *P*. In other words, a project acceptable by the PP criterion may not be acceptable by the *DPP* criterion.

It should be noted that in evaluating investment projects, the *PP, DPP* criteria can be used in two ways:

a) the project is accepted if the payback takes place;

b) the project is accepted only if the payback period does not exceed a certain limit.

2.6. Methodology for Simulation Modelling

The book (O'Neil 2000) provides such a definition of risk: "A measure of the significance of a hazard, including an assessment of its consequences and the likelihood of occurrence." In other words, this concept includes two components:

$$R = P \cdot U,$$

where *R* is the project risk; *P* is the probability of the event and the severity of its consequences; *U* – damage caused by this incident.

Risks are usually divided into the following zones (levels) (Zhanga and Fanb 2014; Zhanga and Thaiab 2016): the upper level is the zone of unacceptable risk and the lower is the zone of negligible risk. Unacceptable risks should be mitigated in any case, regardless of the costs required. Negligible risks are not taken into account. There is a risk zone between these extreme levels, where they should be mitigated, but according to the "risk mitigation – required costs" scheme, an appropriate (reasonable) way to mitigate risks has been chosen. The division of risks into zones depending on the frequency and consequences is shown in Figure **1**.

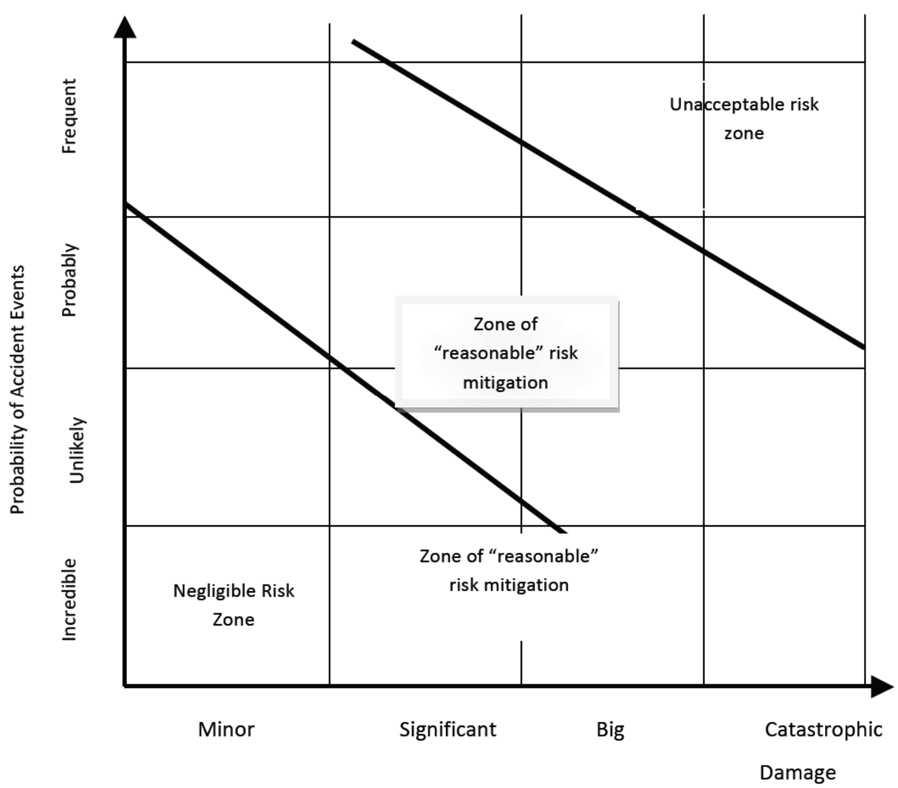

Figure 1: Project risk matrix.

It should be noted that risk assessment of certain events can only be made if sufficient statistics are available. Otherwise, the results will not be accurate, since here we are talking about the so-called "rare phenomena", where the classical probabilistic approach is not applicable. A qualitative approach to risk assessment is also practiced in the operation of a vessel and ship devices (Alexandrovskaya, Shakhov and Shakhov 2011).

