Currently being developed system based on objective, scientific knowledge about the risks in transport. The author presents the foundation of an integrated assessment of the optimization algorithm as a tool to improve safety and reduce operating costs in maritime transport. The algorithm proposed can be applied to all types of vessels operating around the world but the amount of saving can be estimated only by carrying out a comprehensive study and simulation in a virtual world where digital mock-ups can be used to explore various relationships and configurations. Therefore, the author proposes the creation of a navigation optimization assessment centre as a place of research and broader education related to use of the developed algorithm.

INTRODUCTION

Strong pressure has always been exerted on the master with regard to the operational results of the ship. However, especially in this day and age, with the prevailing crisis, he must use all his knowledge and experience, and the tools available in order to optimize the ship’s voyage. The term optimization should be understood as the best route selection, taking into account its characteristics as a control object and the environmental conditions in which the journey is made.

On the one hand, the highest priority is safety; on the other, achieving the most economic result. In order to meet the challenges posed, the master must make complex decisions based on knowledge and experience that will allow him to keep a balance between the necessary risks, which are inherent to life and development, and ensuring safety and protection against those risks. Today, computer tools offer indispensable and invaluable help. The author presents an algorithm that by combining currently available computer programs and systems should improve the safety culture on board ships, facilitate decision-making and reduce operating costs.

At the same time, the author proposes an integrated navigation optimization assessment centre where the algorithm developed would be subject to assessment and which would further the wider education related to the practical application of the algorithm. Evaluation of safety culture and optimization of operation have become two of the many tools for identifying problems that require improvement within companies. Thus, it is leading to improved competitiveness.

1. AN INTEGRATED SYSTEM OF RISK ASSESSMENT OF NAVIGATION

The European industry associated with marine technology currently faces global competition from new, dynamically developing companies. These companies implement new technological solutions and modernized organizational systems. Therefore, in order to meet the competition, it is necessary to undertake additional research, and implement new design and production processes, which should lead to reduced operating costs. In the case of marine units, these solutions should take into account the whole life cycle; that is, about 20 years.

Emerging systems should integrate existing and currently operated components. The inputs and outputs should be understood by operators and convincingly deliver arguments to take certain actions. Combining several elements should translate directly to shorter times taken to assess the situation, and hence directly to an increase in the safety of navigation, improved operating results and protection of the environment by reducing energy consumption.

Analysis of risk factors for navigation and operation of vessels showed that the cause is a set of consecutive and interrelated extremely adverse events.

Over the last few years, the level of safety at sea has improved. However, the scale of the company, keeping in mind that a good safety culture will raise the reputation of the organization, and a single serious incident can ruin a reputation. In fact, a serious incident may determine the reputation of the entire industry and cause damage that impact on a number of independent organizations that contribute to and depend on the success of the industry. Therefore, we should keep in mind existing relationships that can bring benefits to all.

We cannot carry out a risk assessment of navigation based on conclusions drawn only from the analysis of past events and in the form of detached components. Currently being developed system based on objective, scientific knowledge about the risks in transport. The benefits of “nurturing” a good safety culture are as follows:

- Safety is taken into account ("embedded") in the products and services of the organization;
- The potential risks and damage are detected and eliminated or controlled at an early stage;
- Organization products are demonstrably safe;
- The organization implements improvements and cost savings;
There is a reduced risk of non-compliance with obligations under the law.

Fig. 1. Steps to create a safety culture [source: Sitarz M., Silesian University of Technology, 2014]

Description to Figure 2:
- Pathology. If we break the rules, we will be punished.
- Response. We take action only after an accident.
- Calculation. We trust procedures relying on benefits.
- Prevention. We systematically work to improve safety.
- Integration. We build a system in which safety has the highest priority.

A modern application of safety regulations should be:
- Proactive – the ability to predict and forestall threats. This is much more effective than waiting for the event to arise. This is the attitude in which it is assumed that this unit is responsible for your life by making choices;
- Systematic – the use of formal structural processes in order to develop new rules and priority research findings that should be carried out;
- Transparent – must be obvious that the level of risk and reliability can be achieved, and at what cost;
- Effective – efficient, in this case, is a balance between the costs arising from the need to apply the laws and the costs incurred in connection with accidents [4].