The International Maritime Organization (n./d.) has recommended the following individual risk criteria:

- the maximum permissible annual risk for a crew member is 10^{-3};
- the maximum permissible annual risk for passengers is 10^{-4};
- the maximum permissible annual risk for people on the shore is 10^{-4};
- negligible risk (during the flight) 10^{-6}.

Despite the diversity of species, all dangers can be classified for reasons of their occurrence as follows (Kramskyi 2017b):

- natural, arising as a result of geophysical, climatic and space changes on the planet;
- operational, as a result of erroneous actions of operators;
- technical, due to the occurrence of failures in the operation of ship systems or the unsatisfactory state of the elements of ship technical equipment (STE) and ship structures (SS) (Boyko *et al*. 2017).

However, in most cases, a security incident is the result of the combined effects of several factors of various kinds (Kramskyi 2017a). The basic principle of the analysis of complex systems is to connect the potential dangers in their activity (called events) in the form of a tree with a certain number of branches; probability is determined and indicated for each branch. Each junction of two or more branches uses one of two choices (logical operators of Boolean algebra), namely: OR, AND. The first choice is applied if one or several possible conditions (events) are satisfied; the second one requires that all conditions be satisfied before further progress can be made. In a ship situation, a major violation (the top event) is seen as the result of a number of reasons. In other cases, one cause may lead to a violation (accident). For logical operators (OR), the probabilities are summed, for (AND) they are multiplied. When analyzing complex systems, building an event tree allows you to logically link the various causes of violations, establish their probabilities, and thereby better understand the system.

Testing the approaches considered and proposed in the work in practice requires the use of a set of specific data on a particular ship and the projects for which it is used.

In particular, these data include:

- specific data on the capital and cash flows of the shipowner in the course of the project implementation;
- data on the quantitative and qualitative composition of the equipment of the vessel involved in the implementation of projects;
- data on the quantitative and qualitative composition of the ship's crew at the moment before its optimization;
- environment and risk analysis data based on information on current discount rates, interest rates on loans, the level of project risks in the transportation sector, etc.

3. RESULTS

3.1. Stages of Risk Analysis Process in Simulation Modelling

Thanks to the method of simulation modelling and runs of situations, it is possible to predict the state and functioning of the object in real conditions, thereby preventing negative consequences that may occur during the operation of the object or on the object (Kramskyi 2014). The essence of the simulation method is to simulate the functioning of the network in question at any given time interval. To study networks in the stationary mode, it is necessary to first determine the minimum period of the study, which in practice can turn out to be quite large, and the moment the network enters the stationary state. The Monte Carlo simulation technique creates an additional opportunity in risk assessment due to the fact that it makes it possible to create random scenarios (Mazur, Shapiro and Olderogge 2001b). The application of risk analysis uses a wealth of information, whether in the form of objective data or expert estimates, to quantify the uncertainty that exists with respect to the main variables of a project and to reasonably calculate the possible impact of uncertainty on the effectiveness of an investment project.

The result of the risk analysis is not expressed by any single value of NPV, but as the probability distribution of all possible values of this indicator. Consequently, the potential investor, using the Monte Carlo method, will be provided with a complete set of data characterizing the risk of the project. On this basis, he will be able to make an informed decision on the provision of funds. In general, Monte Carlo simulation is a procedure by which a mathematical model for determining a financial indicator (in our case, NPV) is subjected to a series of simulation runs using a computer. During the simulation process, sequential scenarios are constructed using the initial data, which are undefined by the meaning of the project, and therefore are assumed to be random variables in the analysis process. The simulation process is carried out in such a way that a random choice of values from certain probability distributions does not violate the existence of known or assumed correlation relations among the variables. Simulation results are collected and analyzed statistically in order to assess the measure of risk (Shakhov and Kramskoy 2011).

The risk analysis process can be divided into the following stages, which are presented below in Table **1**.

The first stage in the risk analysis process is the creation of a predictive model. Such a model determines the mathematical relationships between numerical variables that relate to the forecast of the selected financial indicator. As a basic model for investment risk analysis, the model for calculating NPV is usually used.

$$NPV = CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + ... + \frac{CF_n}{(1+r)^n} = \sum_{k=0}^{n} \frac{CF_k}{(1+r)^k}$$

The use of this formula in risk analysis is fraught with some difficulties. They consist in the fact that when generating random numbers, the annual cash flow acts as a certain random number obeying a certain distribution law. In reality, this is an aggregate indicator that includes many components considered in previous publications. This aggregate indicator does not change by itself, but taking into account changes in sales. That is, it is clear that it is correlated with volume. Therefore, it is necessary to carefully study this correlation in order to get closer to reality. The general forecast model is simulated as follows. A rather large volume of random scenarios are generated, each of which corresponds to certain values of cash flows (Turner 1993).

The generated scenarios are collected together and their statistical processing is performed to determine the proportion of scenarios that correspond to a negative NPV value. The ratio of such scenarios to the total number of scenarios gives an assessment of the risk of investments. The probability distributions of the model variables (cash flows) dictate the possibility of choosing values from certain ranges. Such distributions are mathematical instruments with the help of which all possible results are given weight (Cremeans 1967). This controls the random selection of values for each variable during the simulation.

The need for a probability distribution is due to attempts to predict future events. A typical investment analysis uses one type of probability distribution for all variables included in the analysis model. This type is called the deterministic probability distribution, and it gives all the probability to a single value. When evaluating the available data, the analyst is limited to choosing the only one from the set of possible results or calculating a composite indicator. Then the analyst must accept that the selected value is necessarily realized, that is, he gives the selected indicator in the most reasonable way with a single value the probability equal to 1. Since this probability distribution has a single result, the result of the analytical model can be

Table 1: Risk Analysis Process

Predictive model		**Probability Distribution (Step 1)**		**Probability Distribution (Step 2)**
Preparation of a model capable of predicting the calculation of project effectiveness.	→	Determination of the probabilistic law of the distribution of random variables.	→	Setting the boundaries of a range of variable values.
Correlation conditions		Simulation runs		Results Analysis
Establishing correlated variable relationships.	→	Generating random scenarios based on a set of assumptions.	→	Statistical analysis of simulation results.

determined on the basis of only one calculation (or one run models).

The risk analysis uses information contained in a probability distribution with multiple values. It is the use of multiple values instead of deterministic probability distributions that distinguishes simulation from the traditional approach.

The determination of random variables and giving them an appropriate probability distribution is a prerequisite for conducting a risk analysis. Successfully completing these steps, you can proceed to the simulation stage. However, a direct transition to modelling will be possible only if a correlation is established in the system of random variables included in the model (Zakharchenko and Zakharchenko 2019).

Correlation refers to a random relationship between variables that is not strictly defined, for example, the relationship between the selling price of a product and sales. The presence of correlated variables in the analysis model can lead to serious distortion of the results of the risk analysis if this correlation is not taken into account. In fact, the presence of correlation limits the random selection of individual values for correlated variables. Two correlated variables are modeled so that if one of them is randomly selected, the other is not freely selected, but in a range of values that is controlled by the simulated value of the first variable.

Although it is very rarely possible to objectively determine the exact characteristics of the correlation of random variables in an analysis model, in practice it is possible to establish the direction of such relationships and the estimated strength of the correlation. For this, methods of regression analysis are used. As a result of this analysis, a correlation coefficient is calculated, which can take values from -1 to 1.

The “model runs” stage is that part of the risk analysis process in which the computer performs all the routine work. However, when studying the stationary characteristics of a network, it is necessary to remember the influence of the initial state of the system. After all assumptions are carefully substantiated, it remains only to sequentially calculate the model (each recount is one “run”) until enough values are obtained for making a decision (for example, more than 1000).

During the simulation, the values of the variables are randomly selected within the boundaries of the given ranges and in accordance with the probability distributions and correlation conditions. For each set of such variables, the value of the project performance indicator is calculated. All obtained values are stored for subsequent statistical processing (Shakhov and Kramskoy 2011).