Maritime safety management in shipping is based on multiple rules, international conventions and legislation. Scientific and technological progress is followed by the regular revision of the rules in force. At the beginning of the 1990s, there was a new, proactive, probabilistic method of predicting risks – Formal Safety Assessment – FSA. The FSA has been described as a “rational and systematic risk assessment process in the field of shipping activities in order to assess the costs and benefits from risk reduction options”. This method can be used as a tool to help assess the consequences of the introduction of new requirements, or to compare the proposed amendments to existing standards.

1. The FSA is implemented in five steps: Risk identification (a list of all relevant accident scenarios, with potential causes and consequences);
2. Risk assessment (assessment of the specific risk factors);
3. Determination of risk-control options (a search for measures to reduce identified risks);
4. Evaluation of the costs and benefits of each (specify the effective costs for each risk-control option);
5. Recommendations for making decisions (information about the threats, assessment of their risk and cost, and options to control this risk) [8].

Proceedings by the FSA can be represented as a response to the following five questions:
1. What can go wrong?
2. How bad, and what is the probability?
3. What are the opportunities to improve this issue?
4. How high are the costs, and what results will it give?
5. What actions should be taken? [8]

There is yet another view of the structure of the method. In recent years, there have been voices requesting the introduction of a sixth step into the application, which would be to monitor the effectiveness of the introduced improvements [8].

The costs entailed in this method are for hardware, which is within the reach of any company, and computer programs, of which the price is not so high that they could not afford them and a properly trained person to carry out the application. Application of the method does not involve high costs together, and only long-term benefits.

2. ELEMENTS OF NAVIGATION OPTIMIZATION ALGORITHM

To meet the demands of safety and operational performance, the captain must constantly take into account three elements during the sea voyage:
- navigation optimization criteria;
- ship stability and criteria;
- weather analyses and forecasts;

In accordance with the requirements of international regulations, a voyage plan that takes into account the above three criteria must be developed before departure.

Fig. 2. The algorithm combines three different tools to underpin the safe operation of the vessel.
The author proposes an algorithm for combining the available tools into one, which, through its final effects on ECDIS, would more easily identify threats, present options for a solution to the problem, assess the costs and benefits, and make recommendations for the optimal and safest route of the ship. That is, to implement all the requirements of the FSA.

3. OPTIMAL ROUTE MODIFICATION CONSIDERING ECONOMIC AND NAVIGATION CRITERIA

Regarding to stability criteria, all cargo ships have to meet certain conditions (i.e. a harmonized concept of probability), which are designed to cover the difference between the various types of ships:

- Preparation of the base for the calculation of NAPA ship stability software to access vessel drawing files for damage condition analysis. The software should include the following: system environment and common system feature, a hull form geometry feature, a ship model feature, hydrostatics, capacities, loading conditions, stability criteria and damage stability;
- Analysis of the strength of the ship – the boundary of moments and shear forces to the operating state of the ship;
- Stability analysis for the fulfillment of all the requirements (intact, damage, other special requirements, etc.) for newly designed and existing ships, together with possible modifications to the proposal needs fulfillment of requirements;
- Performance information about the stability of the vessel – Stability Manual;
- Calculations of stability in a damaged condition (both deterministic and stochastic methods, as well as the calculation of water on board);
- Preparing all other documents required by the provisions of stability (tanks, Damage Control Plan, calculation of freeboard, hydrostatical curves, sounding tables, etc.).

Analysis of the above documents shall be done by the leadership of the ship before taking command, which allows the identification of dangerous hydro-meteorological parameters in various loading conditions. In addition, taking into account the specific nature of the cargo for each journey, current safety criteria should be revised. Especially during the exchange of ballast water – safety criteria are subject to change.

Taking as input parameters the safety parameters associated with the stability criteria and hull strength of the ship, you can use the algorithm determining the prohibited zone and venture capital, which are generated by the current, digital weather data [2]. On the basis of free, publicly available data from the National Oceanic and Atmospheric Administration (NOAA), using probabilistic methods, we can designate areas dangerous for a specific ship. Advanced work on the development of a probability method has been carried out by personnel of the Maritime University, Medina, P. and Chomski, J. This project was original, new, and used mathematical modelling tools to include a full understanding of the operational practices [1].

The navigator, in practice, while planning trip, takes into account:

- The parameters of wind direction and strength;
- The sea state – waves and swell direction;
- Visibility (occasionally; due to modern navigation equipment);
- The risk of icing (during the winter).

Wavelength, and thus wave period, is rarely considered. This is one of the most important safety parameters, which may lead to breaking the ships load, moving the cargo and even capsizing the ship. Also, in the standard meteorological information transmitted by the NAVTEX and INMARSAT systems, these parameters are not available. The wavelength and period are available on facsimile maps and some free websites such as the National Weather Service, for example.

The data obtained will allow an optimum route to be plotted. This route will be most advantageous both from the point of view of safety and economic effects. To this end, the navigator could make use of the Electronic Chart Display and Information System (ECDIS) combined with generally supporting navigation planning program available, for example: Navi-Planner 4000 of TRANSAS Company. By using such a program, the navigator creates an itinerary using electronic navigation maps which contain information about the following:

- Safety contour – includes draft and under-keel clearance;
- Safety depth – a parameter defined by the navigator that extends the ability to detect underwater hazards found at depths greater than specified by safety contour;
- Sounder depth – a parameter defined in the echo sounder as a sensor of ECDIS system;
- The limits of waterways and canals;
- Prohibited and restricted areas;
- Traffic control systems and ferry routes;
- Navigational danger ring – this enables the detection of underwater hazards on the basis of ENC. It also allows detection of:
  - NAVTEX objects that have the attribute "Danger" added;
  - Objects inserted by the user as "user chart object" or "manual correction object", which have been given the attribute "danger" and/or inserted depth less than the "safety depth".

Such a combination of three elements will allow the navigator to make the optimal decision. It will also provide arguments in the case of disputes regarding cargo damage or ship delay.

4. CENTRE OF ANALYSIS AND EVALUATION TO OPTIMIZE NAVIGATION

The author of this article also proposes that interested parties – universities, companies and industries whose goal is to create a Centre of Analysis and Evaluation to Optimize Navigation – can work to improve the proposed solution and carry out wider education. The big problem is the diversity of existing computer programs, particularly their incompatibility. Another direction of research could be a combination of the proposed algorithm of Decision Support Systems. Current systems focus mainly on collision avoidance in different hydrographical situations, but do not include hydro meteorological factors.

The amount of saving and benefits can be estimated only by carrying out a comprehensive study and simulation in a virtual world where digital mock-ups can be used to explore various relationships and configurations.

CONCLUSION

The proposed product clearly fits the trends of modern science. The benefits of "nurturing" a good safety culture and economic impacts are clear:

- Optimizing the safety of the crew and cargo;
- Optimization of economic costs – time and fuel consumption;
- A full review of the current and the future situation;
- Reduced operating costs associated with running the ship by the meteorological service boundary;
Reduced bureaucracy on the ship and in the relevant departments of ship owners.

It is important to gather information from a variety of sources that expand and improve credibility and create the ability to appropriately process and analyse security. The implementation of a proactive safety management strategy offers a chance to reduce the risk of accidents by taking the necessary action – correction, prevention and improvement – in order to minimize the risks. The basis for proactive security management is a systematic formula for taking action in the following areas:

- Identification of hazards;
- Risk analysis;
- Taking adequate preventive measures appropriate to the results of the analyses.

The algorithm developed can be applied to all types of vessels operating around the world. Its implementation in a given unit is simple, due to the mandatory requirements of equipment, and, most importantly, can be used in an unchanged form throughout the life of the vessel, bringing measurable savings in energy consumption and reducing operating costs.

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