For the practical implementation of simulation, you can recommend the package "Risk Master", developed at Harvard University. This package generates random numbers based on the use of a pseudo-random number sensor, which are calculated according to a specific algorithm. A feature of the package is that it can generate correlated random numbers.

The final stage of risk analysis is the processing and interpretation of the results obtained at the stage of model runs. Each run represents an event probability equal to:

$$p = 100 / n,$$

where p is the probability of a single run, %; n – sample size.

For example, if the number of random runs is 5000, then the probability of one run is:

$$p = 100 / 5000 = 0.02\%.$$

It is advisable to use the probability of obtaining a negative NPV value as a risk measure in investment design. This probability is estimated based on the statistical results of simulation as the product of the number of results with a negative value and the probability of a single run. For example, if out of 5,000 runs, negative NPVs are found in 3,454 cases, then the risk measure will be 69.1%. Based on this, risk reduction measures are selected that provide benefits for the enterprise (organization).

3.2. Formation of a Project Team Based on Simulation Modelling

Figure **2** shows an example of building a tree of failures (violations) – a logical diagram showing a causal relationship between events that, individually or in combination, cause the manifestation of an event of a higher level. Such an analysis is carried out to determine the likelihood of an event of the highest level, which may be an accident or an undesirable dangerous outcome, which is accompanied by any damage (Alexandrovskaya, Shakhov and Shakhov 2011). Therefore, the risk from the onset of the *i*-th hazard can be determined by the formula (1), and the total risk for the case presented in Figure **2**.

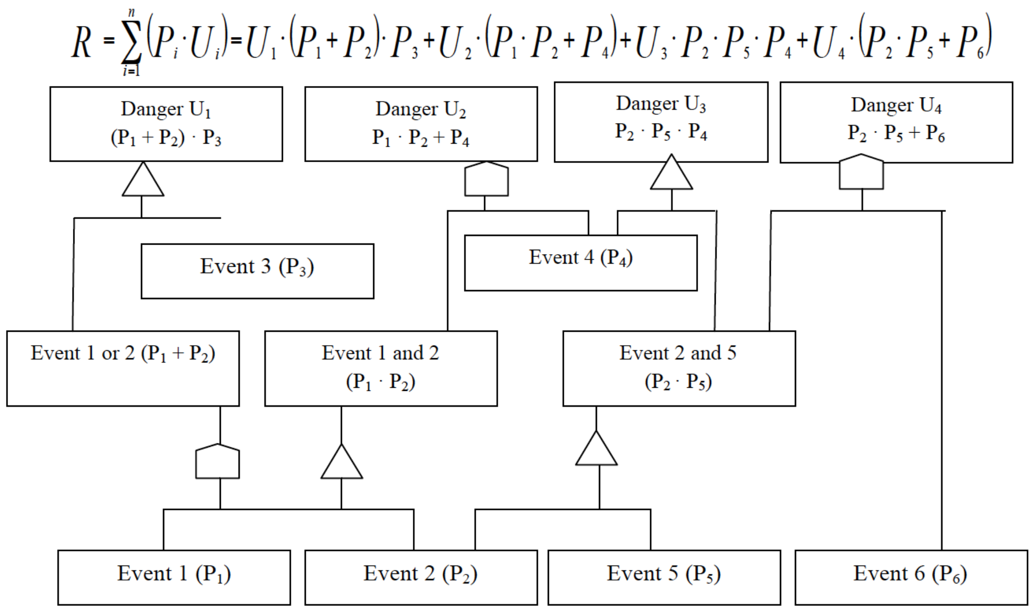

Figure 2: Example of building a project failure tree.

As a criterion for the optimality of the crew in this model, it is proposed to use the value E, defined as the difference:

$$E = \Delta R - \Delta Z \rightarrow \max ,$$

where ΔR is the reduction in the risk of an emergency due to an increase in the number of crew; ΔZ - increase in the cost of the shipowner for the maintenance of the crew.

$$\Delta R = \sum_{i=1}^{I}(P_{1i} \cdot U_{1i}) - \sum_{i=1}^{I}(P_{0i} \cdot U_{0i}),$$

P_{1i} and P_{0i} – the probability of an emergency in the changed and basic version of the team, respectively; U_{1i} and U_{0i} – damage to the shipowner in the event of an emergency in the amended and basic version of the crew, respectively (Kramskyi 2014; Zakharchenko and Zakharchenko 2019).

The results of simulation are presented in Figure **3**.

In addition, the use of the method allows calculating the necessary crew of the vessel, taking into account the actual technical condition of its mechanisms, devices and systems. Using the proposed model will optimize the quantitative and qualitative composition of the team for each planned period of time (cruise, contract, etc.). The main result of the research can be considered evidence of the appropriateness of using the developed models and methods at the stage of formation of project teams on the example of crews of sea vessels.

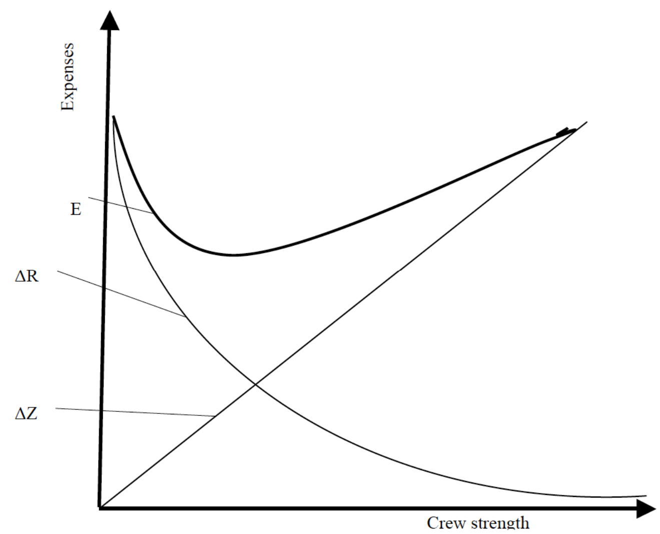

Figure 3: The objective function of the optimization of the number of crew.

4. DISCUSSION

It should be noted that over the previous decades, in connection with the use of advanced computer systems and programs, the method of simulation modelling has been widely used to obtain estimates and possible results of various situations. Because simulation is a method that allows you to build models that describe the processes as they would in reality. Such a model can be “lost” in time both for one test and for a given set of them.

Justified team building of the project in the practice of shipping company needs implementation of the risk simulation modelling. The model of quantitative composition of ship's crew balances the acceptable level of risk with personnel costs, that is, to minimize both the costs incurred by the ship-owner for maintaining the crew and the cost of covering the risk, taking into account the inverse relationship between these financial losses.

The proposed model can be used as a starting point for crew scheduling and crew rostering optimization model (Ernst *et al*. 2001), which will improve not only the process of the ship staffing, but also promote the productive use of human resources.

The model can complement the qualitative fuzzy optimization approach to the selection of the project team (Baykasoglu, Dereli and Das 2007), which will provide a complete process of staffing in terms of both qualitative and quantitative parameters.

The solution to the problem of optimizing the quantitative composition of the team is consistent with the safe manning of merchant ships approach (Alapetite and Kozine 2017), although it does not take into account watch schedules and distribution of competitiveness. However, the approach indirectly takes into account these factors, as overworking the work schedule of employees leads to risk events that occur in the project failure tree and therefore affect the result of the calculations.

Unlike the optimization of quality composition (Zhao and Zhang 2018), the model is more convenient to apply in real conditions, because it does not require the collection of a large amount of data on the crew quality. This benefit is based on the assumption that initial recruitment is carried out by the relevant recruitment organizations based on the collection and processing of relevant information. Therefore, the selected crewmembers will have an acceptable level of professional skills, and a slight deviation from the norm will not lead to such losses as the process of collecting and analysing comprehensive information about employees.

5. CONCLUSIONS

Recently, the Human Factor trend has been widespread and prevailing in the field of formation of project management teams. This phenomenon has long been known, but at the stage of creating project management teams, it must be taken into account in order to avoid unwanted actions and errors when selecting a project team. The research paper proposes an approach that allows optimizing the quantitative composition of the ship's crew by more accurately assessing the level of project risks and costs associated with the maintenance of ship equipment. The practical application of this approach will optimize the quantitative composition of the ship's team, which will both satisfy the needs of managing the technical equipment and minimize the risks and costs of the shipowner.

It should be noted that although the capabilities of modern personal computers allow modelling at large time intervals, increasing the accuracy of the results of the study. A distinctive feature of simulation experiments from field tests is the simplicity of repetition and reproduction of experimental conditions. Processing the results obtained in a series of simulation experiments using methods of mathematical statistics. Processing the results obtained in a series of simulation experiments using methods of mathematical statistics.

The operator needs to take care of reducing its influence or its complete exclusion from the simulation results. Based on the analysis of various models for the formation of the project management team, it is advisable to use simulation models to solve the problems of forming project teams.

The use of risk theory for optimizing the quantitative and qualitative composition of project teams is proposed, which avoids risks. Criteria for the quantitative optimization of the project team depending on the characteristics of the object (type, age, technical condition). As the objective function of optimizing the project team, a complex parameter was used, taking into account the costs of maintaining the crew, on the one hand, and reducing the risk of critical situations during the cruise, on the other.

By conducting simulation, it is determined:

- the effect of the balance and compatibility of the crew on the amount of risk;
- the dependence of the functional state of the ship's technical equipment and ship structures on the optimal team composition and the cost of the ship-owner.

REFERENCES

Alapetite, Alexandre and Igor Kozine. 2017. "Safe manning of merchant ships: an approach and computer tool." *Maritime Policy & Management: The flagship journal of international shipping and port research* 44(3): 323-335. https://doi.org/10.1080/03088839.2016.1276305

Alexandrovskaya, N. I., V. I. Shakhov, and A. V. Shakhov. 2011. "A risk-based strategy for ship maintenance and repair." *Bulletin of Methods and Facilities Managing the Development of Transport Systems* 17: 13-23.

Alluisi, E. A., T. J. Hall, and W. D. Chiles. 1962. *Group performance during four- hour periods of confiment (MRL-TDR-62-70).* Wright-Patterson AFB, Ohio: Aerospase Medical Research Lab. https://doi.org/10.1037/e602302009-001

Altman, Irwin, and Anita Terauds. 1960. *Major variables of the small group field*. Arlington, Va.: Human Sciences Research, Inc.

Barnett, Michael L., and Claire H. Pekcan. 2017. *The Human Element in Shipping*. Retrieved November 17, 2019. https://doi.org/10.1002/9781118476406.emoe033

Baykasoglu, Adil, Turkay Dereli and Sena Das. 2007. "Project team selection using fuzzy optimization approach." *Cybernetics and Systems* 38(2): 155-185. https://doi.org/10.1080/01969720601139041

Boyko, Victor, Nicolay Rudnichenko, Sergey Kramskoy, Yevhen Hrechukha, and Natalia Shibaeva. 2017. "Concept Implementation of Decision Support Software for the Risk Management of Complex Technical System." Pp. 255-269 in *Advances in Intelligent Systems and Computing*, edited by N. Shakhovska. Cham: Springer. https://doi.org/10.1007/978-3-319-45991-2_17

Chapanis, Alphonse. 1961. "Men, maschines and models." *American Psychologist* 16: 113-131. https://doi.org/10.1037/h0040759

Cremeans, J. E. (1968). "Trend in Simulation." *Computers and Automation* 17(1): 44-48.

Ernst, A.T., H. Jiang, M. Krishnamoorthy, H. Nott, and D. Sier. 2001. "An Integrated Optimization Model for Train Crew Management." *Annals of Operations Research* 108(1-4): 211-224. https://doi.org/10.1023/A:1016019314196

Ilina, Elena L., Konstantin A. Miloradov, and Andrey P. Kovaltchuk. 2019. "'Green Hotel': Concepts and Implementation." *Journal of Environmental Management and Tourism* 10(2): 300-306.

International Maritime Organization. n./d. *International convention of standards of training, certification and watchkeeping for seafarers (STCW).* Retrieved November 17, 2019 (http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-on-Standards-of-Training,-Certification-and-Watchkeeping-for-Seafarers-(STCW).aspx)

Kramskyi, Sergiy O. 2014. *"Models and methods of forming project teams on the example of the crew of a ship."* PhD dissertation. Odessa National Maritime University, Odessa.

Kramskyi, Sergiy O. 2017a. "Risk-oriented approach management system of transport safety." *Bulletin of the Volodymyr Dahl East Ukrainian National University* 233(3): 90-94.

Kramskyi, Sergiy O. 2017b. "Risk-oriented instrumentation under conditions of uncertainty of management of a specified inhomogeneous project." Pp. 92-95. Theses of International scientific conference: *Globalization of scientific and educational space. Innovations of transport. Problems, experience, prospects*. Severodonetsk: EUNU. Dal.

Livingstone, Divine Caesar, Stephen Cahoon, and Jiangang Fei. 2014. "Exploring the range of retention issues for seafarers in global shipping: opportunities for further research." *WMU Journal of Maritime Affairs* 14(1): 141-157. https://doi.org/10.1007/s13437-015-0078-0

Mazur, I. I., V. D. Shapiro, and N. G. Olderogge. 2001a. *Project Management: a handbook for professionals.* Moscow: Higher School.

Mazur, I. I., V. D. Shapiro, and N. G. Olderogge. 2001b. *Project Management: a textbook for high schools.* Moscow: LLC Publ. "Economics".

O'Neil, W. A. 2000. *Why risk management in shipping?* Retrieved November 16, 2019 (https://ru.scribd.com/document/86046584/Why-Risk-Management-in-Shipping)

Sawik, Tadeush. 2015. "On the fair optimization of cost and customer service level in a supply chain under disruption risks." *Omega: The International Journal of Management Science* 53: 58-66. https://doi.org/10.1016/j.omega.2014.12.004

Shakhov, A. V. and S. A. Kramskoy. 2011. "Formation of the crew on the basis of simulation." *Eastern-European Journal of Enterprise Technologies* 1/5(49): 69-70.

Turner, John Rodney. 1993. *The Handbook of Project-based Management: Improving the Processes for Achieving Strategic Objectives*. London: McGraw-Hill Book Company Europe.

United Nations. 2019. *Review of maritime transport*. Retrieved November 17, 2019 (https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf)

Wang, Kai, Shuaian Wang, Lu Zhen and Xiaobo Qu. 2016. "Cruise shipping review: operations planning and research opportunities." *Maritime business review* 1(2): 133-148. https://doi.org/10.1108/MABR-04-2016-0007

Zakharchenko, O. V. and M. Yu. Zakharchenko. 2019. "Forming the team of the implementation project on the basis of the simulation model." Materials of the *International scientific and practical conference dedicated to the memory of professors Yu. Ya. Fomin and V. S. Semenov*, April 18-22, Odessa, Ukraine; Istanbul, Turkey.

Zhanga, Guizhen and Vinh V. Thaiab. 2016. "Expert elicitation and Bayesian Network modeling for shipping accidents: A literature review." *Safety Science* 87: 53-62. https://doi.org/10.1016/j.ssci.2016.03.019

Zhanga, Yao and Zhi-Ping Fanb. 2014. "An optimization method for selecting project risk response strategies." *International Journal of Project Management* 32(3): 412-422. https://doi.org/10.1016/j.ijproman.2013.06.006

Zhao, Qian and Lian-Ying Zhang. 2018. "Research on the Effect of DPSO in Team Selection Optimization under the Background of Big Data." *Complexity* 2018: Article ID 1386407. https://doi.org/10.1155/2018/1386407

Received on 19-12-2019 Accepted on 20-01-2020 Published on 21-02-2020

DOI: https://doi.org/10.6000/1929-7092.2020.09.13